

14th International Symposium of Fertilizers

June 22 - 25, 2003
Debrecen, Hungary

Fertilizers in context with resource management in agriculture

PROCEEDINGS

E. SCHNUG, J. NAGY, T. NÉMETH, Z. KOVÁCS and T. DÖVÉNYI-NAGY

INTERNATIONAL SCIENTIFIC CENTRE OF FERTILIZERS (CIEC)
BRAUNSCHWEIG – BUDAPEST – VIENNA

CENTRE OF AGRICULTURAL SCIENCES
UNIVERSITY OF DEBRECEN

RESEARCH INSTITUTE FOR SOIL SCIENCE AND AGRICULTURAL CHEMISTRY OF THE
HUNGARIAN ACADEMY OF SCIENCES (RISSAC),
BUDAPEST

Proceedings of the 14th International Symposium of Fertilizers held at Faculty of Agriculture,
University of Debrecen on 22 – 25 June, 2003 in Debrecen, Hungary.

EDITORIAL BOARD

Ewald SCHNUG, Braunschweig
Tamás NÉMETH, Budapest
János NAGY, Debrecen
Zoltán KOVÁCS, Debrecen
Tamás DÖVÉNYI-NAGY, Debrecen

CIEC's ADVISORY BOARD

Christian HERA	Romania
Georges HOFMAN	Belgium
Luc MAENE	France
Tamás NÉMETH	Hungary
Ewald SCHNUG	Germany

Published by CIEC editorial board

All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical including photocopying or recording, nor may be stored in a retrieval system, or otherwise copied or private use without written permission from the publisher.

Printed in Hungary

ISBN 963 9274 44 5

CONTENTS

OPENING ADDRESS

Christian HERA	1

PLENARY LECTURES..... 10

UTILISATION OF FERTILISER P WITH SPECIAL REGARD TO ORGANIC FARMING

Ewald Schnug, Silvia Haneklaus, Jutta Rogasik and Anja Gassner	11

INTEGRATED GPS, AND INTERNET BASED GIS APPLICATIONS FOR THE SUPPORT OF AGRICULTURAL ADVISORY SYSTEMS

Tamás Németh, József Szabó and László Pásztor.....	30

EVALUATING THE EFFICIENCY OF IRRIGATION AND FERTILIZATION IN MAIZE PRODUCTION

János Nagy, Tamás Németh and László Huzsvai.....	38

SECTION 1

ADVANCED ASPECTS OF MACRONUTRIENT FERTILIZATION..... 48

AGROECONOMIC CRITERIA OF APPLICATION OF NITROGEN FERTILIZERS

H. Roostalu, A. Astover and I. Tamm.....	49

CORRELATION BETWEEN YIELD AND SOIL CHARACTERISTICS IN A HETEROGENEOUS FIELD

I. Buzás, J. Tamás and I. Cserni.....	57

LONG-TERM EFFECTS OF K FERTILIZATION ON PARAMETERS OF SOIL FERTILITY

A. Gransee and T. Popp	68

LATE NITROGEN FERTILIZING OF WINTER WHEAT WITH THE AIM OF QUALITY IMPROVEMENT BASED ON PLANT DIAGNOSTICAL ANALYSES

L. Hangyel, Mrs. M. Hangyel Tárczy and L. Szabó	72

PERFORMANCE OF UREA AND MULTI-NUTRIENT SUPER GRANULES ON RICE.....

S. A. Haque.....	79

DRY MATTER ACCUMULATION AND NUTRIENT UPTAKE OF DUAL UTILIZATION FIBRE HEMP

I. Iványi and Z. Izsáki.....	85

THE IMPACT OF DURABLE FERTILISING ON THE SOIL CHARACTERISTICS DETERMINING THE SOIL FERTILITY AND YIELD

B. Kadlicskó, S. Holló, L. Szabó and L. Fodor	91

ROLE OF FERTILIZATION AND HYBRIDS FOR IMPROVEMENT OF MAIZE GROWING ON K-DEFICIENT SOIL

V. Kovacevic, D. Banaj, M. Antunovic and G. Bukvic	99

IMPORTANCE OF 0,01 M CaCl₂ SOLUBLE ORGANIC NITROGEN IN THE CHARACTERISATION OF N-SUPPLY IN THE TREATMENTS OF WESTSIK'S CROP ROTATION EXPERIMENT

J. Lazányi, J. Loch and P. T. Nagy.....	104

THE OPTIMIZING OF N-FERTILIZATION BY SOIL ORGANIC MATTER MINERALIZATION Z. Lončarić, V. Vukadinović, B. Bertić and T. Teklić	112
THE EFFECT OF N, P, K FERTILIZATION ON YIELD AND ON SHIFTS IN THE MAJOR SOIL CHARACTERISTICS M. Sárvári, Z. Futó and E. Zsom	119
THE INFLUENCE OF MANURE ON THE YIELD OF WHEAT- MAIZE AND FERTILITY OF SOILS M. Ștefănescu	127
CHALLENGES CONCERNING FERTILIZER USE AND MANAGEMENT PRACTICES IN THE BANANA INDUSTRY IN SOUTH AFRICA J.H. van der Waals, C. Kaiser and L. D. Stronkhorst	135
USE OF MINERAL FERTILIZERS AND YIELDS OF MAJOR CROPS IN YUGOSLAVIA P. Sekulić, R. Kastori and J. Vasin.....	141
SOIL P STATUS AND THE FUNCTION OF INCREASING CROP YIELDS IN NORTH OF CHINA Zhou Yimin, Jin Jiyun and Sun Kegang.....	148
SECTION 2	
FERTILIZATION AND FOOD QUALITY	161
EFFECT OF SOIL WATER REGIMES AND INOCULATION WITH MYCORRHIZAE ON GROWTH AND NUTRIENTS CONTENT OF MAIZE PLANTS I. M. Elwan	162
EFFECT ON LONG TERM MINERAL FERTILIZATION ON CEREAL QUALITY Z. Győri	172
RELATIONSHIP BETWEEN THE NUTRIENT SUPPLY AS WELL AS THE YIELD QUANTITY AND QUALITY OF MAIZE Z. Izsáki	178
THE IMPACT OF BIOPREPARATIONS APPLIED WITH MINERAL FERTILIZERS ON SPRING BARLEY J. Hýsek, M. Vach, J. Brožová and M. Javůrek.....	187
NITROGEN IMPACT ON WHEAT QUALITY M. Jolánkai, Zs. Szentpétery, F. H. Nyárai and A. Máté	192
THE INFLUENCE OF FERTILIZATION ON THE QUALITY OF STRAWBERRY FRUITS IN FOUR-YEAR-OLD PLANTATION U. Moor, K. Karp and P. Pöldma.....	198
VARIETY SPECIFIC FERTILIZATION IN WINTER WHEAT PRODUCTION P. Pepó	206
THE INFLUENCE OF FERTILIZATION WITH DIFFERENT AMOUNTS OF NITROGEN ON THE YIELD AND QUALITY OF VIRGINIA TOBACCO I. Turšić, M. Čavlek and T. Čosić.....	214

SECTION 3

FERTILIZATION, ENVIRONMENTAL QUALITY AND SUSTAINABILITY 219

IMPACT OF CATCH CROP IN AN INTENSIVE CROP ROTATION

P. Cepuder..... 220

FERTILIZATION IN THE CZECH REPUBLIC THE CONSUMPTION OF FERTILIZERS AND CONTENT OF NUTRIENTS IN THE SOIL

P. Čermák and M. Budňáková 227

THE INFLUENCE OF P FERTILIZING STRATEGIES ON YIELDS AND P PARAMETERS IN SOIL.

B. Eichler 233

PHYTO-EXTRACTION OF ZN AND CO FROM CONTAMINATED SOIL

I. M. Elwan, F. M. Abdou, M. F. Abdel-Sabour and Y. J. Al-Salama..... 240

CHANGES OF ACIDIFICATION PRESSURE, THE USE OF FERTILISERS AND SOIL REACTION IN POLAND DURING LAST 45 YEARS

T. Filipek, M. Fotyma and W. Lipiński 255

REGIONAL DIFFERENTIATION OF SOIL FERTILITY AND CHANGES OF NUTRIENT BALANCES IN POLAND

J. Igras, J. Kapiński and W. Lipiński 263

FERTILIZER RECOMMENDATIONS TO MEET THE REQUIREMENTS OF GOOD AGRICULTURAL PRACTICE

A. Karklins 272

SUSTAINABLE PHOSPHORUS MANAGEMENT IN THE WESTSIK'S CROP ROTATION EXPERIMENT

J. Lazányi 279

DEVELOPMENT OF THE TECHNICAL ENVIRONMENT OF THE SITE-SPECIFIC NUTRIENT REPLACEMENT

P. Á. Mesterházi, M. Neményi, A. Kovács, K. Kacz and Zs. Stépán 288

SEASONAL CONCENTRATION CHANGES OF ELEMENTS AND NUTRIENTS IN THE SOIL OF A ROOT ZONE WASTEWATER TREATMENT SYSTEM

N. Németh and T. Németh..... 296

PRODUCTION AND EVALUATION OF TWO DIFFERENT ENRICHED ¹¹³Cd LABELED-FERTILIZERS

H. Oda, A. Kawasaki and S. Wang 308

SOIL-PLANT RELATIONSHIP UNDER THE INFLUENCE OF ORGANIC AND CHEMICAL FERTILIZATION IN CONVENTIONAL AND BIOLOGICAL VITICULTURE

A. Șerdinescu and L. Pîrcălabu 315

SPATIAL AND TEMPORAL TRENDS OF ENVIRONMENTAL INDICATORS RELATING TO NITROGEN AND PHOSPHOROUS IN SPAIN

J. Soler-Rovira and J. M. Arroyo-Sanz 321

DEVELOPMENT OF ENVIRONMENTAL FARM GATE NUTRIENT BALANCES IN MIXED FARMS

P. Urfi, K. Sárdi, P. Polgár, Zs. Bacsí and T. Somogyi..... 329

IMPACT OF ACID AND LIMED SOILS OF DIFFERENT FERTILITY TO THE PHOTOSYNTHESIS

R. Veitienė and Z. Kregzdys 337

EFFECT OF A LONG-TERM FERTILIZATION EXPERIMENT ON HEAVY METAL UPTAKE BY RYEGRASS AND LETTUCE

Zs. Kiss, É. Lehoczky, T. Németh and Gy. Baczó 343

REACTIVE PHOSPHATE ROCKS – RPRs AND PARTIALLY ACIDULATED PHOSPHATE ROCKS – PAPRs AS A POTENTIAL SOURCE OF PHOSPHORUS IN AGRICULTURE OF CENTRAL AND EASTERN EUROPE

W. Grzebisz, J. Potarzycki and R. Gaj 350

THE EFFECT OF FERTILIZATION ON THE YIELD OF MAIZE (*ZEAMAYS* L.) IN LONG TIME EXPERIMENTS

J. Nagy 358

EXAMINING THE EFFECT OF FERTILIZER ON THE YIELD OF MAIZE (*ZEAMAYS*) IN DIFFERENT YEARS

T. Rátonyi, D. Sulyok and L. Huzsvai.....366

EFFECT OF FERTILIZATION AND IRRIGATION ON MAIZE (*ZEAMAYS* L.) PRODUCTION IN A LONG-TERM EXPERIMENT

A. Megyes, T. Rátonyi, L. Huzsvai 376

INTERNET-BASED FARMER DECISION SUPPORT FOR FERTILIZER APPLICATION

T. Dövényi-Nagy 383

SECTION 4

INCREASING THE FERTILIZER USE EFFICIENCY IN EXTENSIVE FARMING..... 387

DETERMINATION OF PHOSPHOROUS FERTILIZER REQUIREMENT OF WINTER WHEAT GROWN UNDER IRRIGATED CONDITIONS IN TOKAT AND AMASYA REGIONS

K. Çağatay, A. R. Brohi and M. Eker 388

THE RESIDUAL EFFECT OF P FERTILIZATION, MEASURED IN A LONG-TERM P EXHAUSTION FIELD TRIAL, SET UP ON A CALCAREOUS CHERNOZEM SOIL

P. Csathó and I. Kádár 398

UTILIZATION OF ORGANOMINERAL FERTILIZERS ON LIGNITE SUPPORT, AN IMPORTANT MEANS TO IMPROVE THE FERTILITY OF SOILS WITH REDUCED HUMUS CONTENT

E. Dorneanu, A. Dorneanu and C. Preda 406

THE PERFORMANCES OF *AZOLLA MEXICANA* (2026) ON THE AEGEAN REGION CONDITIONS IN TURKEY

M. N. Gevrek and B. Yağmur 414

RICE STRAW AND SULPHUR ON THE GROWTH AND YIELD OF RICE

S. A. Haque 420

EFFECT OF DIFFERENT NITROGEN LEVELS ON THE YIELD AND NUTRIENT UPTAKE OF EGGPLANT (*SOLANUM MELANGENA* L.) GROWN UNDER GLASSHOUSE ...

C. F. Özkan, A. Deviren, T. Ateş, A. Arpacioğlu and A. Öztürk.....425

SECTION 5

MICRONUTRIENT FERTILIZATION 432

CALCIUM AND MICRONUTRIENTS COMPLEXES IN THE SPANISH FERTILIZER MARKET

J. J. Lucena, A. Gárate, I. García-Salas and M. Villén 433

ROLE OF LONG-TERM FIELD EXPERIMENTS WITH TRACE ELEMENTS IN THE ENVIRONMENTAL RESEARCH IN THE NORTH HUNGARIAN REGION

L. Szabó and L. Fodor 441

USING OF MICRONUTRIENTS FOR LONG TIME PERIOD

R. Veitene 449

SECTION 6

ORGANIC FERTILIZER MANAGEMENT 458

SCREENING OF ORGANIC BIOLOGICAL WASTE PRODUCTS FOR THEIR POTENTIAL TO IMMOBILIZE NITROGEN RELEASED FROM CROP RESIDUES

B. Chaves, S. De Neve, G. Hofman, P. Boeckx and O. Van Cleemput 459

POSSIBLE USE OF DRIED HOTAMIS LAKE SOILS MIXED WITH FARM YARD MANURE AS A GROWTH MEDIUM FOR WHITE CARNATION (*DIANTHUS CARYOPHYLLUS L.*) PRODUCTION

M. R. Karaman, A. R. Brohi and F. Er 466

POSSIBILITIES OF USING THE AQUATIC MACROPHYTE WATERHYACINTH (*EICHHORNIA CRASSIPES*) IN ORGANIC FERTILIZER PRODUCTION

S. A. Ahmed.....473

USE OF ORGANIC-BIOLOGICAL WASTES TO INCREASE SOIL ORGANIC CARBON STOCKS

S. Sleutel, M. R. Prat Roibas, S. De Neve, B. Chaves Daguiar and G. Hofman 481

SECTION 7

FOLIAR FERTILIZATION 489

ROLE OF THE FOLIAR FERTILIZERS IN SUSTAINABLE AGRICULTURE

A. Dorneanu, Z. Borlan, E. Dorneanu, Tr. Cioroianu and T. Prodan 490

INVESTIGATION ON THE SEASONAL VARIATIONS OF MINERAL NUTRIENTS IN THE LEAVES OF WASHINGTON NAVEL ORANGES GROWN IN ANTALYA REGION

N. Ari, C. F. Özkan, T. Ateş and A. E. Arpacioğlu 498

POSTERS 505

EFFECT OF PHOSPHORUS FERTILIZATION ON PHOSPHORUS AND ZINC CONTENTS IN SOIL AND PLANT

D. Bogdanović, M. Cuvardic, F. Miladinovic 506

PRODUCTIONAL AND ECOLOGICAL ASPECTS OF NUTRIENT BALANCE ON FARM LEVEL

R. Bujnovský 513

SUSTAINABILITY OF DIFFERENT FERTILIZATION SYSTEMS ON CHERNOZEM SOIL M. Cuvardic, D. Bogdanovic, M. Ubavic, M. Malesevic.....	520
EFFECT OF DIFFERENT P SOURCES AND SOIL PROPERTIES ON TRACE ELEMENT UPTAKE OF SPRING BARLEY IN A POT EXPERIMENT E. Osztoics, P. Csathó, M. Magyar, T. Németh and A. Osztoics	527
DISSOLVED ORGANIC CARBON (DOC) AND DISSOLVED ORGANIC NITROGEN (DON) CONTENT OF AN ARENOSOL AS AFFECTED BY LIMING IN POT EXPERIMENT T. Filep, P. T. Nagy, I. Kincses and A. B. Kovács	535
THE EFFECT OF MICROELEMENT LOADS ON THE NH_4NO_3 -EXTRACTABLE TRACE ELEMENTS CONTENT OF THE SOIL T. Filep and I. Kádár	541
THE IMPACT OF NUTRIENT SUPPLY ON THE YIELD OF MAIZE HYBRIDS P. Jakab	545
KINETICS OF ELEMENTAL SULFUR OXIDATION UNDER FIELD CONDITIONS K. Cyna and W. Grzebisz.....	552
STORAGE PROTEINS A TOOL TO DETERMINE GRAIN CROP AND POTATO QUALITY J. Bradová and S. Sýkorová.....	556
EFFECT OF NUTRIENT SUPPLY ON THE ARSENIC AND MERCURY TURNOVER IN TRITICALE B. Lásztity and P. Csathó	563
CHANGE OF SOME PROPERTIES AND NUTRIENT CONTENT OF SOILS AS AFFECTED BY FERTILISATION É. Lehoczky, K. Debreczeni and Z. Tóth.....	569
SUSTAINABILITY OF CROPPING SYSTEMS IN A LONG-TERM NUTRIENT SUPPLY EXPERIMENT T. Szalai, É. Lehoczky, F. H. Nyárai, S. Holló.....	576
UTILIZATION FORMS OF AVAILABLE PHOSPHORUS FOR DETERMINATION STABILITY OF SOIL FERTILITY V. Macháček.....	584
EFFECT OF SULPHUR FERTILIZATION ON THE DINAMICS OF SULPHUR CONTENT OF THE WINTER WHEAT IN THE VEGETATION PERIOD É. Mars, Z. Győri, K. Puy and P. Sipos	589
NITROGEN x DESFERAL FERTILIZATION EFFECTS ON MICRO AND TRACE ELEMENT UPTAKE OF <i>CROTALARIA JUNCEA</i> L. L. Márton and P. Csathó.....	595
ENVIRONMENTAL FRIENDLY SIDE-PRODUCT (BIOFERT) APPLICATION IN SUNFLOWER FERTILIZATION SYSTEM P. Pepó, L. Zsombik and A. Szabó	600
AMMONIA FERTILIZATION IN MAIZE PRODUCTION P. Pepó, J. Derzsényi and L. Zsombik.....	606
INFLUENCE OF FERTILIZATION ON THE YIELD, QUALITY AND STORABILITY OF CARROT K. Uurman, P. Pöldma, U. Moor and A. Merivee.....	614
CALCIUM, MAGNESIUM AND SULPHUR CONTENT OF YOUNG PLANTS AS AFFECTED BY DIFFERENT FERTILIZERS AND SOIL PROPERTIES K. Sárdi and F. Éri	619

EFFECT OF FERTILIZATION ON SOIL pH AND GROWTH OF LOWBUSH BLUEBERRY (<i>VACCINIUM ANGUSTIFOLIUM</i> AIT.)	
M. Starast, K. Karp, U. Moor, E. Vool and T. Paal	628
SPATIAL ANALYSIS OF POINT DATASETS TO EXPLORE SUGAR BEET VARIABILITY	
J. Tamás and I. Buzás	636
THE EFFECT OF NITROGEN FERTILIZATION AND WATER SUPPLY ON THE NITROGEN UPTAKE OF <i>LOLIUM PERENNE</i>	
I. Vágó, J. Kátai and P. T. Nagy	647
THE EFFECT OF FOLIAR FERTILIZATION WITH FUNGICIDES ON SUGAR BEET (<i>BETA VULGARIS L.</i>)	657
L. Ruzsányi and L. Varga	657
THE EFFECT OF POTASSIUM FERTILIZATION ON POTATO YIELD QUALITY AND QUANTITY	
J. Kruppa and E. Zsom	664
THE EFFECT OF THE MINERAL FERTILISERS ON THE WATER USE EFFICIENCY OF MAIZE (<i>ZEAMAYS</i>) AT THE EXPERIMENTAL STATION OF LÁTÓKÉP	
M. Piskolczi, A. Dobos and J. Nagy	671
FERTILIZING CAPACITY OF FRESH AND COMPOSTED SOLID FRACTION OF SWINE MANURE ON <i>BRASSICA OLERACEA</i> VAR. <i>CAPITATA</i>	
R. Moral, J. Moreno-Caselles, M. D. Perez-Murcia, A. Perez-Espinosa, C. Paredes and M. A. Bustamante	683
INFLUENCE OF STABILISATION TREATMENT OF SEWAGE SLUDGE ON THE RELEASE OF PLANT AVAILABLE NITROGEN	
R. Moral, C. Paredes, M. A. Pérez-Murcia, A. Pérez-Espinosa, J. Moreno-Caselles, B. Rufete and E. Agulló	690
NITROGEN RATES AND BUDGETS IN TOMATO CROP: A COMPARISON OF FERTILISATION PRACTICES, TECHNICAL RECOMMENDATIONS AND LEGISLATION.	
J. Soler-Rovira, J. M. Arroyo-Sanz	697

OPENING ADDRESS

Christian HERA

President of the International Scientific Fertilizers Centre (CIEC)

**Your Excellency,
Distinguished Members of the Presidium,
Dear Colleagues,
Ladies and Gentlemen,**

As President of the International Scientific Centre of Fertilizers, it is my great honor and pleasure, first, to express my warmest thanks to the government of Hungary who has given its patronage to the occasion enabling this meeting in Hungary to become a reality.

I offer my gratitude to the University of Debrecen – Centre of Agricultural Sciences and Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences which jointly organized together with CIEC this symposium entitled “Fertilizers in context with resource management in agriculture”. Special thanks are due to the President, Prof. Rector Janos Nagy, to the Secretary General, Prof. Zoltan Kovacs of the Organizing Committee and, also, to the CIEC Vice President Prof. Tamas Nemeth who have dedicated so much heartedly work into organizing this meeting.

It is my privilege and great pleasure to welcome here in the name of the International Scientific Centre of Fertilizers all those who honor us today by their presence, which may have particular meaning on our 70th anniversary.

It gives me great satisfaction to share with you, such distinguished participants, the celebration of the 70 years anniversary of the foundation of the International Scientific Centre of Fertilizers (Centre International des Engrais chimiques - CIEC). The grounds for this International Scientific Centre of Fertilizers were created by two memorable first international conferences on chemical fertilizers, one held in Rome, in 1932 and one in Amsterdam, 1933 (the actual event of foundation) when delegates from 29 countries (*Australia, Belgium, Brasil, British India, Canada, Czechoslovakia, Denmark, the Dutch East Indies, Egypt, Finland, France, Germany, Great Britain, Greece, Holland, Hungary, Italy, Latvia, Morocco, Norway, Peru, Poland, Puerto Rico, Romania, Sweden, Switzerland, the Republic of the South Africa, United States of America and Yugoslavia*) decided to come together and to form an association

dealing with the scientific and technical aspects of chemical fertilizers. One year later, the Third International Conference had already been organized in Berne (1934).

Such a close succession of reunions denotes the deep interest and the high expectations of the specialists in problems concerning and connected with the fertilizer production and utilization, the most important material in agriculture.

First of all, please allow me to express a pious homage to the memory of two remarkable Romanian specialists, recognized all over the world for their valuable contribution brought to the agro-chemistry science development, my professors Gheorghe Ionescu-Șișești and Theodor Seidel who both attended Rome and Amsterdam inaugural conferences and later some others CIEC meetings. Another distinguished Romanian scientist, Academician David Davidescu was elected member of Executive Committee of CIEC by the General Assembly at Bucharest, in 1971, fulfilling this position till the IXth CIEC World Congress, Budapest, 1984.

Thanks to them, I am connected with this International Scientific Centre for Fertilizers and I would like to confess that this year I will reach the same age as CIEC. Since 1961 I have been deeply involved and attached to it. For my activity, I received significant life rewards and it is my pleasure to express, once again, my gratitude for the honor of being elected as President of CIEC by General Assembly of June 8th 1996, in Vienna, to be confirmed at the XI CIEC World Congress held in 1997 in Gent and in 2001, at the XII CIEC World Congress in Beijing.

The above-mentioned preliminary conferences and many others, brought to light and publicized many problems calling for resolution through research on soil fertility, fertilizer application and fertilizer production. These problems have been and still are of great world- wide concern, being related to the increased demands for food assurance of an increasing global population. The statutes of CIEC conceived as a non-profit, non-governmental international scientific organization, promote the activities in the field of production, technology and application of fertilizers by stimulating and developing scientific investigations of the plant-fertilizer-water-soil system. In these activities, mineral and organic fertilizers occupy a central position among the factors influencing agricultural production. Their efficient use imposes not only sustained research efforts, but also effective advisory services, asking for a close relation between science and practice and aiming to support the farmers by improving their economic and social situation.

To reach this objective, the international cooperation of scientists and of all persons engaged in the application of experimental results and of all associations involved in agriculture, including national and international authorities, as well as industry and trade is indispensable. CIEC has

assumed this catalytic role, fulfilling successfully the aims to organize joint international meetings, conferences, congresses and exhibitions together with well-known national scientific organizations and societies involved in agriculture and to take the initiative in the study of problems of interest and to disseminate fertilizer-related information.

The 70th anniversary of CIEC offers a unique opportunity to remember the activities in the research field, which belongs to the fundamental disciplines of food production, in assuring food security and safety. Remarkable progress in increasing yields and improving plant quality has been achieved and the fertilizers have contributed significantly to this progress.

The Ist CIEC World Congress held in 1938, in Rome, covered four sessions regarding science, economics, production, distribution and consumption of commercial fertilizers with attendance of the most authorized specialists in the world on these matters.

Special mentions should be paid to the contributions made at this Congress by the first Secretary General, Prof. Franco Angelini, from the University of Naples and CIEC's first President, Dr. E. Feisst, Minister of the Swiss government in Berne, both transforming CIEC into a respected international centre dealing with fertilizer.

The IInd CIEC Congress was also held in Rome, in 1951, after a long time interval due to World War II, thanks to the initiatives and efforts of Prof. Angelini and Dr. Feisst and was oriented on the problems of fertilizer manufacture and production, methods of fertilizer application and the effect of fertilizers on soil microorganisms, human and animal health.

Apart from the regular conferences, a special meeting of CIEC (3rd General Assembly) was organized in 1953 in Darmstadt on the occasion of the 150th anniversary of the birth of Justus von Liebig.

The IIIrd Congress took place at Heidelberg, in 1957 as a spectacular event, accompanied by extensive press commentaries with a considerable public echo. The main task of this congress was to review the results obtained in the first century of modern fertilizing measures. 28 leading experts from almost ***all the world's continents*** discussed the problems concerning the maintenance and the increase of soil fertility and the fertilization effects. The role of macro and microelements on plant life, their decisive influence on the quality and the nutritive value of products were the focal points of the debates, as well as the economic effects of improved fertilizing measures.

Two special mentions are noteworthy: the participation of the Nobel Prize winner, Prof. A.I. Virtanen (Helsinki) with a plenary paper entitled "Our system of manuring in the light of

modern nutritional research” and the highest reward being conferred to the President of CIEC, Minister Dr. E. Feisst for outstanding merits in Agricultural Chemistry – SPRENGEL-LIEBIG MEDAL in gold.

The IVth Congress at Opatija, in 1961, pointed out new problems and the value of collaboration between fundamental and applied science. Here the advantages of the use of radioactive tracers in the solving of many fertilizer problems were stressed.

At the Vth Congress at Zurich, in 1964, the main topic was represented by the principles and aims of Fertilizer Extension Services as a bridge between the interests of the science, fertilizer industries and the fertilizer users.

There was then another time gap until the VIth Congress, in Lisbon, in 1968, organized under the new CIEC President, Ing. Rafael Montjardino. The Congress was again a great success and the results achieved there had plentiful repercussions in agriculture, industry and fertilizer market.

At the 11th General Assembly, held in 1969 in Geneva, Prof. D. Jelenic from University of Belgrade was elected President of CIEC and Prof. E. Welte from the University of Goettingen Vice President responsible for scientific planning and publication. In 1996 Prof. Welte was elected Honorary President of CIEC. Our organization owes its success and survival in difficult times to the never resting efforts of Erwin Welte and mourns for one of its most prominent leaders.

The VIIth Congress of CIEC at Vienna and Baden, in 1972, realized with Prof. A. Zeller from Agricultural University of Vienna enjoyed, also, a great success with most comprehensive published results concerning different fertilizer problems in the highly-developed and developing countries. The congress was attended by more than 300 participants from 29 countries.

One of the largest meetings of experts in agriculture, agricultural science and industrial chemistry was the VIIIth CIEC World Congress held in 1976, in Moscow. A large group of famous scientists, among them being Prof. A.M. Artiushin, Prof. A. Posniacov, Prof. A.D. Peterburgski, Prof. V. Ladonin, Prof. G.V. Minejev brought a significant contribution to the organization of this Congress. About 3000 delegates, nearly approximately half of them coming from countries of all continents, including delegates from the developing countries of Asia, Africa and Latin America attended the Congress.

The theme of this Congress was “Fertilizers-Harvest-Nature” and the eight sections debated the following subjects: the theory of plant nutrition and world practice of effective fertilizer application, mechanization of fertilizer application, agrochemical services, chemization in agriculture and environmental control, fertilizers and crop quality, economics of fertilizers production and application, production technology and agrochemical evaluation of new forms and types of fertilizers, atomic techniques in chemization of agriculture. Based on the conclusions that fertilizers play an essential role in increasing agricultural production that is essential in assuring adequate food for the world population, the conference recommendations were to increase fertilizer production throughout the world and to increase the range of compound fertilizers.

The high recognition of this Congress was, also, due to the elaboration of guidelines for the future course of science and practice of fertilizer usage: perfecting the theory of mineral nutrition of plants and the application of fertilizer and the study of the soil fertility evolution in relation to increased fertilizer use; studying the conditions for the efficient use of the fertilizer nutrients by the crop and the reduction of unproductive nutrient losses; establishing optimal rates, forms and nutrient ratios of fertilizer to increase yield and quality in relation with crop varieties and ecological condition; perfecting application methods to obtain optimum results and to solve the problems of environmental protection; developing new and improving the existing fertilizer materials and their utilization; developing and perfecting agrochemical services, identifying the most suitable means in various countries for rapid transfer of scientific results to farmers.

Due to this very efficient congress, the ensuing years were marked by a high interest of fertilizer companies of several European countries in membership of CIEC.

The IXth CIEC World Congress held in 1984 in Budapest was dedicated to the 50th anniversary of the CIEC foundation and represented another milestone in the history of CIEC.

The Congress facilitated large and efficient contacts between CIEC and non-governmental and governmental international scientific organization (such as FAO, UNEP, UNESCO, INIDO, IAEA etc.), assisted by the Hungarian Academy of Sciences, Hungarian Society of Agricultural Services, Hungarian Soil Science Society and the Federation of Technical and Scientific Societies of Hungary. Scientists from 35 countries contributed with new ideas and approaches on the congress theme “The Conquest of Hunger through the Better Provision of the Nutrient Needs of Plant” with emphasis put on the role of fertilizers in world crop production, today and

tomorrow. The President of the Congress was the well-known Hungarian Academician, Prof. István Lang, assisted by Prof. István Szabolcs.

Welcoming interventions of the representatives of FAO, UNEP and the International Soil Science Society underlined the highly-qualified subject of this important CIEC Congress.

The following time period was heavily marked by the increase of soil, water and ground water reserves pollution that was mainly and incorrectly attributed to the intensive fertilizer usage. As a consequence, the fertilizer industries in Europe declined and with them the activities of CIEC.

Yet, in spite of this image loss, CIEC organized the Xth World Congress in 1990 at Nicosia with an attendance of about 350 representatives from 51 countries. The President of Congress was Dr. C.S. Serghiu and Secretary General Prof. I. Papadopoulos. With a close co-operation with the Agricultural Research Institute of the Ministry of Agriculture and Natural Resources of Cyprus, the Congress was a great success.

The main topic was “Efficient fertilization, manuring and irrigation for improving yield, food quality and renewable resources”.

After the 19th General Assembly in Vienna, the CIEC organization reformed through an infrastructural change and staff renewal and it enters again an ascendent phase, fulfilling the objectives of promoting a well-balanced plant nutrition and adequate measures of compensation for the increasing “export of plant nutrients” from the soil.

Between 1990 and 1996, CIEC has organized several international meetings such as: the 7th Symposium on “Agroforestry” in 1994, in Berlin (with about 150 representatives from 18 nations), the 18th Symposium – “Fertilizers and Environment” in the same year, at Salamanca (about 200 participants from 28 countries). In 1995, the 9th Symposium held in Kusadasi was mainly oriented by special fertilizer problems in the Near East regions (with participants from 12 countries).

The 10th Symposium of CIEC organized as a joint conference together with the Institute of Plant Nutrition and Soil Science of the German Federal Agriculture Research Centre, held in 1996 in Braunschweig, registered great interest. As an answer to the urgent needs to recycle the industrial waste, the theme of this symposium was “Recycling of the plant nutrients from industrial processes”.

The imperative to maintain the soil nutrient equilibrium by replacement of all nutrients removed by cultivation through harvesting (productive loss and unavoidable non-productive losses-erosion, leaching, volatilization) focused the proceedings of the XIth CIEC World Congress,

held in 1997 at Gent, as a joint conference together with the Faculty of Agricultural and Applied Biological Sciences. The Congress was attended by more than 300 specialists from 67 countries. Prof. Oswald van Cleemput and Prof. Georges Hofmann served as President and Secretary General of this Congress.

The main items that are decisive to the mankind survival were identified and the trends of agricultural research were recommended (improvement of soil yield potential by any possible suitable – containing materials; a more efficient monitoring and diminishing of “non-productive” nutrient losses; approaches of the most appropriate analytical methods and certification measures for the materials originating from recycled wastes and waste waters; the assessment of the crop nutrient demand in optimal application conditions).

The XIIth CIEC World Congress was organized jointly together with Chinese Academy of Sciences and Shenyang Institute for Applied Ecology in Beijing, in 2001. The President of the Congress was Prof. Yiyu Chen, the Vice President of Chinese Academy of Sciences and Prof. Lanzhu Ji, together with Prof. Guanxiong Chen were served Secretaries General. The attendance to this congress was exceedingly high with representatives from about 60 countries and regions of the entire world. The theme of the Congress was of tremendous concern and large perspective for all participants – “Fertilization in the Third Millennium – Fertilizer, Food Security and Environmental Protection”.

The interest areas were ranging from fertilizer use related by the environmental impact, methods and strategies of fertilizer application, advanced aspects of N, P, K fertilizer use, fertilization with micro-nutrients, sulphur nutrition and fertilization, fertilization in organic farming and bio-fertilizers, controlled release fertilizers, fertilization and food quality, to trade and markets of the fertilizers and alternative sources of plant nutrients.

A clear message emerged from all the specialists and this message confirmed the anticipated goal of CIEC: to sustain and increase soil fertility and crop productivity, quality together with paying special attention to the environmental preservation.

Realizing the sustainable development of agricultural production is the target aimed by the related scientists all over the world. I would like to emphasize the fact that “agricultural sustainability is of incontestable importance for the future of mankind, but we must also develop ways to add performance to the sustainable agriculture, in order to be able to satisfy the needs of “our daily bread” for present and future generations”.

This recollection of the CIEC history is intended to reveal CIEC's enhanced role and position gained along its worthy existence. More and more specialists have striven to attend CIEC meetings from more and more continents, regions and countries. The topics of debates have been increasing continuously in number and scientific level, being permanently adapted to the agricultural development requirements. Various co-operations have been enlarging and run deep.

We have to learn from the past. During 70 years, CIEC accumulated an immense mine of data and useful ideas in the area of fertilizer production and fertilizer utilization. These ideas, resulted from the CIEC activities, organized as a bridge between fertilizer industry and agriculture, represent a great opportunity to build a right strategy for optimizing fertilizer utilization in agriculture.

I strongly believe that **fertilizers** played, are playing and will play a **key role for improving agricultural production**, not only quantitatively, also qualitatively. Fertilization plays a very important role in terms of sustainable and performing agriculture, with a clean environment. It is our duty to be aware that the improper use of fertilizers can affect the agricultural system in a negative way. This is why, the scientists from all over the world, involved in soil fertility, plant nutrition and fertilizer application, should intensify their activities, by utilizing the most advanced techniques, to find the best methods, times, types and rates of fertilizers application, in function of crop requirements, expected yields, for each specific soil and climatic conditions, corresponding to each zone and micro zone. Precise fertilizer application will be indispensable, essential for a sustainable and performing agriculture, with less or no negative effect on the environment.

CIEC has been aiming and has succeeded to become the cornerstone of extensive interdisciplinary approaches in fundamental and applied sciences, agricultural services, fertilizer industry and practice.

May I foresee a long lasting life with roots going deeply in the fertile soil of worldwide cooperation and bearing valuable fruits for the general benefit and prosperity.

Building a better future for humanity rests heavily on us, all the workers in the agricultural field and this is a difficult task but, also, an immense privilege, the contribution of scientific area activity being essential

Please allow me to take this opportunity to express, once again my particular thanks and appreciation to Hungarian local organizers and to the Advisory Board of CIEC, especially to

Prof. Ewald Schnug, Deputy President, Prof. Tamas Nemeth, Secretary General and Prof. Silvia Haneklaus, Deputy Secretary General, for their contribution to the successful CIEC activities. Also, I would like to underline Dr. Luc Maene's contribution to convince experts from fertilizer industries to participate at Beijing CIEC Congress and Tokat Symposium.

Finally, I wish the symposium a great success and I wish all of you a very pleasant and fruitful stay in this marvelous country.

Thank you.

Plenary lectures

UTILISATION OF FERTILISER P WITH SPECIAL REGARD TO ORGANIC FARMING

Ewald Schnug, Silvia Haneklaus, Jutta Rogasik and Anja Gassner

Institute of Plant Nutrition and Soil Science, Federal Agricultural Research Centre (FAL), Bundesallee 50,
D-38116 Braunschweig, Germany

Abstract

Phosphorous (P) is the first non-renewable resource, which is becoming scarce in less than 100 years. Thus it is vital for sustainable agriculture to develop strategies and measures to close anthropogenic P cycles. In this context agriculture has to strive for a complete utilisation of the P employed in production. The paper presents a model which describes the utilisation of fertiliser nutrients with special regard to P. Provided that only water soluble (or in some cases citric acid soluble) P is used on physical, chemical and biological intact soils and within infinite time, a fully utilisation of applied P can be expected. In organic farming easily soluble, inorganic P forms are banned, but with phosphates of low solubility, which do not enter the site-specific P cycle, even within infinite time a full utilisation cannot be expected. Under the restrictions of a balanced fertilisation where fertiliser inputs shall not exceed the amount of P removed, organic farming easily may drift into nutrient mining, diminishing soil fertility and sustainability of production. A possible way out of this dilemma offers the concept of "in situ digestion" where low soluble forms of P (rock phosphates or meat/bone ashes) are granulated with elemental sulphur and the release of sulphuric acid during microbial sulphoxidation transforms low into easy soluble P forms. This concept enables the realisation of balanced P fertilisation in organic farming, too.

Keywords: balanced fertilisation, sustainability, nutrient utilisation efficiency, organic farming, phosphorous, phosphate

Introduction

Phosphorus (P) is essential for all living beings. The main entrance path into the food chain is by plant uptake, which utilise phosphates in soils. Besides being essential for plant growth, P is an environmentally relevant nutrient (Frede and Bach, 2003) which natural resources are limited (Pradt, 2003). Thus an efficient utilisation of P with minimum losses is a prerequisite for sustainability in agriculture.

Although, estimates of world phosphate reserves and the availability of exploitable deposits vary greatly, it is commonly recognised that high quality reserves are being depleted rapidly and that the prevailing management of phosphate, a finite non-renewable resource, is not fully in accordance with the principles of sustainability (Steen, 1998). The key to sustainable P utilisation is on the one hand the concept of balanced fertilisation (Tunney, 1990) and on the other hand to close the urban-rural P cycle. In a balanced fertilisation approach the fertiliser rate is calculated from the balance between the natural supply by soil and environment, the nutrient

demand of the crop and inevitable losses to the environment (Vermeulen et al., 1998). Closing the anthropogenic P cycle means that residues are subjected to environmental sound recycling in order to preserve natural resources. Presently, amongst the phosphate containing organic residues two groups are particular suitable for recycling: sewage sludge and animal bone meal. Both groups are available in large quantities, and bear severe health related risks and problems. The challenge for scientific research is to develop technologies that extract the nutritional important P in such a way that it can be made available for plant production, while eliminating any health risks from contaminations such as heavy metals or organic xenobiotics.

The aim of the present paper is to quantify the amount of P that is needed to ensure a sustainable agricultural production and to define the quality requirements of P fertilisers. The paper is therefore divided into two parts. In the first part a model, which describes the utilisation of fertiliser nutrients with special regard to P, is presented. In the second part a new method for utilising phosphate containing organic residues will be introduced.

Agronomic effectiveness of P fertilisers

The main goal of fertilisation in conventional farming systems is the supply of an adequate amount of a nutrient in order to achieve a desired target yield. Apart from crop demand any fertiliser strategy has to take losses into account, which are inevitable under field conditions. Therefore plant uptake is not necessarily equivalent to fertiliser demand. In the case of P the situation is even more complicated as its strong affinity to soil particles and thus changes in solubility need to be considered.

The most important quality parameter of a fertiliser is the “plant availability” of its nutrients. For a better understanding of the matter a brief excursion into the basic understanding of the utilisation efficiency of fertilisers will be presented.

The relevance of the utilisation efficiency for the rate of fertilisation

The nutritional supply of the crop is the sum of nutrients added to the soil as fertiliser, the residual nutrients in the soil from previous fertiliser applications and the natural fertility of the soil.

One can define fertiliser utilisation efficiency at crop level as the ratio of the actual yield of a crop and the nutrient supply of this crop. The amount D needed to achieved an envisaged target yield can be calculated according to the formula given in equation 1 and which is visualised in fig. 1:

$$D = \frac{E - \frac{B * b}{100} + \frac{C * c}{100}}{d} * 100 \quad \text{Equation 1}$$

- with: D = fertiliser rate in kg nutrient ha⁻¹
 B = residual nutrients in the soil in kg ha⁻¹ from former fertiliser applications
 C = native nutrient content of the soil in kg ha⁻¹
 E = nutrient off-take in kg ha⁻¹
 b = utilisation efficiency of residual nutrients in %
 c = utilisation efficiency of native nutrients in %
 d = utilisation efficiency of nutrients in fertilisers in year of application in %

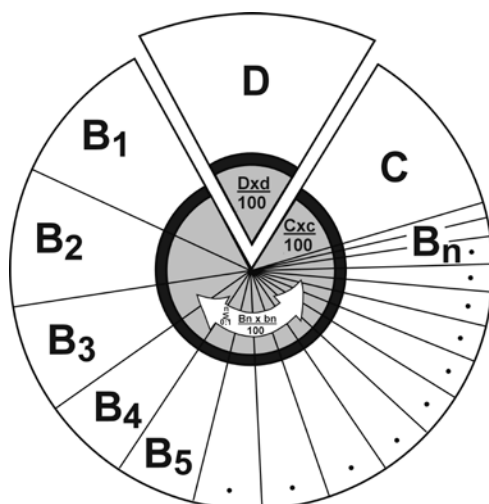


Figure 1: Origin of nutrients taken up by crops.

● off-take for target yield; D = fertiliser rate; B = residual nutrients in the soil from former fertiliser applications; C = native nutrient content of the soil; E = nutrient off-take; b = utilisation efficiency of residual nutrients; c = utilisation efficiency of native nutrients; d = utilisation efficiency of nutrients in fertilisers in year of application

During the first year of application plants utilise only a fraction of the total amount of nutrients applied by fertilisation. Apart from gaseous losses (relevant for nitrogen), soil erosion (potentially relevant for P) or leaching (relevant for nitrogen and sulphur), the amount of fertiliser that is not taken up by plants during the growth period will remain in the soil and becomes potentially available during the next growth period. Its potential availability depends

on its reaction with the soil and its subsequent immobilisation. As this is a continuous process

the term $\frac{B * b}{100}$ in equation 1 is actually a cumulative quantity:

$$\frac{B * b}{100} = \frac{B_1 * b_1}{100} + \dots + \frac{B_n * b_n}{100} \quad \text{Equation 2}$$

with: $B, B_1, \dots, B_n =$ Residual nutrients from fertilisation

1 = of last year

2 = of year before last year

n = of n years ago

$b_1, b_2, b_n =$ corresponding utilisation efficiencies of $B_1, B_2 \dots B_n$

On agricultural fields with regular fertiliser applications it is necessary to consider the total efficacy of applied nutrients. Besides the potential supply from native resources,

$$\left(\frac{C * c}{100} \right)$$

the utilisation of nutrients by fertilisers in the year of application

$$\left(\frac{D * d}{100} \right)$$

and their potential residual effect

$$\left(\frac{B * b}{100} \right)$$

need to be determined for calculating the required fertiliser input. Due to the enrichment of soils with nutrients over time the term

$$E - \left(\frac{B * b}{100} + \frac{C * c}{100} \right) = 0 \quad \text{Equation 3}$$

equals zero if the utilisation efficiency is calculated for the year of application in dependence on nutrient off-take and supply by the residual nutrient content so that it is sufficient to replace losses by off-take, leaching, erosion and fixation (fig. 2). To do so the utilisation in the first year of application and following years need to be considered. Fertiliser rates, which warrant this status quo, are economically optimum and ecologically balanced.

The utilisation efficiency in the year of application represents the "actual" utilisation, while the utilisation over long periods of time with its cumulative efficacy expresses the "effective" (Karlovsky, 1962) or "apparent" (Kaila, 1965; Finck, 1979) utilisation efficiency (s)

$$\frac{D*s}{100} = \frac{D*d}{100} + \frac{B*b}{100} \quad \text{Equation 4}$$

whereby the apparent utilisation efficiency can be calculated as follows

$$s = \frac{\frac{D*d}{100} + \frac{B*b}{100}}{D} * 100 \quad \text{Equation 5}$$

Changes in the nutrient content of the soil by fertilisation based on the actual and apparent utilisation efficiency are presented in fig 2.

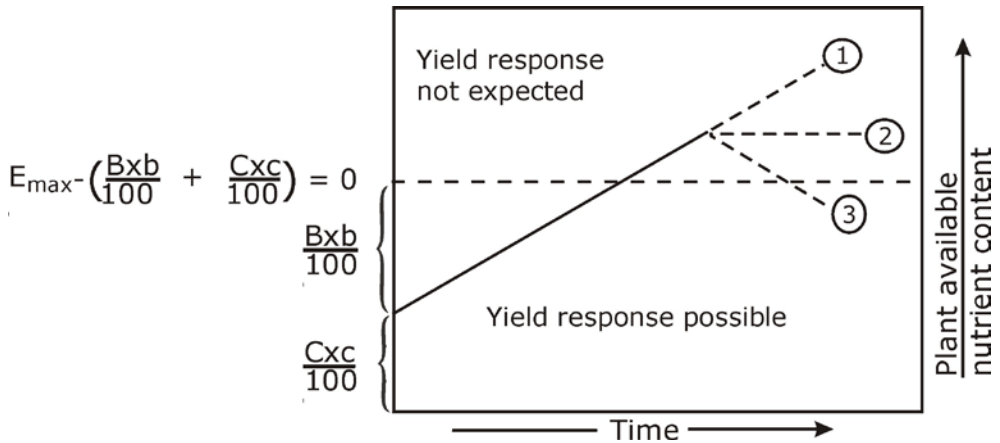


Figure 2: Changes in soil nutrient concentration after reaching the optimum soil fertility level. Based on fertilisation considering the utilisation efficiency of the fertiliser in the year of application (1), or fertilisation considering the effective or apparent utilisation efficiency of the fertiliser (2), without fertilisation (3) according to Engelstad and Parks (1976).

The turnover of nutrients supplied by fertilisation can be balanced as follows

$$D = E + V + F \quad \text{Equation 6}$$

with V = Losses by leaching and erosion

F = Losses by nutrient fixation

and after considering a potential supply from native resources the following equation can be derived

$$\frac{E + V + F - \frac{C \times c}{100}}{D} = 1 \quad \text{Equation 7}$$

Practical aspects of the agronomic effectiveness of P fertilisers

The agronomic effectiveness of P fertiliser is mainly governed by the chemical, physical and biological reactions of the fertiliser with the soil environment.

With the exception of low-weight organic molecules, P is only available to plants in the form of soluble orthophosphate (Barber, 1980). Nevertheless, plants developed a number of mechanisms to revise the process of P immobilisation in the soil. Apart from general mechanisms that influence the agronomic effectiveness of fertiliser P (Schnug et al., 2003), all strategies are of particular importance that modify the root environment to either decrease the affinity of soil particles for orthophosphate, or to increase the solubility of phosphate minerals. Organic acids excreted by the root, such as citric, oxalic and galacturonic acid, form stabile complexes with metals, and thus are able to exchange and utilise even strongly bound P (Nagarajah et al., 1970; Rovira, 1965). Methylated galacturonic acid forms the main compound of the outer pectic wall layer, which functions as a buffer between root hairs and soil (O'Neill et al., 1990).

The low agronomic efficiency of not more than 15% of fertiliser P in the first year of application (Schnug, et al., 2003) suggests that most plants meet their P demand mainly from residual fertiliser P. For most agricultural systems P losses to the environment by leaching are considered low with maximum of 0.1- 0.2 kg ha⁻¹ (Boysen, 1977; Hoffmann, 1978). Consequently, all anthropogenic P input, if it is not taken up by plants, is preserved in the soil. At the same time is the physical movement of P restricted to the movement of P associated with

soil particles and large molecular-weight organic matter (particulated P) by either bioturbation, soil tillage activities or soil erosion during flow events (Catt, 1997; Sharpley et al., 2000).

The characteristics of soil P were recognised long ago by European geographers and since then used in archaeology to trace back ancient settlements (Arrhenius, 1929; Broadbendt, 1981; Proudfoot, 1976). Nevertheless, all P, natural or anthropogenic is subjected to geochemical aging (fig. 3).

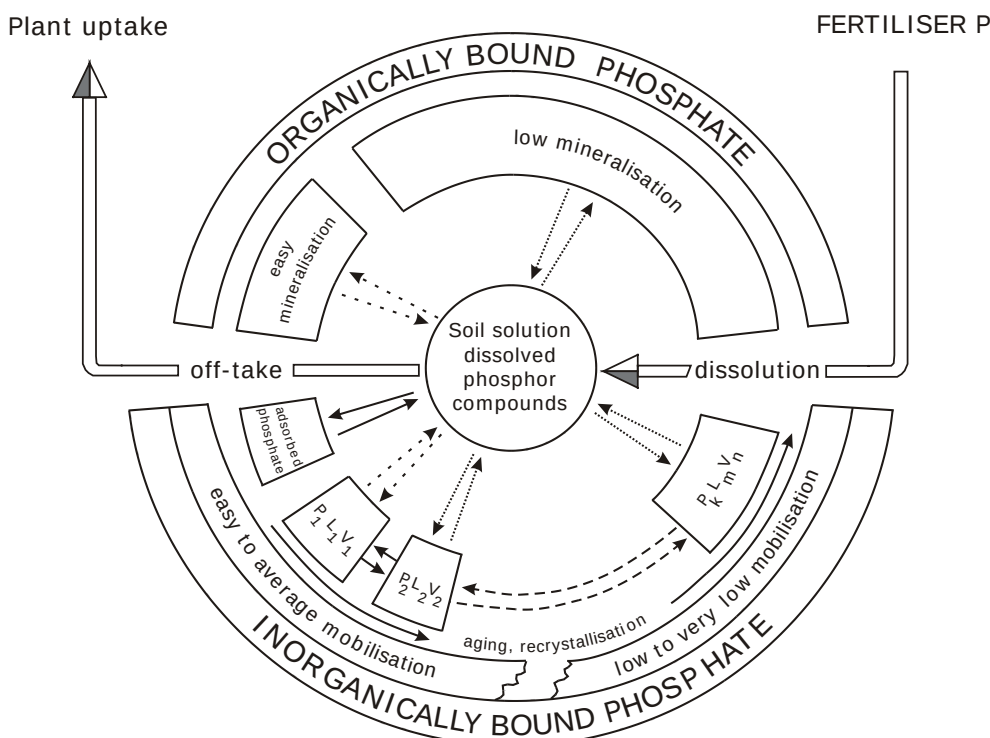


Figure 3: Illustration of geo-chemical aging of fertiliser P in the soil. $P_1, P_2, \dots, P_k$ = inorganic P species; $L_1, L_2, \dots, L_m$ = Solubility of $P_1 - P_k$, decreasing from L_1 to L_m ; $V_1, V_2, \dots, V_n$ = rate of solubility of $P_1 - P_k$, decreasing from V_1 to V_n .

It is widely accepted that more than 80 % of the applied P is immobilized in the soil due to precipitation and sorption processes, whereby the limiting step to furnish crop requirements is the dissolution of initial reaction products during the cropping season (Frossard et al., 2000). Half or more of the total P in soils may be present in organic forms (Harrison, 1984), without being as readily available for absorption by the plant as the inorganic P pool. More than 50 % of fertiliser P occurs as high molecular weight molecules such as esters of the phosphoric acid or inositol phosphates (Baeumer, 1971; Schachtschabel, 1960, Anderson, 1980). Inositol phosphates form a number of very insoluble salts and also form strong complexes with proteins

and with some metal ions, which cannot be utilised by the plant without prior mineralisation by micro-organisms. Ivanov and Sauerbeck (1972) estimated an annual utilisation efficiency of about 1.0 – 1.5 % for these P species. The rest of the organic P species occurs in form of easily soluble nucleic acids and phospholipids. The annual utilisation efficiency is estimated to be 15 – 20 % (Ivanov and Sauerbeck, 1971; 1972).

The release of organic P into the soil solution, where it can move to the root and be adsorbed, is controlled by the rate of organic matter mineralisation. Generally, tillage of the soil promotes the decomposition of organic matter by stimulating the activity of soil microflora (Harrison, 1984). As with N, a high ratio of soil organic matter to organically bound nutrient can result in a deficiency of this nutrient in the soil system. The so-called biological “P-lock” has been reported for soils with a C : P_{org} ratio > 150 (BAEUMER, 1971; FINCK, 1976; KAILA, 1949). In this process the fixation kinetics of the different organic P species follow the same principles as the aging of the inorganic P fraction. Thus in the first year of application, the utilisation efficiency of P applied as organic fertilisers do not differ from those reported for P in inorganic fertilisers (DIEKMANN, 1966; DEBRUK and VOEMEL, 1970; ASMUS et al., 1973; ISERMANN, 1978; LATKOWICZ, 1977; SANDERSON and JONES, 1997; IBRIKEI et al., 1999; ANDERSON et al., 2001; WHALEN and CHANG, 2001). While crop type and associated land management practices influence decomposition processes, in the long run, each management system will stabilise around a steady organic P level (Suenksen, 1977).

With respect to the presented model of the utilisation efficiency of fertiliser P it is to note that the organic P pool consists, like the inorganic P pool, of a continuum of different P species that differ with respect to their solubility and plant availability. As with mineral P species it is assumed that none of the organic P species is irreversibly bound, but may become available during long-term soil transformations.

The utilisation efficiency of mineral P fertilisers is proportional to the P adsorption capacity of the soil, which is predominantly dependent on the negative surface charges as well as the specific surface area of soil particles and is mainly a function of the amount and nature of available adsorption sites in the soil (Schwertmann and Taylor, 1989). The utilisation efficiency of mineral P fertilisers decreases with increasing number of adsorption sites relative to the P concentration (Römer, 2003). Döring (1956) estimated an annual utilisation efficiency of about 30-55 % for particulated P.

The almost universally followed practices of applying water-soluble P fertilisers to soils having moisture contents appreciably below “field capacity”, results in a rapid dissolution of the granules and an increase of the P concentration in the soil solution. Upon formation of a nearly saturated solution in and around the fertiliser granules an osmotic potential gradient is established between the concentrated fertiliser solution and the soil pore water. In extreme cases the pH of the pore water is decreased to that of the fertiliser, resulting in the dissolution of cations, such as Ca, Fe and Al and the subsequent precipitation of secondary P minerals (Sample et al., 1980).

While the solubility of water-soluble P fertilisers is mainly controlled by the pH and Ca concentration of the soil solution, the rate of transformation is controlled by the size of the granules (Fassbender and Ulrich, 1965 a, b; Ulrich, 1963). For acidic soils low in available P, it is generally accepted that early crop response increases with increase in granule size of water soluble P applied. Differences in the utilisation efficiency of different fertiliser types in the year of application (Blaser and Mc Auliffe, 1949; McAULIFFE et al., 1949; HALL et al., 1949; OLSEN and GARDENER, 1949) result from the time required by the initial reaction products to alter into readily available P forms (RUSSEL, 1973; MURRMANN and PEECH, 1969). However, with respect to the effective (site specific soluble) P concentration (Finck, 1969) these differences are considered to be minor.

The speciation of fertiliser P is mainly governed by the soil pH: in acidic soils Fe- and Al-phosphates prevail, while in neutral to alkaline soils Ca-phosphates are predominant (Munk and Gross, 1975; Werner, 1969). These initial, still labile precipitation products undergo further reactions with the soil environment, whereby they change into more stable and less soluble, and thus less plant available P compounds (Sample et al., 1980). These processes follow thermodynamic principles, and are thus driven by an increase in entropy. In calcareous soils the first reaction product is brushite, whereby a continuous exchange of Ca^{2+} for H^+ on the crystal surface leads to the formation of hydroxyapatite. However, for temperate soils in fields the formation of apatite has never been documented (Werner, 1970, 1971; Lookman et al., 1995). In acidic soils the aging of fertiliser P is characterised by a change from amorphous to more crystalline phosphate minerals, whereby orthophosphate displaces OH^- from coordination positions at the surface of the Fe or Al oxides (Werner 1971; Werner and Wiechmann, 1972).

Although the initial reactions of P fertilisers in the soil are rapid and result quickly in an equilibrium between reactions products and soil solution, the aging, the formation into more stable and less available P forms is a continuous process (Werner and Wiechmann, 1972,

Schafrat and Finck, 1973; Sample et al., 1980). Werner and Wiechmann (1972) reported an average, effective utilisation efficiency of 48 % for residual fertiliser. They evaluated this low efficiency as an indication of P fixation in the soil (Platzen and Munk, 1975; Wiechmann and Werner, 1976).

Given these estimations and adding the reported initial utilisation efficiency of fertiliser P in the application year of 15 % one derives at a total utilisation efficiency of only 60 % (Arbeitskreis Phosphate, 1976). However, early in the paper it was pointed out that this assumption is outdated. Today, it is generally accepted that “absolutely” plant unavailable P, so-called “fixed” or “occluded” P does not exist during long-term P transformations. One of the reasons why these myths of occluded or fixed soil P persisted for such a long time within the soil science community lies within the experimental design of fertiliser trials. Classically, the utilisation efficiency of residual fertiliser is assessed by measuring the P uptake by crops grown repeatedly on soils subjected to prior long-term fertilisation without additional supplements of fresh fertilisers (Werner, 1971, 1972; Werner and Wiechmann, 1972). These so-called “exhaustion trials” can induce a temporary P deficiency, which in turn has a negative impact on the viability and thus the ability of plants to take up nutrients. The common fallacy is to interpret the physiological disability of the plants to take up nutrients as a nutrient fixation in the soil. Furthermore, the thermodynamic processes of energy releasing phosphate transformations are accompanied by energy consuming microbiological processes that have a solubilising effect on the phosphate minerals (Sharma and Singh, 1971; Mosse et al., 1976; Frossard et al., 2000).

The conclusion to be drawn is that under soil conditions where the natural P supply is exhausted ($C \approx 0$ or $c \approx 0$) and the fill up of soil solution P is fully depending on the dissolution of applied fertiliser, the apparent (Finck, 1979) or long-term cumulative utilisation efficiency of P is easily deduced by balancing plant removal and supply in form of fertilisation, given that the losses to the environment by either leaching or soil erosion are negligible:

$$s = \frac{E}{D} * 100 \quad \text{Equation 8}$$

The utilisation efficiency of fertiliser P under field conditions

Unlike C and N, which can be added to the soil systems from the atmosphere, the P status of natural systems is essentially controlled by the occurrence of primary apatite minerals (Walker and Syers, 1976; Bowman et al., 1998). While this is true for most tropical soils, in temperate soils the importance of primary minerals is neglectible and subsequently the aging of applied fertiliser essentially controls the P cycle. Thus, in temperate agro-ecosystems the utilisation

efficiency of fertilisers can be expressed as a percentage of the plant uptake (Koehnle and Knauer, 1965). Karlovsky (1962) introduced the so- called “balance method”, whereby under the condition of constant yield and fertiliser application rates the effective utilisation efficiency can be calculated by balancing fertiliser input and plant uptake.

The non-equilibrium behaviour of phosphate sorption reactions, known as hysteresis, whereby the desorption reaction usually does not take place as fast as the sorption reaction (Uehara and Gillman, 1981) led to the prevailing opinion that P immobilisation is higher than the dissolution of adsorbed fertiliser P and thus justifies a fertiliser rate higher than plant uptake (Arbeitskreis Phosphat, 1978; Johnston, 1976). However, in a seven years field trial Schachtschabel (1976) demonstrated that an application rate of water-soluble P fertiliser equivalent to plant uptake did not change the soil P level of the soils. As the natural supply of P by the soil did not have an effect on the results he concluded that a fertilisation rate higher than the uptake was not economically sound. An application rate higher than the uptake will result in an increase of the soil P level which equals an accumulation of P, whereby a rate lower than the uptake would result in a decrease of the soil P level, thus in mining of P. Bergmann and Witter (1965) obtained similar results (fig. 4). Both field trials clearly demonstrate that the dissolution of initial fertiliser reaction products during the cropping season was sufficient to keep the concentration of P in the soil solution at the level of the plant requirement. In these trials the apparent utilisation efficiency of fertiliser P was therefore 100 %.

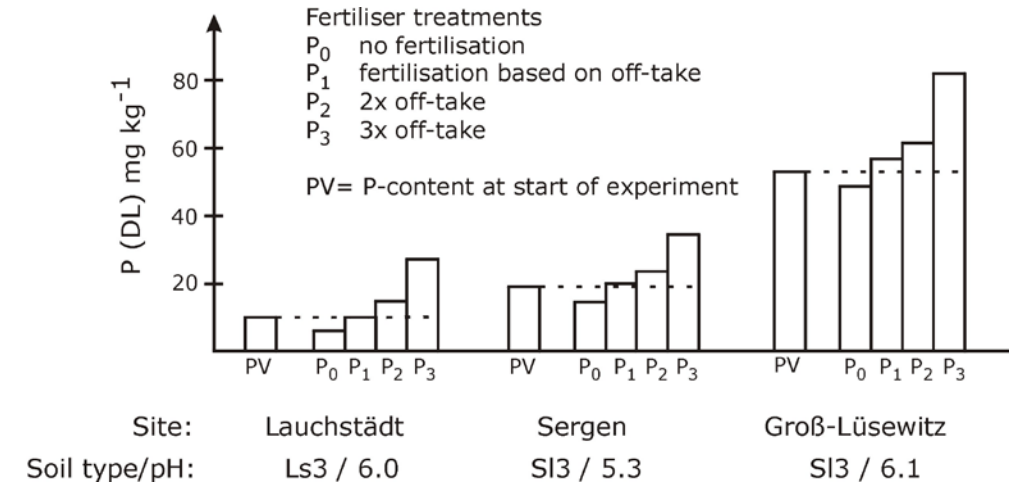


Figure 4: Changes in the concentration of DL- soluble P in the surface soil during a 9-year field trial with increasing P fertilisation using super phosphate (according to Bergmann and Witter, 1965).

These results not only demonstrate that plants are capable of utilising aging fertiliser products despite their decreasing solubility, but also that fixation and desorption processes are in an equilibrium. In the light of the above discourse the intrinsic hypothesis is derived that in soils where P fertilisation does not result in an surplus in crop yield (fig. 5) as the P level is already optimum, the fertiliser rate should be equivalent to the plant uptake, as an utilisation efficiency of 100 % can be assumed.

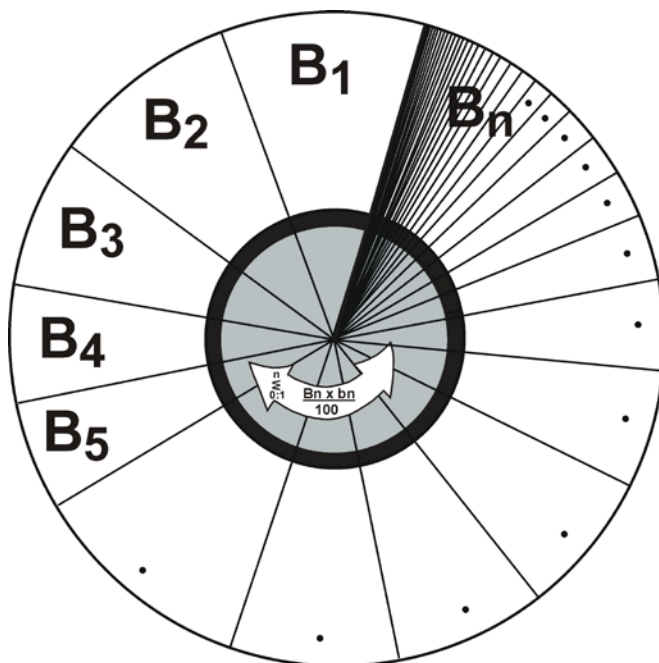


Figure 5: Origin of P in crops for soils with an optimum P level.

● off-take for target yield; D = fertiliser rate; B = residual nutrients in the soil from former fertiliser applications 1-n (B_1 - B_n); b = utilisation efficiency of residual nutrients from former years of application B_1 - B_n

For the validation of the hypothesis it is important to note that the assumption of a 100 % utilisation efficiency and thus a balanced orientated fertiliser strategy is only feasible for P inputs, which will undergo total dissolution during one cropping season. For the majority of agricultural soils this effective proportion of P fertilisers corresponds to their water-soluble P concentration, for soils with a pH between 5.6 and 7.5 and the citrate soluble concentration for soils with a pH < 5.8, respectively. For organic fertilisers it is assumed that in the long run all P undergoes mineralisation and will be converted into orthophosphate. Thus, the effective proportion of organic fertilisers corresponds with the total P concentration.

Following the concept of balanced fertilisation as it is proposed by environmentalists (Sharpley and Withers, 1994; Higgs et al., 2000), in particular by a variety of conventions for the protection of oceans (Vermeulen et al., 1998; Schnug et al., 2001), it would be sufficient for agricultural production to replenish the soil P withdrawal by crops by the equivalent amount of water-soluble P.

Consequences for agricultural production under consideration of organic farming

Phosphorus is an essential plant nutrient also in organic farming, too. However, in contrast to conventional farming systems, where nutrient inputs aim at a targeted yield level, organic farming aims at feeding the soil and thus at maintaining the natural soil fertility. The core of organic farming is thus to support the transformation ability of the soil rather than the straightforward idea of supply and demand. The EU Council regulation 20092/91 points out in Appendix I (Soil fertility): “ the basis of a sustainable soil utilisation and the maintenance of soil fertility for future generations is an amendment of the soil not plant nutrition (Schmidt and Haccius, 1998). In organic farming only the use of non water-soluble P fertiliser as listed in the Appendix IIa of the regulation is permitted: Guano, farmyard manure, animal bone meal, wood ash and softly ground rock phosphate. The latter are more specifically defined in the regulation 76/1116/EEC as to have a proportion of formic acid (2 %) soluble P of at least

55 %, whereby 90 % has to be smaller than 0.063 mm and 99 % smaller than 0.125 mm. Such a material is unlikely to be soluble on a short time scale and thus cannot be expected to influence the soil P cycle during one cropping season.

As outlined in the previous section of this paper, using these kinds of “slow soluble” P fertilisers for a balanced fertilisation strategy that is solely based on replenishing P exports by the crops (Schnug et al., 2001), will consequently mine the soil with respect to P and subsequently reduce the soil fertility (fig.6).



Figure 6: P deficiency in a cornfield, Livada, Rumanian (Photo: A. Gassner, 2002).

A solution to the problem might be the new concept of “in situ” digestion of rock phosphates (RP) (Fan et al., 2003), which can also be used to increase the solubility of low soluble Ca-phosphates in acidulated RP’s. The principle is to manufacture compound fertilisers containing the RP and a suitable amount of elemental sulphur to ensure its transformation in soluble forms by means of the sulphuric acid produced in the course of sulphoxidation. The process is enhanced by inoculating the soil with *Thiobacillus spp.*. *Thiobacillus spp.* are characterised by their ability to gain energy from the oxidation of reduced sulphur and iron compounds. Experiments combining RP with elemental S° were conducted as early as 1916 (Lipman and McLean, 1916 and 1918). The underlying principle is that soil microbes oxidise S° to H₂SO₄, which in turn dissolves R particles that are in close proximity to S° (fig. 7):



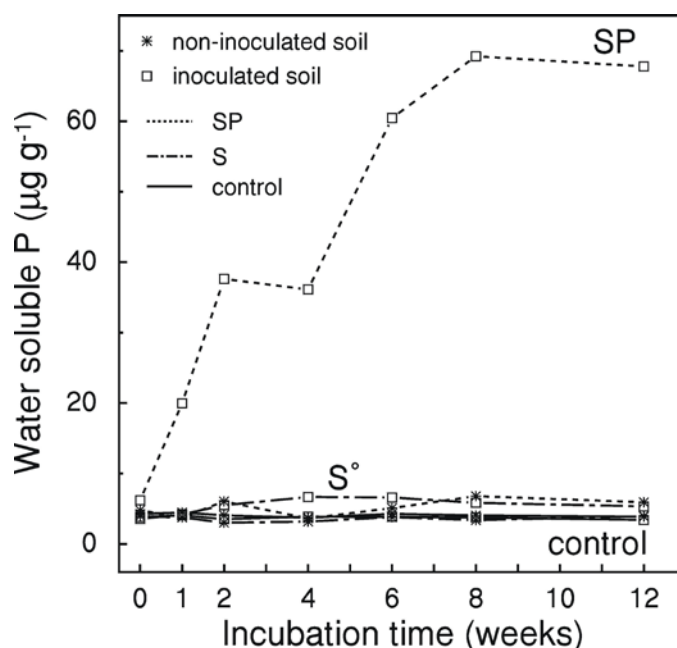


Figure 7: Influence of incubation time on water soluble P concentrations in dependence on inoculation with *thiobacillus* spp. after application of elemental S and SP fertilizer material at an incubation temperature of 23.8° C.

Earlier attempts to enhance the solubility of RP with bacteria were not very successful (Abd El-Haleem et al., 2003; Sharma and Singh, 1971). The main draw back of these experiments was the low survival rate of the added micro-organisms. In contrast, the “in situ” digestion is based on the activation of *Thiobacillus* spp. already existing in the soil. The activation is enhanced by adding a culture medium which directs the natural competition in favour of *Thiobacillus* spp..

Nevertheless, the contamination of RPs with heavy metals that inevitably will become soluble in the process of the “in situ” digestion does limit the suitability of RPs as a source for agriculture P (table 1). Thus, bone meal ashes, which are produced from bone meal, burned separately and not in the so called “co-incineration” with municipal solid waste, appear to be the more suitable source for P needed for agricultural use.

Table 1: Phosphor, Zinc and Cadmium concentrations in Animal bone meal and softly ground rock phosphate (Rogasik et al., 2003).

Material	P (%)	Cd (µg g ⁻¹)	Zn (µg g ⁻¹)
softly ground rock phosphate	13	46	400
animal bone meal	19	0.1*	252

* in original residue, prior to incineration

Animal bone meals have been known as fertilisers for a long time. As early as 200 years ago Chinese farmers applied finely ground bones to their fields (Shapiro, 1985). Also in Europe at the beginning of the 19th century it was common to process the carcasses from the battlefields of Leipzig, Austerlitz and Waterloo to fertilisers (Shaw, 2000). With the development of mineral fertilisers the utilisation of bone meals became less popular, mainly for practical reasons, but also because of the low solubility of their P forms. In Germany, the meat industry produces annually 634,000 tons of animal meal (blood, meat and bone meal) and 372,000 tons animal fat. Due to the feed ban within the EU, implemented after the BSE crisis, the question of alternative utilisation of these products are imposed. Given the shortage of the geological P resources (Steen, 1998; Pradt, 2003), the limitation of industrial fertilisers application in organic farming and the relative cleanness of bone meal ashes when compared to sewage sludge ashes (Schnug et al., 2003) it is inevitable that European agriculture remembers its old tradition of utilising the nutritional value of animal bone meals (Rogasik et al., 2003). The “in situ” digestion thus offers an important tool to implement a balanced fertilisation approach within organic farming systems.

References

- Abd El-Haleem A A, Abdel-Salam A A, Abd El-Hadi A H, Moursy M E (2003) Improving wheat response to phosphorus in a calcareous soil using phosphate dissolving bacteria. Egypt. J. Soil Sci. (in press).
- Arbeitskreis Phosphat der deutschen Düngerindustrie 1978: „P₂O₅; Phosphatdüngung – unentbehrlich für Boden und Pflanze“. Information für die Beratung.
- Arrhenius O (1931) Soil analysis in the service of archaeology. Z. Pflanzenernährung, Düng., Bodenkde. 10b: 427-439.
- Asmus F, Hermann V, Lange M, Specht G. (1973) Wirkung und Ausnutzung des Stickstoffs aus Gülle. Archiv f. Acker- u. Pflanzenbau, 17: 927-934.
- Baeumer K (1971) Allgemeiner Pflanzenbau. UTB 18, 99-137, Ulmer Verlag, Stuttgart.
- Barber S A (1980) Soil-plant interactions in the phosphorous nutrition of plants. In: Khasawneh F E, Sample E C, Kamprath, E J (eds) The role of phosphorus in agriculture. ASA CSSA and SSSA, (ISBN 89118 062 1. Madison, pp. 591-613.
- Bergmann W, Witter B (1965) Die Wirkung der Phosphorsäure in statischen P-Steigerungsversuchen und der Verbleib der Restphosphorsäure im Boden. Albrecht-Thaer-Archiv 9: 901-922.
- Blaser R E, Mc Auliffe C (1949) Utilisation of phosphorus from various fertilizer materials: I. orchard grass and ladino clover in New York. Soil Sci. 68: 145-150.
- Böden. Proc. Symposium „Rückgewinnung von Phosphor in der Landwirtschaft und aus Abwasser und Abfall. Berlin, 06.-07. Februar 2003, Umweltbundesamt, Institut für Siedlungswasserwirtschaft der RWTH Aachen, ISBN 3-932590-99-6.
- Boysen P (1977) Nährstoffauswaschung aus gedüngten und ungedüngten Böden in Abhängigkeit von Standorteigenschaften und Nutzung der Moränen- und Sandergebiete Schleswig-Holstein. Dissertation Kiel.
- Brams E (1968) The mucilaginous layer of citrus roots its delineation in the rhizosphere and removal from roots. Plant and Soil 30: 105-108.
- Catt J A, Johnston A E, Quinton J N (1997) Phosphate losses in the Woburn erosion reference experiment. In: Tunney H, Carton O T, Brookes P C, Johnston A E (eds) Phosphorous loss from soil to water. CAB International, pp 374-377.
- Debruk J, Voemel A (1970) Die Verwertung der Nährstoffe in Abwasserschläm. Landwirtsch. Forsch. 27/I. SH 39-60.
- Diekmann K (1966) Unser Acker. 9. Auflage Parey Hamburg.
- Döring H (1956) Untersuchungen über die Ausnutzbarkeit der an Kolloiden sorbierten Phosphorsäure durch die Pflanze. Z. Pflanzenernährung, Düng., Bodenkde. 73: 235-245.
- Drake M, Steckel J E (1955) Solubilization of soil and rock phosphate as related to root cation exchange capacity. Soil Sci. Soc. Amer. Proc. 19: 449-454.

- Einicke W, Hagemann O (1969) Forschungsbericht, Lehrstuhl für Physiologie und Ernährung der Pflanzen, Sektion Pflanzenproduktion der Universität Halle/Saale.
- Engelstad O P, Parks W L (1976) Buildup of P and K in soils and effective use of these reserves. TVA Fertilizer Conference 27.-28. July 1976 Cincinnati, Ohio TVA Bull 016: 50-58.
- Fan X, Habib L, Fleckenstein J, Haneklaus S, Schnug E (2003) In situ digestion - a concept to manage soil phosphate in organic farming. Proc. 13th International Symposium of CIEC, Tokat, Turkey, June 10-13, 2002 (in press).
- Fassbender H R, Ulrich B (1965a) Löslichkeit und Löslichkeitsprodukt von Hydroxylapatit und Rohphosphaten. Z. Pflanzenernähr., Düng., Bodenkde 112: 101-113.
- Fassbender H R, Ulrich B (1965b) Lösungsgeschwindigkeit von Rohphosphaten. Z. Pflanzenernähr., Düng., Bodenkde 112:212-219.
- Finck A (1969) Bewertung von Rohphosphaten. Bauernblatt fuer Schleswig-Holstein. Sonderdruck vom 5.4.1969.
- Finck A (1976) Pflanzenernährung in Stichworten. Hirt Verlag Kiel.
- Finck A (1979) Dünger und Düngung. Verlag Chemie Weinheim.
- Frede H G, Bach M (2003) Heutiger und künftiger Beitrag der Gülle bei der Phosphorversorgung der Böden. Proc. Symposium „Rückgewinnung von Phosphor in der Landwirtschaft und aus Abwasser und Abfall. Berlin, 06.-07. Februar 2003, Umweltbundesamt, Institut für Siedlungswasserwirtschaft der RWTH Aachen, ISBN 3-932590-99-6.
- Frossard, E.; Condron, L. M.; Oberson, A.; Sinaj, S.; Fardeau, J. C. Processes governing phosphorus availability in temperate soils. J. of Environ. Qual. 2000, 29, 15-23.
- Hall N S, Nelson W L, Krantz B A (1949) Utilisation of phosphorus from various fertilizer materials. II. Cotton and corn in North Carolina. Soil Sci. 68: 151-156.
- Harrison A F (1987) Soil organic phosphorus: A review of world literature. Wallingford, UK:CAB International.
- Higgs B, Johnston A E, Salter J L, Dawson C J (2000) Some aspects of achieving sustainable phosphorous use in agriculture. J Environ. Qual. 29: 80-87.
- Hoffmann W (1978) Phosphor- und Stickstoffzufuhr aus der Landwirtschaft in die Ostsee, insbesondere durch die Schwebstoffe der Gewässer. Umweltforschungsplan des Bundesministers des Inneren – Wasser – Forschungsbericht 120 04 015 Kiel.
- Ibrieki H, Hanlon E A, Recheigl J E (1999) Inorganic phosphorous and manure effects on bahiagrass on a Spodosol. Nutrient Cycling in Agroecosystems 54: 259-266.
- Isermann K (1978) Die Phosphat und Kali Bilanz von viehstarken Grünland- und Ackerbau-Betrieben. Limburgerhof 1978.
- Ivanov P, Sauerbeck D (1972) Die Pflanzenverfügbarkeit des Phosphors aus verschiedenen organischen Substanzen. Landwirtsch. Forsch. 25: 216-225.
- Ivanov P, Sauerbeck D (1971) Festlegung, Umwandlung und Aufnehmbarkeit von Phytin-Phosphor im Boden. Z. Pflanzenernährung, Düng., Bodenkde. 129: 113-123.
- Johnston A E (1976) Additions and removals of nitrogen and phosphorous in long term experiments at Rathamsted and Woburn and the effect of the residues on total soil nitrogen and phosphorous. Techn. Bull. Min. Agric. Food UK 32: 101-119.
- Kaila A (1949) Biological absorption of phosphorous. Soil Sci. 68: 279-289.
- Kaila A (1965) Apparent recovery of fertilizer nitrogen. J. Sci. Agric. Soc. 37: 163-174.
- Karlovsy J (1962) Method of assessing the utilisation of phosphorous on permanent pastures. Int. Soil Conf. New Zealand Rukuhia Soil Res. Sta. Hamilton N.Z.: 726-730.
- Koehnlein J, Knauer N (1965) Ergebnisse der Kieler Dauerdüngungsversuche mit Phosphat und Kali. Schriftenreihe der Landwirtschaftlichen Fakultät der Christian-Albrecht-Universität Kiel: H. 39.
- Larsen S, Gunary D, Sutton C D (1965) The rate of immobilization of applied phosphate in relation to soil properties. J. Soil Sci. 16: 141-148.
- Latkowicz I (1977) Wirkung von organischen und Mineraldüngern in Mais-Monokulturen. Agrochimica 11. 67-73.
- Lipman, J.G., McLean, H.C. (1916) Sulfur oxidation in soils and its effect on availability of mineral phosphates. Soil Sci. 2, 499-538.
- Lipman, J.G., McLean, H.C. (1918) Experiments with sulfur-phosphate composts conducted under field conditions. Soil Sci. 5, 243-250.
- Lookman R, Freese D, Merckx R, Vlassak K, van Riemsdijk H (1995) Long-term kinetics of phosphate release from soil. Environ. Sci. Technol. 29:1569-1575.
- Matzel W (1974) Probleme der Ausnutzung des Dünger- und Bodenphosphors – Übersichtsbeitrag. Archiv f. Acker- u. Pflanzenbau u. Bodenkde. 18: 471-487.
- Mc Auliffe C I, Peech M, Bradfield M (1949) Utilisation by plants of phosphorous in farm manure: II. Availability to plants of organic and inorganic forms of phosphorous in sheep manure. Soil Sci. 68: 185-195.
- Mosse B, Powell C L, Haymann D S (1976) Plant growth responses to vesicular arbuscular mycorrhiza. IX. Interactions between V.A. mycorrhiza, rock phosphate and symbiotic nitrogen fixation. New Phytologist 76: 331-342.
- Moyer J R, Thomas R L (1970) Organic phosphorous and inositol phosphates in molecular size fractions of a soil organic matter extract. Soil Sci. Soc. Amer. Proc. 34: 80-83.
- Munk H, Gross K (1975) Phosphatfraktionierung an langjährig differenziert gedüngten Böden. Landwirtsch. Forsch. 31/I: 96-108.

- Murrmann R P , Peech M (1969) Relative significance of labile and crystalline phosphates in soil. *Soil Science* 107: 249-255.
- O'Neill, M.; Albertsheim, P.; Darvill, A.C. (1990) The pectic polysaccharides of primary cell walls. *Methods Plant Biochem.* 2, 415-441.
- Olsen S R, Gardener R (1949) Utilisation of phosphorous from various fertilizer materials: IV. Sugar, beets, wheat and barley in Colorado. *Soil Sci.* 68: 163-170.
- Paauw van der F (1960) Die optimale Versorgung von Boden und Pflanze mit Phosphor. *Landwirtsch. Forsch.* 14: Sonderheft 55-60.
- Platzen H, Munk H (1975) Zur Frage nach der optimalen P-Zufuhr auf Böden mit ausreichendem Nährstoffpotential. *Landwirtsch. Forsch.* 31/I: 258-269.
- Pradt D (2003) Verfügbarkeit und Vermarktung von Roh- und Recyclingmaterial aus Sicht der Düngemittelindustrie. Proc. Symposium „Rückgewinnung von Phosphor in der Landwirtschaft und aus Abwasser und Abfall. Berlin, 06.-07. Februar 2003, Umweltbundesamt, Institut für Siedlungswasserwirtschaft der RWTH Aachen, ISBN 3-932590-99-6.
- Rogasik J, Rosiady I, Fleckenstein J, Haneklaus S, Fan X, Scholz R, Schnug E (2003) Phosphorpotenziale von Tiermehl und Schlachtabfällen sowie Möglichkeiten des Phosphorrecyclings. Proc. Symposium „Rückgewinnung von Phosphor in der Landwirtschaft und aus Abwasser und Abfall. Berlin, 06.-07. Februar 2003, Umweltbundesamt, Institut für Siedlungswasserwirtschaft der RWTH Aachen, ISBN 3-932590-99-6.
- Römer W (2003) Pflanzenverfügbarkeit von Phosphor bei verschiedenen Düngematerialien -insbesondere bei Klärschlamm. Proc. Symposium „Rückgewinnung von Phosphor in der Landwirtschaft und aus Abwasser und Abfall. Berlin, 06.-07. Februar 2003, Umweltbundesamt, Institut für Siedlungswasserwirtschaft der RWTH Aachen, ISBN 3-932590-99-6.
- Rovira A D (1965) Ecology of soil-borne pathogens. (Ed. K F Baker, W C Snyder) University of California Press Berkeley.
- Russell W (1973) Soil conditions and plant growth. A) The residual value of phosphatic fertilizers. Longman, London, 594-602.
- Sample E C, Soper, R J, Racz, G J (1980) Reaction of phosphate fertilizers in soils. In: Khasawneh F E, Sample E C, Kamprath E J (eds) The role of phosphorus in agriculture. Madison, WI: ASA-CSSA-SSSA, pp 263-304, ISBN: 0-89118-062-1
- Sanderson M A, Jones R M (1997) Forage yields, nutrients uptake, soil chemical changes and nitrogen volatilization from bermudagrass treated with dairy manure. *J. Prod. Agric.* 10: 266-271.
- Sanderson M A, Jones R M, Mc Farland J, Stroup J, Reed R L, Muir J P (2001) Nutrient movement and removal in a switchgrass biomass filter-stripp system treated with dairy manure. *I. Prod. Agric.* 10: 266-271.
- Schachtschabel P (1960) Umwandlung der Düngerphosphate im Boden und Verfügbarkeit des Bodenphosphors. *Landwirtsch. Forsch.* 17: Sonderheft 30-36.
- Schachtschabel P (1976) in: Scheffer-Schachtschnabel: Lehrbuch der Bodenkunde, Kap. XI, Nährstoffe: 196-264. Enke Verlag.
- Scharafat I, Finck A (1973) Umwandlung und Verfügbarkeit von Rophosphaten (Hyperphos) verglichen mit aufgeschlossenen Phosphaten unter kontrollierten Temperaturen- und Feuchtebedingungen. *Z. Pflanzenernähr.; Düng., Bodenkd.* 134: 257-267.
- Schmidt H, Haccius M (1998) EU regulation “Organic Farming” a legal and agro-ecological commentary on the EU’s council regulation (EEC) No. 2092/91.pp 417.
- Schnug E, Rogasik J, Haneklaus S (2003) Methoden und Probleme der Bestimmung des Ausnutzungsgrades von Nährstoffen in Düngemitteln. *Landbauforschung Völkenrode* 2/2003 (im Druck).
- Schnug E, Sparovek B, Storck W, Jering A, Volkgenannt U (2001) The HELCOM Working Group on Agriculture (WGA). *Landbauforschung- Völkenrode* 51: 5-9, ISSN 0458-6859
- Schwertmann, U.; Taylor, R. M. Iron oxides. In *Minerals in soil environments* Dixon, J. B.; Weed, S. B. Eds.; SSSA: Madison, WI, 1989; 379-427.
- Shapiro J (1985) An introductory lecture at the International Symposium “Phosphorous in freshwater ecosystems”, *Hydrobiologia* 170, 9-17.
- Sharma H C, Singh R M (1971) Effect of phosphobacteria culture on the efficiency of phosphatic fertilizers and on the yield of maize. *Indian J. Agronomy* 16: 422-424.
- Sharpley A, Foy B, Withers P (2000) Practical and innovative measures for the control of agricultural phosphorus losses to water. An overview. *J. Environm. Qual.* 29: 1-9.
- Sharpley A, Withers P (1994) The environmentally-sound management of agricultural phosphorous. *Fert. Res.* 39: 133-146.
- Shaw K (2000) The Little Book of bad taste. A special selection from: The mammoth book of tasteless lists. Robinson Publishing 1998.
- Steen I (1998) Phosphorus availability in the 21st century - Management of a non-renewable resource. *Phosphorus & Potassium British Sulphur Publishing* 217:25-31.
- Suencksen H (1977) Erfahrungsbericht über die Lely-Fräse Bauernblatt für Schleswig-Holstein vom 26.2.1977.
- Tunney, H (1990) A note on a balance sheet approach to estimating the phosphorus fertilizer needs of agriculture. *Irish J. Agric. Res.* 29:149-154.

- Uehara G, Gillman G (1981) The mineralogy chemistry and physics of tropical soils with variable charge clays. Boulder: Westview Press.
- Ulrich B (1963) Die Umsetzung der anorganischen Phosphate als Funktion des Kalkpotentials. Z. Pflanzenernähr., Düng., Bodenkde.100: 97-102.
- Ulrich B, Benzler J H (1955) Der anorganisch gebundene Phosphor im Boden. Z. Pflanzenernähr., Düng., Bodenkde.70:220-224.
- Vermeulen S, Steen I, Schnug E (1998) Nutrient balances at the farm level. Proc. 11th Int. Symposium of CIEC "Codes of good fertilizer practice and balanced fertilization", 108-123.
- Walker T W, Syers J K (1976) The fate of phosphorus during pedogenesis. Geoderma 15:1-19.
- Werner W (1969) Kennzeichnung des pflanzenverfügbaren Phosphats nach mehrjähriger Düngung mit verschiedenen Phosphaten. Z. Pflanzenernähr., Düng., Bodenkde. 122: 19-32.
- Werner W (1970) Untersuchungen zur Pflanzenverfügbarkeit durch langjährige Phosphatdüngung angereicherten Bodenphosphats. 1. Mitt.: Die Verfügbarkeit der Umwandlungsprodukte in sauren Böden. Z. Pflanzenernähr., Düng., Bodenkde. 126: 135-150.
- Werner W (1971a) Phosphatdynamik in carbonathaltigen Böden. Der Deutsche Weinbau: 30, 31.
- Werner W (1971b) Untersuchungen zur Pflanzenverfügbarkeit durch langjährige Phosphatdüngung angereicherten Bodenphosphats. 2. Mitt.: Die Verfügbarkeit von Umwandlungsprodukten mit defekter Apatitstruktur in neutralen und carbonathaltigen Böden. Z. Pflanzenernähr., Düng., Bodenkde. 129: 30-42.
- Werner W, Wiechmann H (1972) Untersuchungen zur Pflanzenverfügbarkeit des durch langjährige Phosphatdüngung angereicherten Bodenphosphats. 3. Mitt.: Die Verfügbarkeit der Umwandlungsprodukte in neutralen und kalkhaltigen Böden. Z. Pflanzenernähr., Düng., Bodenkde. 133: 3-17.
- Whalen J K, Chang C (2001) Phosphorous accumulation in cultivated soils from long-term annual applications of cattle feedlot manure. J. Environm. Qual. 30. 229-237.
- Wiechmann H, Werner W (1976) Umwandlung von Phosphaten im Boden. DLG-Mitteilungen 91: 1147-1150.

INTEGRATED GPS, AND INTERNET BASED GIS APPLICATIONS FOR THE SUPPORT OF AGRICULTURAL ADVISORY SYSTEMS

Tamás Németh, József Szabó and László Pásztor

Research Institute for Soil Science and Agricultural Chemistry of the
Hungarian Academy of Sciences; GIS Lab
H-1022 Budapest, Herman Ottó út 15, Hungary

Abstract

Complex GI systems were elaborated by the GIS Laboratory of RISSAC in close co-operation with various institutions and firms. In addition to carrying out the digital reambulation and GIS adaptation of large-scale soil surveys further information, related to land and agricultural management, was integrated into these systems. As a next step Intranet/Internet based realization was worked out using Autodesk MapGuide Program providing fast access to the spatial data in an operating system independent way. The intranet GIS server can also be reached from mobile clients, which (supplied with suitable GPS-cards) make GIS supported, real-time, in-situ survey possible. The intranet based GI service together with the mobile technology jointly can be efficiently used during the preprocessing works and the elaboration of sampling design, on the field as well as during the post processing period. Consequently, the elaborated system can prove to be very useful in the whole process of the agricultural counselling practice thus it is not suggested to be used only on pilot areas, but can serve as a model for the preparation of similar applications all around the country.

Introduction

A great amount of soil information is available in Hungary due to earlier agrogeological surveys (Várallyay, 1989). The collected data are available in different scales: national, regional, micro-regional, farm and field level and they are generally related to maps. In the 1990s a great deal of these soil data were organized into geographic soil information systems by RISSAC GIS LAB. At the beginning small-scale (1:100,000 – 1:500,000) systems were elaborated, recently we concentrate on the more challenging large-scale systems. Beside the elaboration of a national, 1:25,000 scale soil information system (Pásztor et al., 2002), there have been some initiatives for the GIS-based reprocessing of the large-scale (1:10,000) practical soil mappings. Digital processing and GIS adaptation of soil information carried by these archives is unavoidable due to recent challenges like requirements set up by Hungary's European Union's accession and introduction of national agri-environmental program as well as demands of site-specific or precision agriculture.

Agricultural advisory and recommendation systems summarize current knowledge on soil fertility, nutrient supply and limiting factors with respect to the expected yield. In Hungary in the mid-'70s a systematic program (including sampling, analysis and recommendation) was introduced for controlling the plant nutrient status of cultivated soils. In the mid-'80s a new

computerised fertiliser system was elaborated (Várallyay et al., 1992), which was used to characterise more than 500,000 ha in recent years. After the political and economical changes in the late '80s - early '90s, which had drastic influence on the Hungarian agriculture, a demand rose for a new, cost saving, environmentally friendly fertiliser recommendation system (Csathó et al., 1998). The next step in the improvement of these advisory and recommendation systems should be the extension of their spatial features that is integrating them with GIS.

Site-specific management unlike the general agricultural practice, does not treat management units as homogenous plots. Precision agriculture requires three main components: accurate positioning (based on GPS), real-time technology for controlling various agrotechniques applied and appropriate spatial databases that provide information necessary to obtain the promised benefits of precision agriculture (Cambardella and Karlen, 1999). In this context soil represents one of the most important factors to be involved, and the larger the applied scale the more accurate is the achieved result. For site-specific management the relevant map-equivalent scale of spatial information is at least 1:10,000. Larger scale base data could provide better results but can seldom be obtained. It is partly large-scale spatial soil information systems that made the evolution of precision agriculture possible.

Spatial information management (GIS tools and methods, digital mapping, remote sensing, image processing, GPS technology) has been expanding and spreading over almost every sector of life. According to some estimations approximately 80 percent of data recently used for various purposes is geographically located (i.e. georeferenced). A GIS is a tool that uses the power of the computer to pose and answer geographic questions by arranging and displaying data about places in a variety of ways, such as maps, charts, and tables. People have used maps for thousands of years to clearly present information about places, and GIS is a modern extension of that ancient tradition. Geographic Information Systems have been developed to facilitate the computerized, spatial modelling and analysis of the geographical environment (Longley et al., 1999). The spreading of these systems has brought with it the development of their theory and on the other hand their everyday usage induced the extension of their service functions. GIS, originally the abbreviation of Geographic Information System, is recently known as Geographic Information Science (Longley et al., 2001) and also becoming Geographic Information Service (Dangermond, 2001).

Internet was designed as a medium for both graphics and text. The higher became the speed of network connections the more and more graphics were used by web designers in their pages. Image maps were soon developed which allowed a degree of interaction. Defined areas under

the image acted as the graphical equivalents of the text hyper-links and allowed users to interact with the image. This arrangement allowed maps to be published on the web and information to be linked to region of the map. With the next technological step the versatility of a desktop GIS was aimed. This is effectively a remote control facility with which the user is able to specify the map needed over the web. The user's commands are relayed to a web server where they are interpreted and passed to a map server, effectively a remote controlled GIS. The map server generates a new map image by using the GIS engine to carry out the necessary operations and create a new vector map, which is then converted into a raster image and returned to the web browser (Barr 2002). Some MapGuide based operational, web-based GI systems were already elaborated by RISSAC GIS Lab in close co-operation with HungaroCAD Ltd. (<http://maps.ktm.hu/taki/index.htm>; Szabó 2002).

The elaboration and treatment of digital spatial databases has been dominated by locally bounded technology. Recently handheld computers (Personal Digital Assistant, tablet PC etc.) brought a breakthrough in mobility. The field versions of GIS software products running on these devices make the in-situ administration of digital maps possible. This includes viewing, updating, measuring, furthermore positioning and navigation supplied with a compact GPS which can be attached to these devices with the aid of appropriate card and software.

Materials and Methods

In the early sixties a system was elaborated by the Hungarian soil scientists, soil surveyors and soil-mapping specialists for the large-scale soil survey to satisfy the practical needs of soil information of large farming units (state and co-operative farms), which characterized the Hungarian agriculture between 1950 and 1990. Such maps were prepared for about one-thirds of the area of Hungary. The system consists of four main parts: (i) genetic soil map, indicating soil taxonomy units, and the parent material; (ii) thematic soil maps on the most important physical and chemical soil properties; (iii) thematic maps, indicating recommendations for rational land use, cropping pattern, amelioration, tillage practice and fertilization; (iv) explanatory booklets including a short review on the physiographical conditions; description of soils, recommendations for their rational utilization; field description of soil profiles; results of field observations or measurements and data of laboratory analyses (Sarkadi et al, 1964; Szabolcs, 1966). These maps were widely and successfully used and became an easily applicable scientific basis of intensive, large-scale agricultural production, in spite of the fact that generally these maps were not published in printed form and has been available only as manuscripts at the given farming units or at the Plant and Soil Conservation Stations. The large-

scale soil-mapping programme restarted in 1986 within the framework of the National Land Evaluation Programme (AGROINFORM, 1987). The aim of this Programme was to evaluate the agricultural land based on soil information surveyed in a scale of 1:10,000, but was also left uncompleted. These huge archives provide appropriate raw material for recent digitally based applications. Spatial soil information systems based on these data could be efficiently used in the cases listed in the previous section.

The Hungarian agricultural land redistribution and the privatisation process in the early nineties induced a co-operative transformation process, which entailed a certain degree of decentralization. The over-large co-operative farms separated to form smaller more localized enterprises and converted into other company forms which are considered as new types of potential economic business organizations needed in the development process. However, no special privileges are given to them and they should be able to stand competition. Concerning these challenges some co-operative farms initiated to introduce up-to-date methods in their agricultural practice. Collection, computerization of relevant data on the farming units, elaboration and/or introduction of information and expert systems, compilation of farm scale integrated geographical information systems can be mentioned. During the second half of '90s RISSAC GIS Lab was commissioned to carry out GIS adaptation of practical soil maps created for the territory of some of these newly formed agricultural companies.

At the beginning this only meant digitization of the current map sheets. Later new demands emerged and the digitized soil maps were transformed into Hungarian Unified Map Projection System. This operation opened the opportunity to integrate soil information with additional environmental/topographic spatial data available or newly processed digitally in compatible scale. This also made a more precise spatial determination and delineation of actual management units possible. Usage of up-to-date remotely sensed images also helped by revealing some changes in landuse. As a next step multitemporal data of the management unit registers were linked to their geometrical representation and thus jointly used with other geographical, agri-environmental spatial information. Simply spatially advisory systems were elaborated.

There was an initiative in RISSAC for the integration of three fields of research to elaborate a GIS based precision fertilisation recommendation system (Czinege et al 1999). The within-plot soil inhomogeneities were taken into account, since they generally have different fertility potential. The method provides improvement compared to recent Hungarian agriculture practice, if there are several soil types within one management unit. For the detailed elaboration

of our objectives, we chose two sample areas in the central part of Hungary with different geographical characteristics. Integrated spatial soil information databases were developed for the pilot areas based on practical soil mappings and 1:10,000 scale topographic and cadastre maps. The resulted system provided maps, which were used for planning the sampling design as well as the basis for the compilation of fertilisation recommendation plans.

After the above-mentioned ‘early’ initiatives a complex system was elaborated by RISSAC GIS Lab in co-operation with the Plant and Soil Conservation Service of Fejér County for the whole territory (about 3,500 ha) of a co-operative farm in Central Hungary. In addition to carrying out the digital reambulation and GIS adaptation of large-scale soil mappings further information was integrated into the system: (i) topographic data, ensuring the delineation of the geographical environment and helping information processing and positioning; including a DTM; (ii) property register data determining the ownership and registration conditions of parcels; (iii) multitemporal data of nutrient control based fertilization advisory system monitored yearly.

The objective of the project was to develop an integrated database for the area of Agromark 2000 farming company containing all available soil related information, property registry and agricultural management data together with information on agri-environmental factors and operate in a sustainable Geographical Information System. The elaborated complex system is structured as follows.

Uniform topography and terrain data:

- Raster images of the 1:10,000 scale topographic maps transformed into Hungarian Unified Map Projection System.
- The digital terrain model (DTM: grid cell size is 10x10 meters) of the demonstration area elaborated on the basis of the contour lines of the topographic maps.
- Exposure of slopes, and slope gradient conditions derived from DTM.
- The 1:10,000 scale basic topographic data (main roads, waterways, railway lines), and the boundaries of built-up areas.

Data of complex property register:

- Raster images of the 1:10,000 scale generalized cadastre maps of outskirts for the territory of the concerned villages transformed into Hungarian Unified Map Projection System.
- The geo-coding of the complex property register (cadastre) is represented by points, which are located on the center of the parcel (point shape).
- The property register containing data on parcels, plots and sub-classes grouped according to settlements and terrain.

- Borders of management units as they can be identified using 1:10,000 scale generalized cadastre maps of outskirts.
- Corner points of parcels and plots based on County Land Office register.

Soil data:

- Relevant segment of the 1:25,000 scale Digital Kreybig Soil Information System (Szabó et al., 2000) including data on the chemical and physical properties of soils as well as field and laboratory analyses results of soil profiles linked to agro-ecological units.
- Data of the 1:10,000 scale practical soil mappings (genetic soil map, indicating soil taxonomy units, and the parent material; thematic soil maps on the most important physical and chemical soil properties; and thematic maps, indicating recommendations for rational land use, cropping pattern, amelioration, tillage practice and fertilization).
- Data of explanatory booklets including results of field observations together with the measurements and data of laboratory analyses.

Time series provided by the nutrient control based fertilization advisory system monitored yearly which includes digital tabulated data on:

- nutrient supply,
- micro and macro elements,
- heavy metal contamination,
- yield attributed to management units.

As a next step an Intranet based realization of the system was worked out. Autodesk GIS environment was used for this purpose. Autodesk MapGuide software was developed for distributing maps and designs on the web. With its aid it is possible to develop, manage, maintain, and deploy GIS and digital data applications on the Internet, intranet, or even in the field. Autodesk MapGuide software's powerful, easy-to-implement client/server technology assembles spatial and attribute data from multiple sources and delivers it in real time where it is needed via the Web to thousands of simultaneous users. A MapGuide solution can be broken down into three core environments: map authoring and design; application and data serving; viewing and interacting environments (www.autodesk.com). The MapGuide GIS server can also be reached from mobile clients (handheld computers) which (supplied with suitable GPS-cards) make GIS supported, real-time, in-situ survey possible.

Results and Discussion

The elaborated information system contains both spatial and tabulated data. Their joint applications provide a wide palette of outputs: simple maps reproducing thematic cartograms, new maps derived from base elements, results of spatial queries and analysis carried out with

optional combination of point, polygon and tabular data. The base GI system was completed in 2001. The web based version of the system as a user interface can be learnt and used by anyone and could provide fast access to the spatial data and is operating system independent. Internet also provides other useful advantages since Internet browsers are available almost everywhere and this technology provides access to the server for unlimited number of users. With suitable technical background even real-time, in-situ field application is feasible. In its recent form the applicability of the elaborated system in agricultural counselling may be considered according to the following scenario:

Sampling design: The intranet based GI service may replace the tiresome preprocessing work, during which the consultant considers the topography, terrain, soil and management conditions and analyse them form the explanation of spatial inhomogeneities in yield. This is essentially spatial analysis, basic service of a GIS. The results of nutrient control can be also integrated with the continous refeeding into the system (intranet publication). The overall analysis results in sampling design which means the determination of spatial sampling units within them the sampling plots (to be sampled for average samples) and a sampling track which is followed in the field. All of this enter into the system as new thematic layers.

Preparatory work: If rational on-line connection between the field device and the intranet server is not feasible, the data layers to be used in the field should be downloaded in advance. The layers related to sampling design have the highest priority, however all of the considered themes can prove to be useful, since the actual field conditions may require changes in the predetermined sampling.

Field work: Navigation and tracking of sampling route should be emphasized. The GPS provides the present location almost in real-time (naturally with some seconds of integration). The WGS co-ordinates however must be converted to the actual projection system (HUMPS in our case), which is solved with an appropriate software modul. This makes the display of the actual position on the other themes possible. Meanwhile field navigation is carried out for the tracking of the predefined sampling route. There is also opportunity for the identification of local anomalies (weed or waterlogged plots etc.). Walking them around GPS can be actually used as a digitizing tool and spatial features of these anomalies can be attached to the GIS.

Subsequent work: Returning from the field the collected data (actual sampling plots, identified anomalies, field measurements) can be uploaded to the server. The results of laboratory measurements should be also continuously refeeded into the system (intranet publication) to increase the efficiency.

Acknowledgements

Our work was partly funded by the Hungarian National Research Foundation (OTKA, Grant No. T033003) and the National Research and Development Program (NKFP, Grant No. NKFP-4/037). The fruitful co-operation with Hungarocad Ltd. (László Bakos, Róbert Cservenák, Károly Pogrányi) and Plant and Soil Conservation Service of Fejér County (Gabriella Szabóné Kele and Kristóf Antal) is highly appreciated. The authors are grateful to the staff of RISSAC GIS Lab: Zs. Bakacsi, G. Csökli, Z. Krammer, J. Matus and B. Zágoni.

References

- AGROINFORM, 1987, 'Melioration-irrigation and nutrient supply, guide to the completion of national large scale practical soil mapping (in Hungarian)', AGROINFORM, Budapest.
- Barr R., 2002, 'Autodesk MapGuide 6', GI News, April
- Cambardella C.A., D.L. Karlen, 1999, 'Spatial Analysis of Soil Fertility Parameters', Precision Agriculture, Vol.1, No.1, pp:5-14.
- Csathó P., T. Árendás, T. Németh, 1998, 'New environmentally friendly fertiliser advisory system, based on the data set of the Hungarian long-term field trials set up between 1960 and 1995', Soil Sci. Plant Anal., 29(11-14), p:2161-2174.
- Czinege E., T. Németh, L. Pásztor, J. Szabó, Zs. Bakacsi, 1999, 'Elaboration of a farm level, GIS based fertilizer advisory system in Hungary', In: J.V. Stafford (ed.) 'Precision Agriculture '99, Part 2', Academic Press, Sheffield, p:969-975.
- Dangermond J., 2001, 'g.net – A New GIS Architecture for Geographic Information Service', ArcNews Vol. 23 No.1.
- Longley P.A., M.F. Goodchild, D.J. Maguire, D.W. Rhind (eds.), 2001, 'Geographic Information Systems and Science', Wiley, London.
- Longley P.A., M.F. Goodchild, D.J. Maguire, D.W. Rhind (eds.), 1999, 'Geographical Information Systems, Principles and Technical Issues', Wiley, London.
- Pásztor L., J. Szabó, Zs. Bakacsi, 2002, 'Compilation of a national 1:25,000 scale digital soil information system in Hungary', In: Proceedings of the 17th World Congress of Soil Science, Bangkok, CD-ROM.
- Remetey-Fülöpp G., Zs. Sikolya, 1998, 'Case Study of NSDIs in Countries in Transition – Hungary', In: '3rd Global Spatial Data Infrastructure (GSDI) Conference', <http://www.gsdi.org/docs/canberra/hunagi.html>.
- Sarkadi, J., L. Szűcs, Gy. Várallyay, 1964, 'Large-scale genetic farm soil maps (in Hungarian)', OMMI Genetikus Talajterképek. Ser. 1. No. 8. Budapest.
- Szabó J., 2002, 'Compilation of a watershed level, complex land information system for internet service', Agrokémia és Talajtan, 51: 283-292.
- Szabolcs, I. (ed.), 1966, 'Methodology of the genetic farm scale soil mapping (in Hungarian)', OMMI Genetikus Talajterképek. Ser. 1. No. 9., Budapest.
- Várallyay, Gy., 1989, 'Soil mapping in Hungary', Agrokémia és Talajtan, 38. p:696-714.
- Várallyay, Gy., I. Buzás, I. Kádár, T. Németh, 1992, 'New plant nutrition advisory system in Hungary', Soil Sci. Plant Anal. 23, p:2053-2073.

EVALUATING THE EFFICIENCY OF IRRIGATION AND FERTILIZATION IN MAIZE CULTIVATION

János Nagy, Tamás Németh and László Huzsvai

Debrecen University, Center for Agricultural Sciences
Department of Land Use and Rural Development
HAS Research Institute for Soil Science and Agricultural Chemistry

Introduction and scientific overview

The size of plant culture's yield is a resultant of interactions by genetic, ecological and technological factors. In scientific research it is necessary to evaluate certain factors – in this case, plant cultivation factors – separately and jointly as well.

The basis for the research work comes from the results of multifactorial **long-term experiments** (sowing x soil cultivation x fertilization x irrigation x plant density x genotype) of the Center for Agricultural Sciences, Debrecen University, that are **unique** and acknowledged **in Europe**. The research program builds upon the results of research work with similar thematics carried out by Györfy and Berzsényi at Martonvásár, which covers many decades and provides a reliable scientific background.

The method and extent of fertilization, should be determined not on the basis of maximum yield but solely on the basis of profitability (*Irvine* 1963). According to *Debreczeni* (1980) the upper limit of fertilizer application has to be determined on the basis of optimal level of economical cultivation originating from surplus yield. Both Hungarian and foreign scientific publications agree that from the factors influencing fertilizer effect, weather, soil characteristics, water supply, uniformity of plant stock, cultivated plant and the nutrient reaction of the strain are the most decisive. Weather – since it regulates heat- and moisture supply of the cultivation site – has an effect on material transformation in the soil as well as on the growth and nutrient uptake of plants and thus on the efficiency of fertilizers (*Kramer* 1963, *Kovács* 1982, *Nagy* 1996). According to the majority of experiments the fertilizer effect is medium or good in moderately dry year. In case of drought, plants develop well during the first half of development, in the second half due to the increased LAI as well as the increased need for water, maize will get into a severe water deficiency, which results significant yield decrease (*Debreczeni and Debreczeniné* 1983, *Nagy* 1997). The amount of precipitation, or the moisture stored in the soil modifies the need and effect of fertilizers. Fertilizer effect increases when approaching optimal water supply and decreases when reaching harmful levels of excess water (*Nagy* 1994). The influencing effect of soil characteristics depends primarily on soil fertility, thickness of the

productive layer and on water balance (*Sarkadi 1975, Győrfy 1976*). Optimal N-supply significantly contributes to grain number per cob, and to a smaller extent to the increase of the thousand grain weight (*Bocz and Nagy 1981*). In case of N-deficiency, dry matter accumulation is smaller in maize plants and the dynamics of dry matter accumulation is slower (*Hanway and Russel 1969, Berzsenyi 1993*). Fertilization is decisive both in macro- and both in micro element uptake (*Németh and Búzás 1991*). With appropriate N-supply, the fast increase of leaf area in the early phase of development can be promoted and thus the optimal LAI value can be sustained longer, which means an advantage from the aspect of assimilate flow to the grain yield and also has a favourable harvest index value (*Dobos and Nagy 1998, Berzsenyi 1993*). This advantage though does not mean an economic profit since maize goes through water deficiency earlier, which peaks in the reproductive phase and thus results a yield decrease.

We can ensure the constant water supply and undisturbed physiological operation of plants with irrigation. In areas that are poor in precipitation, irrigation is the guarantees yield. Results of experiments prove, that irrigation in general, especially in case of drought, highly increases the yield of maize. Irrigation will be more essential on specific parts of the country for safe and intensive production of maize (*Szőke Molnár 1977*). It is crucial for farmers irrigate maize on greater areas to avoid yield fluctuations due to the effect of years. Especially the extremely droughty weather lasting from the second half of the 1980's until the mid 1990's put irrigation in the center of attention. Accurate precipitation forecast can only be given with the knowledge of precipitation and groundwater conditions regarding a specific plot (*Balogh 1978*). If precipitation and the easily accessible water supply of the soil does not satisfy the needs of the plant, then the deficiency has to be compensated with irrigation (*Petrasovits 1978*).

Water supply plays a significant role in the utilization of fertilizer active substances especially that of nitrogen. Due to the changing precipitation, the effect of fertilization strongly varies on an annual basis. The correlation of irrigation and fertilization has been investigated by many Hungarian researcher. The irrigation and fertilizer research results of *Nagy (1995, 1997, 1999)* have indicated that irrigation improves the efficiency of fertilization and there is strong correlation between fertilizer utilization and the water supply of a plant. In irrigated treatments – which means a higher yield level – the economical fertilizer doses are greater, due to the positive correlation of irrigation x fertilization, than in unirrigated treatments. In irrigated treatments the effect of year is moderate, yield fluctuation decreases. The annual fertilizer reaction differs to a smaller extent than in unirrigated treatments, thus nutrient supply can be planned with greater safety. The irrigation and fertilization experiment results of *Hank and*

Frank (1951) have justified that irrigation increases the efficiency of fertilization. The efficiency of fertilizers also depends on the agroecological conditions (*Láng* 1981).

Materials and Methods

We have been continually examining examining the fertilizer- and irrigation reaction of commonly cultivated maize hybrids – for nearly twenty years at the Látókép experimental station of the **Center for Agricultural Sciences, Debrecen University**.

Soil characteristics. The soil of the Experimental Station is lowland chernozem with lime deposits formed on loess. The N- and P-supply of the soil is medium, its K-content is high (humus content= 2,8-3,0 %, Total. N = 0,14-0,18 %; AL- P_2O_5 = 130-200 mg/kg, AL- K_2O = 240-280 mg/kg). The thickness of the humus layer is 70-90 cm. The pH (KCl) value is 6,2; the saturation percentage is 43. Microelement deficiency could not be detected. The groundwater level is between 6-8 m. The VK_{min} value of the soil is 27-29 tf%. The 0-100 cm soil layer can store 275 mm, while the 100-200 cm layer can store 265 mm moisture. The useful VK at 0-100 cm is 157 mm, at 100-200 cm it is 150 mm.

Fertilizer treatments: In the 1 N:0,75 P_2O_5 :0,88 K_2O constant ratio NPK dosage experiment the basic dose is 80 kg/ha – from which N is 30 kg/ha – and we have applied 1,2,3,4,5 –times this dosage, along with an unfertilized control. The identical NPK ratio doses were simply marked with the quantity of N, during the evaluation.

We have applied **irrigation** in an amount that is close to the calculated need of the plant (273 mm): irrigation was done with a NADIR type, 75 cm division trickle irrigation system.

The experiment is in four repetitions, in a row setup. 6 fertilizer treatments were setup in random order within one repetition, in irrigated and unirrigated treatments with identical 70 thousand plant density. The size of one repetition is: 1260 m², the fertilized plots 210 m².

Weather characteristics. We have used the data between 1961-1990 to characterize the climate of Debrecen (30 year average). (Source: National Meteorological Service, *tables 1-2.*)

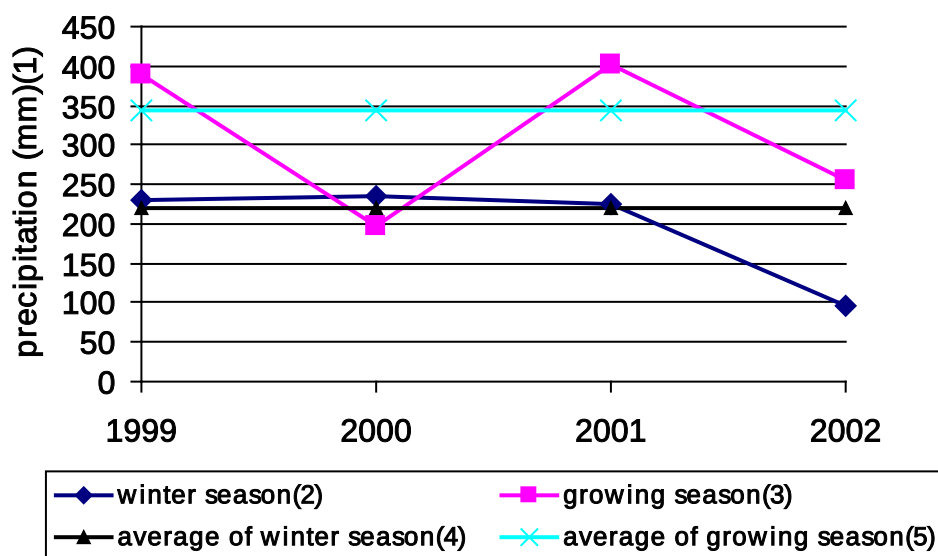
Table 1: 30 year average of Debrecen's air temperature(°C)

Month(1)	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Mean(2)	-2,6	0,2	5,1	10,7	15,8	18,7	20,3	19,6	15,8	10,3	4,5	-0,2
maximum(3)	0,6	4,1	10,4	16,6	21,7	24,6	26,5	26,1	22,4	16,5	8,5	2,6
minimum(4)	-5,5	-3,0	0,6	5,4	10,1	13,1	14,4	13,7	10,3	5,3	1,3	-2,8
Average temp. (5) of winter season (X. - III.)							2.9					
Average temp. (6) of growing season (IV. - IX.)							16.8					
Annual mean temp. (7)							9.85					

Table 2: 30 year average of precipitation(mm) in Debrecen

Month (1)	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Precipitation (2)	37	30	34	42	59	80	65	61	38	31	45	44
Total precip. (3) of the winter season(X. - III.)							221					
Total precip. (4) of the growing season (IV. – IX.)							345					
Total annual precip.(5)							566					

Upon evaluating the precipitation of the examined period, it can be established, that in the year of 2002, during the winter season (X-III.), less precipitation fell than the average of 30 years. In the other years, there was average amount of precipitation. The precipitation, that fell during the growing season shows great fluctuation. In 2000, very little, while in 2001 an amount that exceeded the average fell (*figure 1.*)

**Figure 1:** Total precipitation of the examined period mm (Debrecen, 1999-2002)

The temperature of the growing season, except for 2002, exceeded the 30 year average in all years. The temperature of the winter season fluctuated around the average, it was significantly warmer in 2001. The low value of the 2002 winter season can be due to the record cold of december 2001 (figure 2.)

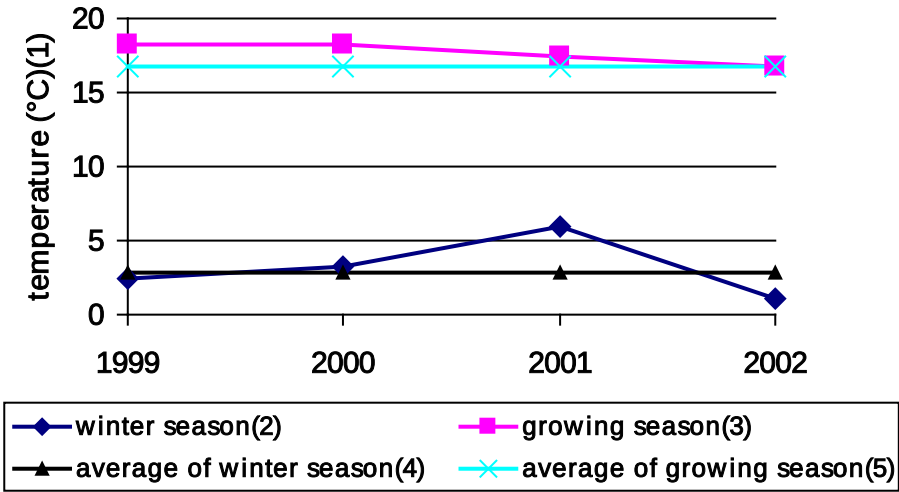


Figure 2: Temperature of the examined period (Debrecen, 1999-2002)

Method of evaluation

The statistical evaluation was done with an IBM compatible personal computer, by using SPSS 9.0 for Windows statistical program package. The computer program includes the most modern statistical methods about the operation of the database, from descriptive statistics to the most complicated multivariable mathematic statistical methods. A great advantage of the program package is that we can use not only prepared statistical tests but we can also prepare simple models and we can do their statistical evaluations. An advantage of this, is that many built in statistical tests require very strict application conditions, which are not realized in the soil-plant-atmosphere system, but the methods fitted to the characteristics of the examined phenomenon can provide more reliable results. Variance analysis is often used for the evaluation of experiemental data in agricultural research. Presently, many techniques of variance analysis exist, which make it possible to choose the most appropriate evaluation method by considering the distinctiveness of the task. The reliability of the evaluation depends on the method of determining the error, which is really the function of squared deviance (SQ) calculation

technique. The statistical program package makes it possible to reliably evaluate the linear model according to the true setup of the experiment.

We have chosen a General Linear Model, which is the generalised form of the variance analysis to compare the mean values of the treatment effects. This method is a combination of linear regression analysis and variance analysis. In this model, yield (t/ha) is the dependent variant while irrigation and fertilization is the fix factor. The effects of treatments on the yield are symmetrically around the main average of the experiment. Since the main average of the experiment differs from zero, we have built in a constant parameter into the model. Since the experiment is multifactorial, balanced and there are no missing plot data, we have chosen the third type (Type I-IV.) from the four options built into the statistical program package when calculating squared sums of deviances. The square sum deviances were identical with ones that were calculated with the Yates method. The Yates method essentially uses the weighted square deviance technique of the averages when calculating square sums. This method is widely known in agricultural research, since Sváb describes this technique when introducing variance analysis in his book.

Results and conclusions

We have examined the effect of fertilization on the yield of maize by using the yield data of four years, at six fertilizer levels in four repetitions, in irrigated and unirrigated treatments at the experiment set up at the experimental station of Látókép. Data obtained during the experiment was evaluated with variance analysis. According to the examinations, irrigation and fertilization are strong factors in influencing yield, the main effect of irrigation and fertilization are strongly significant (Table 3). The irrigation x fertilization correlation is significant, which indicates that the yield increasing effect of fertilization does not differ in irrigated or unirrigated treatments. Since the main effect and correlation of fertilization are significant, it can be established, that in the years of examinations fertilization has reliably and significantly increased yield in all years.

Table 3: Result of analysis of variance (Debrecen, 1999-2002)

Dependent Variable: t/ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	15921.088	11	1447.371	373.847	.000
Intercept	483215.067	1	483215.067	124811.419	.000
Irrigation	2282.149	1	2282.149	589.465	.000
Fertilization	13540.094	5	2708.019	699.464	.000
Irrigation x Fertilization	98.843	5	19.769	5.106	.000
Error	20581.220	5316	3.872		
Total	519717.373	5328			
Corrected Total	36502.307	5327			

a. R Squared = .436 (Adjusted R Squared = .435)

The comparison of estimated values by the linear model and the values measured in the experiment are interesting, that the r-square value indicates, this shows a strong correlation among yield, fertilization and irrigation. It has to be emphasized, that the medium strong correlation is statistically reliable. The explanation for this, is that variance analysis, or General Linear Models used in the up-to-date statistical computer programs build up the amount of yield from linear combinations of treatment effects. In our experiments we have had six fertilizer doses and as it is commonly known, fertilizer does not influence yield in a linear way, thus disregarding the squared effect weakens the value of linear correlation.

The yield increasing effect of fertilization is not more than 4 t/ha in irrigated treatments, in the average of the examined period. In irrigated treatments this value is close to 5 t/ha (Table 4). Irrigation also improves the natural nutrient utilization of maize, since irrigation increased yield by 1t/ha on average in unfertilized treatments. With greater fertilizer doses, the yield increasing effect of irrigation is also greater, which can be explained with the positive correlation between nutrient and water supply. In case of 120 kg N/ha, irrigation increased the yield of maize by 1,7 t/ha on average.

Table 4: Effect of fertilization and irrigation on yield of maize (Debrecen, 1999-2002)

		Years				
		1999	2000	2001	2002	Average
Non irrigation	Fertilization kg/ha					
	Non fertilization	7.10406	4.75853	6.17360	5.39191	5.84579
	N30, P23, K27	9.65721	7.04755	9.07853	6.99381	8.18110
	N60, P45 K53	10.78821	8.46341	10.11313	8.06734	9.34514
	N90, P68, K80	11.70811	8.81026	10.61030	8.48229	9.88648
	N120, P90, K106	12.55059	9.39638	10.65479	8.15027	10.16672
	N150, P113, K133	12.69718	9.08568	10.10295	7.36949	9.78785
	Average	10.75089	7.92697	9.45555	7.40918	8.86884
Irrigation	Non fertilization	8.15734	5.82608	6.76232	6.79000	6.87246
	N30, P23, K27	10.99097	7.60855	9.76174	8.69374	9.24819
	N60, P45 K53	12.29525	9.24585	10.71096	9.52752	10.42822
	N90, P68, K80	13.12638	9.79866	11.28975	10.78315	11.23258
	N120, P90, K106	13.73399	10.54522	11.44413	11.60194	11.81418
	N150, P113, K133	13.55553	10.14902	10.56689	11.68730	11.47107
	Average	11.97658	8.86223	10.08930	9.84727	10.17778
LSD5%		Irrigation				
		Fertilization				
		Irrigation x Fertilization				
		0,106				
		0,183				
		0,259				

When evaluating the specific years separately, the above mentioned tendency can be established, in years with better water supply, the utilization of fertilizer is better and has greater yield increasing effect. In irrigated treatments it is rare, that greater fertilizer doses cause yield depression, maybe in cases of the highest dose.

The 3. figure shows the average yields of the 1999-2002 period. In unirrigated treatments, 90 kg N/ha fertilizer dose is enough to achieve yields that are close to maximum, while in irrigated treatments this can even be 120 kg N/ha.

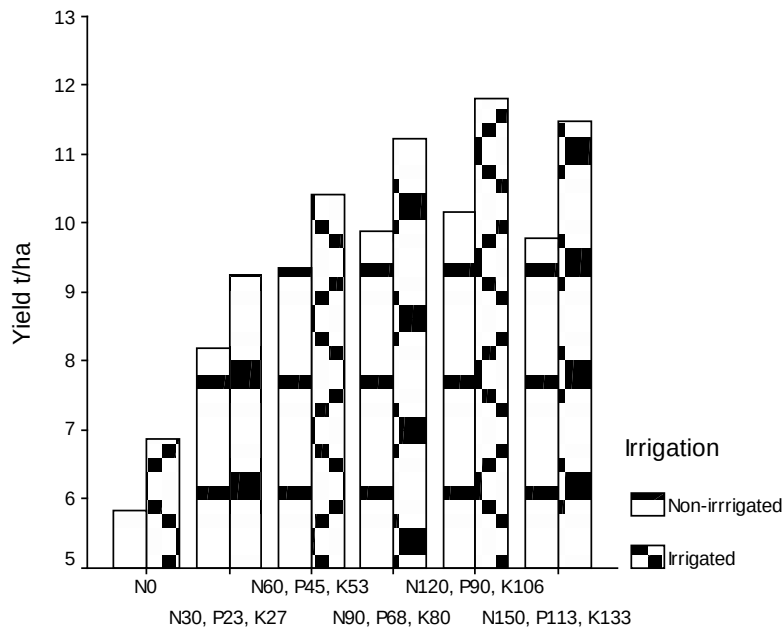


Figure 3: Effect of fertilization on maize yield under irrigated an non-irrigated conditions (Debrecen, 1999-2002)

Conclusion

Upon evaluating the results it can be established, that year significantly influences the size of yield. Between the years of 1999 and 2002, in the average of applied fertilizers the difference is 3,4 t/ha, but even in irrigated treatments it reaches 3 t/ha. This is more than the effect of irrigation. From the applied agrotechnical elements, the yield increasing effect of fertilization is the greatest, this can even be greater than the effect of year. The yield increasing effect of fertilization can be reliably detected with small and medium doses, but at higher doses a plato section is reached, where it is not worth it to apply more nutrients. Cultivation with irrigation can only be done with appropriate nutrient supply, due to the positive correlation of the two factors. The positive correlation also means, that if the water supply of the plant declines, less fertilizer is needed for safe production. The two factors (irrigation and fertilization) have to be increased or decreased at the same time.

According to the experiment in unirrigated treatments 90 kg/ha nitrogen and the related phosphorus and potassium is enough, while in irrigated treatments this was 120 kg.

Acknowledgement

This research was supported by the Hungarian National Research Fund (OTKA T031989).

References

- Balogh J.: 1978. Calculating water needs in irrigation farming. Mezőgazdasági Kiadó, Budapest.
- Berzsenyi Z.: 1993.: The effect of N-fertilization and year on the grain yield of maize hybrids (*Zea mays* L.) and N-fertilizer reaction in long-term experiments, in the years of 1970-1991. években. Növénytermelés, 42:1.49-63.
- Bocz E. – Nagy J.: 1981. Optimizing water and nutrient supply of maize and its effect on the weight of yield. Növénytermelés, 30.6: 539-549.
- Box, G.E.P. - Wilson, K.B.: 1951. On the Experimental Attainment of Optimum Conditions. Journal of the Royal Statistical Society, 13:1.
- Debreczeni B.: 1980. Artificial fertilization. Acta Agronomica, 29:117-225.
- Debreczeni B. - Debreczeni B.-né 1983. Correlation of nutrient water supply. Mezőgazdasági Kiadó, Budapest.
- Dobos A. - Nagy J.: 1998. The effect of year and fertilization on the dry-matter production of maize. (*Zea mays* L.) Növénytermelés, 47:5. 513-524.
- Győrffy B.: 1976. Evaluating plant cultivation factors on the yield of maize. Agrártudományi Közl., 35: 239-266.
- Hank O. - Frank M.: 1951. Correlation between soil nutrient supply and water consumption in specific plants. ÖKI Évkönyv, Szarvas.
- Hanway, J.J. - Russel, W.A.: 1969. Dry-matter accumulations in corn (*Zea mays* L.) plants: Comparisons among single-cross hybrids. Agron J. 61: 947-951.
- Huzsvai L. - Nagy J.: 1995. Optimizing experiments in planning of tillage and plant cultivation research. Növénytermelés, 44:5-6. 483-491.
- Irvine, F.R.: 1963. Soils and crops. Oxford University Press, London.
- John, P.W.M.: 1971. Statistical Design and Analysis of Experiments. New York, McGraw-Hill.
- Kovács G. J.: 1982. A kukorica víz- és tápanyag-dinamikájának kritikus ökológiai kapcsolata. Növénytermelés, 31.4: 355-365.p.
- Kramer, P.I.: 1963. Water stress and plant growth. Agron J. Madison, 55: 31-35.
- Láng I.: 1981. Beszámoló az agrárökológiai potenciál országos felmérésének eredményeiről. Agrártudományi Közl., Budapest, 40:29-98.
- Nagy J.: 1994. The effect of fertilization and irrigation on the yield of maize (*Zea mays* L.) hybrids with various genotypes. Unipress, Padova, 421-440.
- Nagy J.: 1995. A műtrágyázás hatásának értékelése a kukorica (*Zea mays* L.) termésére eltérő évjáratokban. Növénytermelés, 44:5-6. 493-506.
- Nagy J.: 1996. A talajművelés és műtrágyázás hatásának értékelése a kukorica(*Zea mays* L.) termésére. Agrokémia és Talajtan, 45:1-2. 113-124.
- Nagy J.: 1997. A műtrágyázás hatása a kukorica (*Zea mays* L.) termésére öntözés nélküli és öntözéssel termesztésben. Agrokémia és Talajtan, 46:1-4. 275-288.
- Nagy J.: 1999. Evaluation of interaction between irrigation and soil cultivation in maize production. Acta Agronomica, 47:2. 181-190.
- Németh T. - Buzás I.: 1991. Nitrogéntrágyázási tartamkísérlet humuszos homok- és mésztepedékes csernozjom talajon. Agrokémia és Talajtan, 40: 399-408.
- Petravits I.: 1988. Main questions of agrohydrology. Akadémiai Kiadó, Budapest.
- Sváb J.: 1981. Biometrical methods in research..Mezőgazdasági Kiadó, Budapest.
- Szőke Molnár L.: 1977. Economical questions of irrigated maize production. Akadémiai Kiadó, Budapest.
- Winer, B.J.: 1971. Statistical Principles in Experimental Design. New York, McGraw-Hill.

Section 1

Advanced aspects of macronutrient fertilization

AGROECONOMIC CRITERIA OF APPLICATION OF NITROGEN FERTILIZERS

H. Roostalu, A. Astover and I. Tamm

Estonian Agricultural University, Estonia

Abstract

Agronomically effective amounts of nitrogen fertilizer which ensure the maximum barley yield depend on the variety of barley, soil humus content, climatic conditions, preceding crop and its fertilization. On moderately moist soils with a humus content of 2-4% the average effectiveness of the N60 fertilizer norm for the intensive barley varieties is 15-18 kg N kg⁻¹. On gleyic and gley soils with a humus content of 6-8%, the effectiveness of nitrogen fertilizer is 8-11 kg N kg⁻¹. For the conventional barley varieties the effectiveness of nitrogen fertilizer is 30-40% lower and the agroecological and economic risk of fertilization higher. Delay in the seeding of barley reduces the effectiveness of nitrogen fertilizer on average 20-30%, or 0.2-0.26 kg N kg⁻¹ per day.

Keywords: nitrogen fertilizers, effectiveness, barley, probability, profitability

Introduction

The concentration of organic C and N appear good indicators of soil quality and productivity, affecting the physical, hydrophysical, chemical and biological characteristics of the soil (Reeves, 1997). The pools of soil carbon and nitrogen play an important role in nutrient cycling, plant productivity and the quality of the environment. The content and balance of soil C and N can be influenced by various management practices, such as rate of fertilization, soil tillage, cultivation of different field crops, application of crop rotation, etc. For guaranteeing maximally high and stable yields of field crops in contemporary intensive agriculture, common practice is to use comparatively large quantities of mineral and organic fertilizers. However, application of high fertilizer norms can bring about appreciable nutrient losses from the soil, which affects the quality of groundwater and contributes to eutrophication of water bodies.

The effectiveness of fertilizers depends on soil characteristics and fertility as well as on climatic conditions and the cultivated crop. Of the nitrogen introduced in the soil with mineral fertilizers, plants utilize 40-50% in the first year and 50-60% during the whole rotation period (Piho, 1975). The effectiveness of fertilizers is higher on humus poor soils and relatively lower on humus rich soils. However, depending on climatic conditions, the effectiveness of nitrogen fertilizers may vary 2-6 times. Agroecologically and economically grounded use of fertilizers can significantly reduce nutrient losses from the soil and the load to the environment, which are the prerequisites for sustainable agriculture.

Methods

The present study summarizes the results of the nitrogen fertilization experiments with barley, conducted to date (during 80 years) on highly different soils and with different varieties in Estonia. In analysing the developed joint database, the effectiveness of nitrogen fertilizes was estimated using the following square equation:

$$Y = a_0 + a_1x - a_2x^2,$$

where Y - yield, t ha⁻¹
 x - amount of nitrogen fertilizer, N kg ha⁻¹

Derivation ($Y' = a_1 - 2a_2x$) of a quadratic equation shows the differential efficiency of fertilizer, (t N kg⁻¹).

To estimate the effectiveness of fertilizers, the humus state of soils and the effect of climatic conditions, the following regression equations were solved, whose general form is:

$$Y'_{N60} = a_0 - a_1H - a_2P + a_3P^2 - a_4P^4,$$

where Y'_{N60} - average efficiency (kg N kg⁻¹) of nitrogen fertilizer amount N_{60}
 H - soil humus content, %
 P - probability, %

To calculate the average profitability of fertilization (R_v , %), the differential profitability of fertilization (R_{vd} , %) and the profitability of crop cultivation (R_t , %) we used the following formulas:

$$R_v = \left[\left(\frac{P_y(a_1x - a_2x^2)}{C_f x + C_h(a_1x - a_2x^2)} \right) - 1 \right] \times 100$$

$$R_{vd} = \left[\left(\frac{P_y(a_1 - 2a_2x)}{C_f + C_h(a_1 - 2a_2x)} \right) - 1 \right] \times 100$$

$$R_t = \left[\left(\frac{P_y(a_0 + a_1x - a_2x^2)}{C_f x + C_h(a_0 + a_1x - a_2x^2) + C_0} \right) - 1 \right] \times 100$$

where P_y - price of yield (1400 EEK t⁻¹)*; C_f - cost of fertilization (7 EEK N kg⁻¹)

C_h - cost of harvesting (200 EEK t⁻¹); C_0 - other production expenses (2000 EEK ha⁻¹)

* 1 EUR = 15.6 EEK

$$\text{Agronomically effective amount of fertilizer} - x_{\text{agr.}} = \frac{a_1}{2a_2}$$

$$\text{Economically effective amount of fertilizer} - x_{\text{econ.}} = \frac{a_1(P_y - C_h) - C_f}{2a_2(P_y - C_h)}$$

Results and Discussion

As there exists a close correlation between total soil nitrogen content and soil humus content ($N, \% = 0.0254 + 0.0478 \cdot H, \%; R^2 = 0.970$), it is possible to estimate the need for nitrogen fertilizer and its effectiveness proceeding from soil humus content. On soils with low humus content ($\leq 2\%$), accounting for 18% of the area of arable land in Estonia, average yield increase of barley at the expense of nitrogen fertilizers can exceed yield increase with the use of agronomically effective fertilizer amounts 1-1.5 t ha⁻¹ (Fig.1).

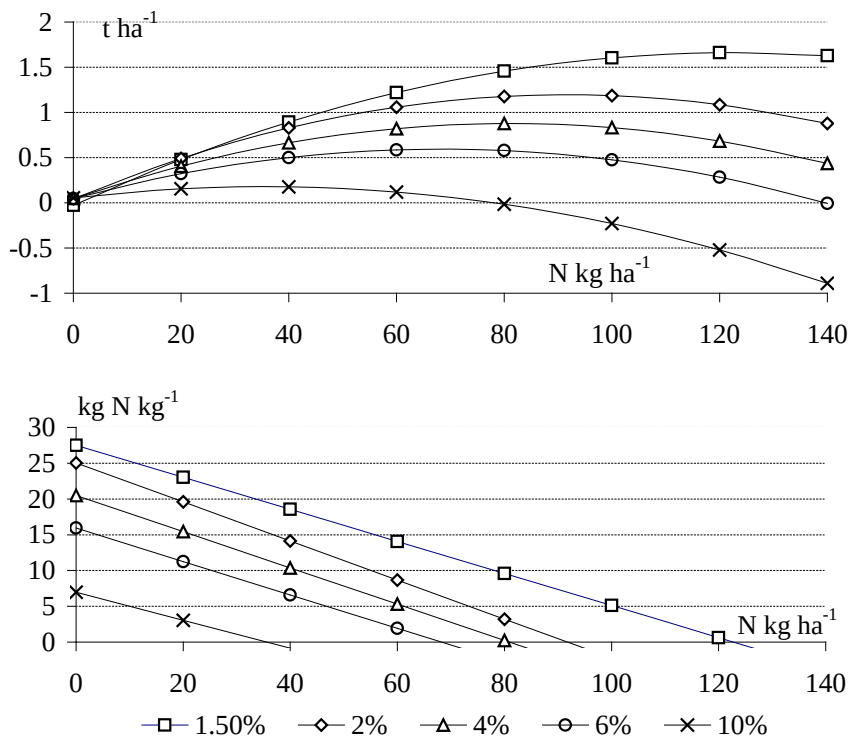


Figure 1: Yield increase of barley and the differential effectiveness of nitrogen fertilizers depending on soil humus content.

When soil humus content is 4-6% then maximum yield increase ranges from 0.5 to 1.0 t per hectare; at still higher soil humus content, the effect of nitrogen fertilizers is minimal.

Depending on the humus content of soils, the first kilogramme of nitrogen fertilizer introduced in the soil for barley results in 5-27 kg of yield increase. However, the effectiveness of additional fertilizer amounts decreases continuously; the differential effectiveness of fertilizers given at agronomically effective amounts is zero (Figure 2).

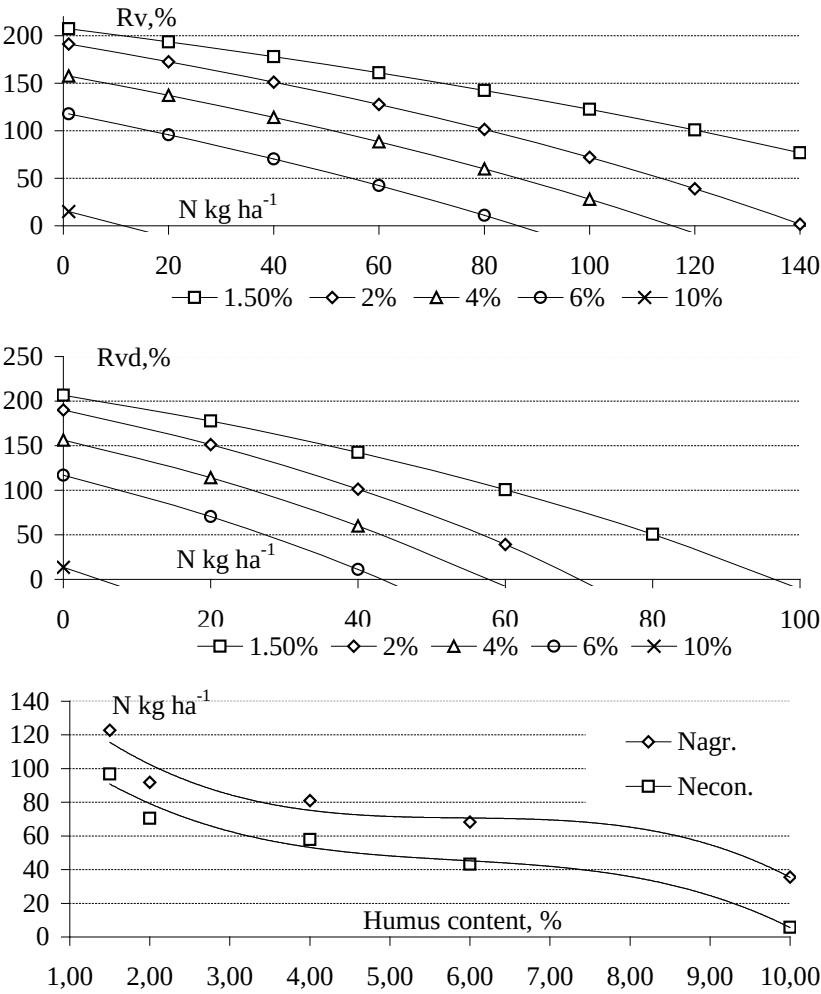


Figure 2: Average and differential profitability of fertilization and agronomically and economically effective nitrogen fertilizer amounts.

The agronomically effective amounts of nitrogen fertilizer which ensure the maximum barley yield are 36-123 kg N ha⁻¹ depending on soil humus content. Application of still higher fertilizer amounts leads to lodging of barley and, consequently, decrease in the yield. Thus in fertilization of barley it should be taken into account that each additional kilogramme of fertilizer introduced in the soil will yield a gradually weaker effect, owing to which the average profitability of fertilization (Rv, %) decreases with increasing fertilizer norms. Although use of agronomically

effective fertilizer amounts ensures the maximum yield, this practice is not economically justified, as beginning from a certain fertilizer amount the profit gained from yield increase does not any more cover the expenses for fertilization. The fertilizer amount at which the differential profitability of fertilization (R_{vd} , %) turns to zero but which guarantees maximum profit and production profitability (R_t , %) is named economically effective fertilizer amount. With current relatively low prices of fodder barley the economically effective norm of nitrogen fertilizer is 26-30 kg lower than the agronomically effective fertilizer amount.

The agronomically effective amount of nitrogen fertilizer depends on the soil, the precrop and its fertilization as well as on the variety but, in particular, on climatic conditions. On moderately moist soils of Estonia, whose humus content is 2%, the many-year average agronomically effective amount of nitrogen fertilizer for intensive barley varieties is 103 kg N ha⁻¹ (Fig.3).

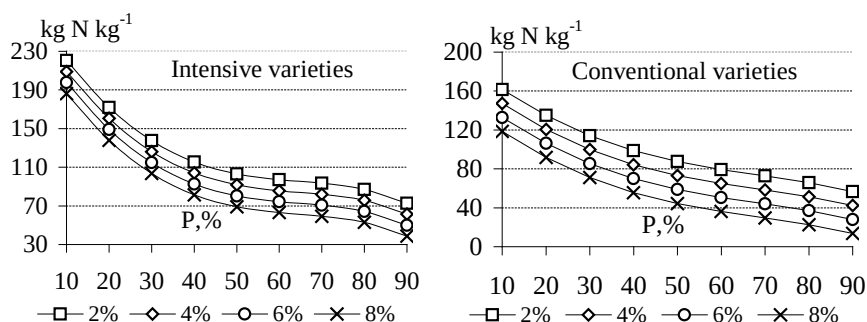


Figure 3: Probability of agronomically effective amounts of nitrogen fertilizer depending on soil humus content and the barley variety.

In single years, unfavourable fo barley growth, this amount can exceed 200 kg N ha⁻¹, while in droughty years it can be less than 70 kg N ha⁻¹. The higher is soil humus content, the lower is the soil requirement for nitrogen fertilizer and hence the fertilizer amount necessary for ensuring the maximum yield. For conventional barley varieties, the agronomically effective amounts of nitrogen fertilizer are 15-25 kg lower.

The effectiveness of nitrogen fertilizer reveals considerable differences also in fertilization of different barley varieties (Fig. 4).

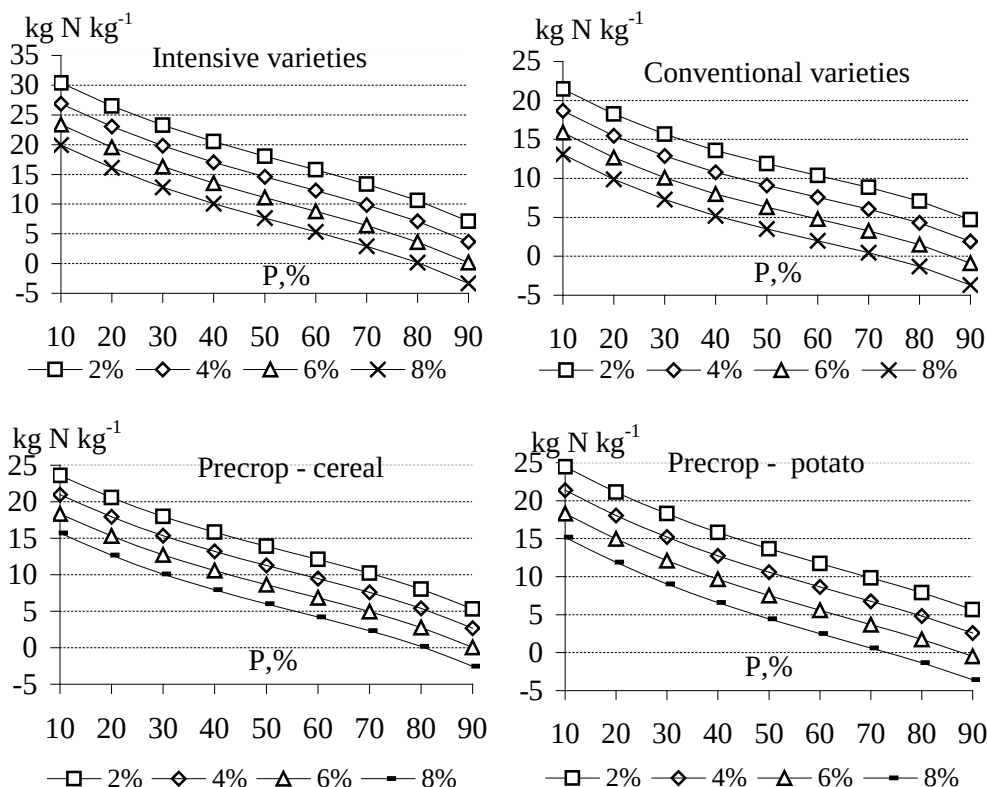


Figure 4: Probability of the effectiveness of the N_{60} fertilizer norm depending on soil humus content, the barley variety and the preceding crop.

For intensive barley varieties, nitrogen fertilizer produces far larger yield increase compared with conventional varieties. On the basis of all field experiments conducted to date, it can be calculated that in the case of application of the N_{60} fertilizer norm for intensive barley varieties on moderately moist soils, with soil humus content ranging between 2 and 4%, yield increase is 15-18 kg N kg⁻¹. In highly favourable years as much as 25-30 kg of grain can be obtained, with a probability of 10-20%, at the expense of 1 kg of nitrogen. However, on gleyic and gley soils, which are richer in humus, this amount of nitrogen can lead to lodging of the crop and yield decrease in 1-2 years out of ten. Compared with the intensive varieties, the effectiveness of nitrogen fertilizer in the case of the conventional varieties is 30-40% lower. Somewhat lower effectiveness of nitrogen fertilizer can also be observed in fertilization of barley after potato, and this on humus rich soils, because here is revealed the after-effect of manure given for potato.

The effectiveness of nitrogen fertilizers depends significantly on the seeding time of barley as well (Fig. 5). The highest effectiveness can be expected in the case of early barley seedings done in the first opportunity (I). Many-year average yield increase at the expense of 1 kg of nitrogen is 17.2 kg. A two-week delay in barley seeding (II) results in the 3.6 kg decrease in effectiveness per N kg⁻¹, or 21%. When the seeding of barley is delayed four weeks (III), fertilizer effectiveness decreases 0.2 kg N kg⁻¹ per day.

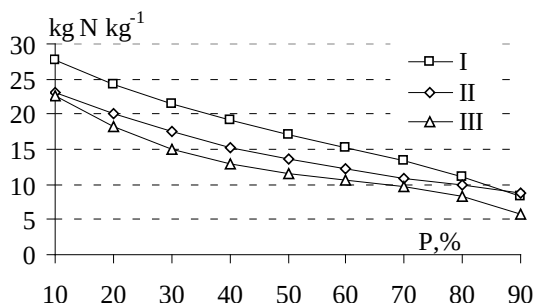


Figure 5: The probability of the effectiveness of the fertilizer norm N₆₀ depending on the seeding time of barley.

Although the current prices of fodder barley are relatively low (1.4 EEK kg⁻¹) and nitrogen fertilizers are expensive (7 EEK N kg⁻¹), agroeconomically grounded use of fertilizers allows to increase the profit gained from grain cultivation 3.5 times (Fig.6). The profitability of fertilization and barley cultivation can be increased by turning the crop into products of animal husbandry instead of selling the grain. At the same time, it should be taken into consideration that the market of agricultural products is instable and production is related with high economic risk. Application of nitrogen fertilizer has an impact not only on the barley yield but also on yield quality. When the yield increases 40% with use of agronomically effective fertilizer amounts and starts to decrease thereafter, then grain protein content continues to increase with still higher nitrogen fertilizer norms. Still, it can be claimed that use of small fertilizer amounts does not significantly influence yield quality. Hence fertilization should be differentiated depending on the purpose of using the yield: lower norms of nitrogen fertilizer should be applied in cultivation of food grain and higher norms in cultivation of fodder grain.

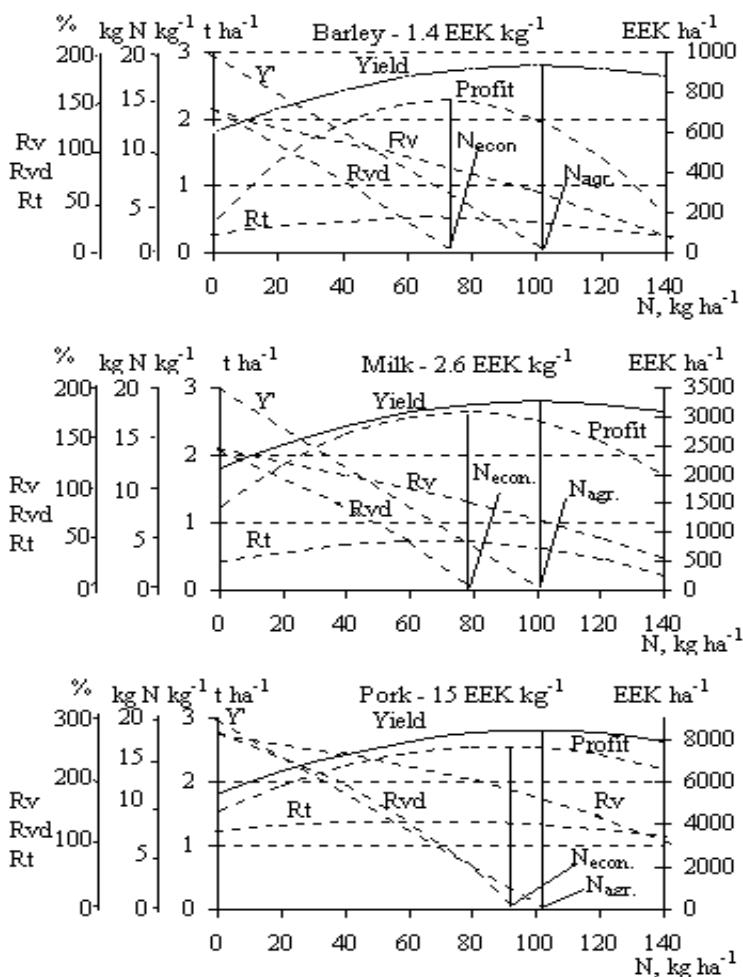


Figure 6: Profitability of barley cultivation depending on application of nitrogen fertilizers.

Acknowledgement

The study was supported by the Estonian Science Foundation grant No. 4819.

References

- Piho, A., 1975. The efficiency of fertilizers in the rotation of crops and some functions necessary for drawing up fertilizers utilization plans. *Trans. Eston. Res. Inst. of Agr.* XXXV: 94-101.
- Reeves, D. W., 1997. The role of soil organic matter in maintaining soil quality in continuous cropping systems. *Soil Till. Res.* 43, 131-167.

CORRELATION BETWEEN YIELD AND SOIL CHARACTERISTICS IN A HETEROGENEOUS FIELD

I. Buzás¹, J. Tamás² and I. Cserni¹

¹College of Kecskemét, Hungary

²University of Debrecen, Hungary

Abstract

A 2 ha sugar beet plot on chernozem soil was chosen for the trial in the neighbourhood of Komárom excluding the corners and turning points of the field. Plant and soil samples, 0-30 cm deep, were taken at the intersection points of a 20 x 20 m square grid. Soil samples were analysed in the soil laboratory (TVG).of the Plant and Soil Protection Service of County Vas for parameters as below: pH(KCl), SP (saturation percentage), calcium carbonate (Scheibler), humus, total salts, 1 mole KCl soluble nitrate+nitrite nitrogen and Mg, AL-soluble phosphorus, K and Na, 0.05 mole EDTA+0.1 mole KCl soluble Zn, Cu, Mn, Fe, Mo, Al, B, Cd, Cr, Co and Pb contents.

To demonstrate heterogeneity changes in sugar beet yield and quality and soil analysis results are presented in plane diagrams of two and three dimensions.

For sugar beet yield 500%, for some quality traits 40-50% deviation was found. The difference between the highest and lowest sugar content was nearly 4% while for white sugar content the difference was more than 5%.

As the measured differences could also be attributed to simple failure in plant production technologies correlation was studied between soil analysis results and yield indices. Correlation could be found between yield results and soil indices within plots but also between certain soil indices.

The effect of the soil N and K content on yield quality and quantity is particularly clear to see as well as the correlation between pH, lime content (Scheibler) and availability of micronutrients.

Trials indicated also **i.** a very high heterogeneity of soils in the field, **ii.** mean yield was composed of several very different part yields, **iii.** it would be important useful to focus efforts on trying to eliminate disparity in soils.

Material and Methods

A 2 ha trial plot on chernozem soil was marked out in the neighbourhood of city Komárom. Soil samples, 0-30 cm deep, and plant samples at the intersection points of a 20 x 20 m square grid, were taken. Sugar beet served as a marker plant as sugar beet reacts very sensitively to changes in soil characteristics.

Sugar beet root yield and pollution, sugar content (digestion%), potassium, sodium and alpha-amino-nitrogen contents were evaluated (Table. 1). Sugar yield/ha, the white sugar content (Hc%) were calculated from above data

$$\text{Hc\%} = \text{digestion\%} - [0,343(\text{K} + \text{Na}) + (0,094\text{N}) + 0,2],$$

where K=K content of the sugar beet, mmol/100g sugar beet,

Na=Na content of the sugar beet, mmol/100g sugar beet,

N=alfa-amino-N content of the sugar beet, mmol/100g sugar beet.

Hc% was used to calculate the white sugar yield/ha and the thick juice purity quotient % (Q%):

$$\text{Q\%} = 99,36 - 1,427(\text{K}' + \text{Na}' + \text{N}') / \text{digestion\%},$$

where K'=K content of the sugar beet, mmol/kg sugar beet,

Na'=Na content of the sugar beet, mmol/kg sugar beet,

N'=alfa-amino-N content of the sugar beet, mmol/kg sugar beet.

In soil samples the following parameters were studied: pH(KCl), SP (= saturation percentage), calcium carbonate (Scheibler) (further on: CaCO₃ %, humus, total salt, 1 mol KCl soluble nitrate+nitrite-nitrogen (further on: nitrate-nitrogen) and Mg, AL-soluble phosphorus, K and Na, 0.05 mole EDTA+0.1 mole KCl soluble Zn, Cu, Mn, Fe, Mo, Al, B, Cd, Cr, Co and Pb contents (Table 2).

Plants were analysed at the Sugar Factory Petőháza and soil samples at the Laboratory of the Plant and Soil Protection Service of County Vas, Hungary.

Table 1: Yield and quality of sugar beet

Plant test	S.beet yield	S.beet pollution	Netto yield	Thick juice	White sugar	Sugar yield	White sugar yield
	t/ha	%	t/ha	Q%	%	t/ha	t/ha
I/1	72,6	7,13	67,42	89,00	12,62	10,36	8,51
I/2	63	7,44	58,31	91,87	13,73	9,26	8,00
I/3	81,2	5,74	76,54	90,60	12,49	11,48	9,56
I/4	75,5	7,19	70,07	92,94	14,64	11,74	10,26
I/5	96,8	1,09	95,75	88,80	12,49	14,82	11,96
I/6	82	7,62	75,75	89,40	11,54	10,74	8,74
I/7	25,1	11,37	22,25	91,09	13,23	3,48	2,94
I/8	91,2	8,45	83,50	91,02	12,79	12,66	10,68
I/9	119	2,74	115,74	88,07	11,14	16,27	12,90
I/10	115,9	10,29	103,98	87,56	10,61	14,18	11,03
II/1	65,4	7,84	60,27	91,34	13,59	9,59	8,19
II/2	49	6,00	46,06	92,95	15,35	8,05	7,07
II/3	72,1	6,76	67,23	92,74	14,67	11,31	9,86
II/4	83,1	0,00	84,87	91,59	14,16	14,18	12,02
II/5	96,3	4,85	91,63	90,09	12,79	14,24	11,72
II/6	94,6	5,21	89,67	91,45	13,65	14,37	12,24
II/7	57,8	8,27	53,02	92,47	14,09	8,63	7,47
II/8	100	5,23	94,77	92,84	14,82	16,10	14,04
II/9	90,6	7,08	84,18	92,41	14,00	13,66	11,78
II/10	103,1	7,04	95,84	90,79	12,94	14,82	12,40
III/1	62,1	5,16	58,90	90,71	13,39	9,40	7,88
III/2	90,4	7,20	83,89	92,28	14,81	14,30	12,42
III/3	96,8	4,33	92,61	90,82	13,63	14,93	12,63
III/4	101	7,34	93,59	90,13	13,15	14,79	12,31
III/5	71,3	6,54	66,64	90,97	13,50	10,65	9,00
III/6	100,1	7,58	92,51	91,42	13,53	14,67	12,51
III/7	95,2	6,01	89,47	91,23	13,49	14,19	12,07
III/8	108	7,72	99,67	90,16	13,19	15,69	13,15
III/9	130,1	26,03	96,24	91,93	14,06	15,68	13,53
III/10	84,1	5,85	79,18	92,01	14,00	12,90	11,08
IV/1	82,6	4,02	79,28	90,66	12,73	12,08	10,09
IV/2	89,6	0,00	93,49	92,82	14,78	15,81	13,81
IV/3	101,9	5,08	96,73	93,42	15,33	16,80	14,82
IV/4	100,1	6,01	94,08	92,58	14,67	15,83	13,80
IV/5	85,6	4,86	81,44	91,70	13,99	13,38	11,39
IV/6	95,3	6,42	89,18	92,11	14,35	14,97	12,79
IV/7	87,4	5,70	82,42	91,22	13,03	12,73	10,74
IV/8	77,9	6,78	72,62	89,75	12,11	10,78	8,80
IV/9	93,8	7,43	86,83	92,09	13,41	13,63	11,64
IV/10	100,2	6,50	93,69	92,13	14,19	15,54	13,29
V/1	37	7,83	34,10	91,48	13,26	5,38	4,52
V/2	81,3	0,00	81,44	91,94	14,57	13,84	11,86
V/3	82,1	5,10	77,91	94,24	15,99	13,97	12,46
V/4	80,1	6,16	75,17	93,62	15,91	13,49	11,96
V/5	105,8	27,38	76,83	90,25	12,88	11,89	9,90
V/6	99,8	6,03	93,79	91,97	14,04	15,26	13,17
V/7	82,4	6,40	77,13	90,74	13,50	12,43	10,41
V/8	86,3	6,88	80,36	90,68	12,64	12,23	10,16
V/9	72,9	0,00	81,83	88,89	12,72	12,85	10,41
V/10	82,8	6,50	77,42	92,62	14,49	13,01	11,22
VI/1	75,7	3,04	73,40	91,78	13,35	11,42	9,80
VI/2	89,1	6,07	83,69	91,42	12,97	12,70	10,85
VI/3	59,9	6,25	56,15	93,31	15,21	9,72	8,54
VI/4	65,5	6,94	60,96	93,38	14,51	10,11	8,85
VI/5	60,3	7,20	55,96	92,50	13,53	8,80	7,57
VI/6	70,3	1,16	69,48	92,07	14,41	11,69	10,01
VI/7	76,8	0,00	82,52	92,56	14,66	13,95	12,10
VI/8	92,2	5,83	86,83	91,88	13,90	14,20	12,07
VI/9	88,9	6,74	82,91	92,10	14,65	14,14	12,15
VI/10	99,3	6,84	92,51	92,32	14,33	15,35	13,25
Mean	84,61	6,44	79,33	91,48	13,70	12,75	10,84
Minim.	25,10	0,00	22,25	87,56	10,61	3,48	2,94
Max.	130,10	27,38	115,74	94,24	15,99	16,80	14,82

Evaluation of Results

Data are represented in diagrams 2-3 dimensions. For example: Fig. 1 represents yield evolution and Fig.2 changes in sugar content within the plot.

Table 2: Soil analysis data

Soil test		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
code		I/1	I/2	I/3	I/4	I/5	I/6	I/7	I/8	I/9	I/10	II/1	II/2	II/3	II/4	II/5	II/6	II/7	II/8	II/9	II/10
pH (KCl)		7,48	7,44	7,35	7,36	7,44	7,42	7,50	7,45	7,37	7,43	7,42	7,45	7,32	7,38	7,30	7,33	7,44	7,36	7,40	7,31
SP	%	37	39	34	37	36	37	45	38	39	42	35	36	33	33	36	36	35	41	38	37
Total salts	%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CaCO ₃	%	11,0	7,0	5,0	4,0	4,0	5,0	6,0	6,0	4,0	1,0	11,0	9,0	3,0	3,0	0,0	1,0	5,0	3,0	2,0	1,0
Humus	%	2,07	2,04	1,93	2,21	2,18	2,47	2,24	2,27	2,23	2,32	1,73	2,01	2,09	2,31	2,15	2,61	2,14	2,33	2,19	2,08
NO ₃ -N	mg/kg	6,4	8,1	6,4	4,1	3,7	8,5	11,4	17,4	16,1	30,3	2,8	2,9	2,3	3,9	2,6	3,4	4,5	3,5	3,8	4,5
P ₂ O ₅	mg/kg	272	319	231	196	237	318	216	240	226	254	184	213	258	158	154	254	171	186	149	118
K ₂ O	mg/kg	553	319	295	296	260	380	298	411	235	447	184	215	170	220	191	209	299	238	206	149
Mg	mg/kg	113	151	90	97	95	124	143	135	102	128	83	87	91	106	94	103	151	141	117	163
Zn	mg/kg	3,25	1,47	1,68	1,38	1,34	1,73	1,26	1,53	1,08	1,70	0,88	1,14	1,23	1,24	1,12	1,42	1,01	1,30	1,07	1,11
Cu	mg/kg	5,71	4,76	5,00	4,17	3,17	3,59	3,34	3,13	2,66	5,25	3,37	3,87	3,86	4,04	3,82	4,68	3,36	4,13	3,37	4,26
Mn	mg/kg	10,9	17,3	30,1	35,1	35,9	33,5	23,0	31,2	28,0	97,7	9,3	16,2	42,8	50,4	75,7	80,9	22,7	56,8	33,8	86,3
B	mg/kg	0,26	0,38	0,29	0,31	0,37	0,49	0,48	0,48	0,38	0,46	0,23	0,40	0,34	0,38	0,33	0,33	0,43	0,35	0,39	0,42
Soil test		31	32	33	34	35	36	37	38	39	40	21	22	23	24	25	26	27	28	29	30
code		IV/1	IV/2	IV/3	IV/4	IV/5	IV/6	IV/7	IV/8	IV/9	IV/10	III/1	III/2	III/3	III/4	III/5	III/6	III/7	III/8	III/9	III/10
pH (KCl)		7,34	7,30	7,38	7,45	7,52	7,59	7,62	7,61	7,56	7,59	7,44	7,45	7,18	7,28	7,22	7,23	7,29	7,34	7,28	7,34
SP	%	34	33	33	39	37	36	34	36	34	31	43	33	34	37	38	37	34	36	39	34
Total salts	m/m%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CaCO ₃	m/m%	5,0	3,0	6,0	10,0	16,0	18,0	21,0	14,0	15,0	16,0	11,0	6,0	1,0	3,0	1,0	2,0	3,0	3,0	3,0	3,0
Humus	m/m%	2,70	2,16	2,30	2,22	1,87	1,53	1,59	1,66	1,87	1,89	1,81	1,94	2,12	2,39	2,42	2,50	2,40	2,34	2,29	2,23
NO ₃ -N	mg/kg	2,7	3,2	3,7	3,4	3,1	3,5	5,0	12,1	4,5	3,0	3,5	3,7	3,8	5,4	7,6	3,8	9,3	5,5	4,3	3,6
P ₂ O ₅	mg/kg	220	225	250	221	278	172	231	223	199	207	158	217	216	187	206	211	199	178	189	163
K ₂ O	mg/kg	216	177	264	225	239	215	323	338	315	360	131	258	258	251	275	266	280	271	289	251
Mg	mg/kg	89	100	95	122	92	84	118	90	111	95	108	163	126	106	115	104	107	116	93	112
Zn	mg/kg	1,25	1,65	1,51	1,33	1,10	0,87	1,26	1,17	1,22	2,71	0,82	1,51	1,75	1,32	1,74	1,67	1,29	1,25	1,32	1,31
Cu	mg/kg	4,16	4,71	3,72	2,38	2,90	2,33	2,76	2,30	3,07	2,81	2,99	3,52	5,53	4,05	5,79	6,00	4,58	3,62	3,83	3,38
Mn	mg/kg	20,4	43,2	24,5	11,4	7,9	5,7	9,8	8,5	8,3	9,2	9,1	22,4	145	43,1	184	96,2	64,8	50,2	41,5	40,5
B	mg/kg	0,24	0,41	0,36	0,39	0,25	0,21	0,27	0,25	0,25	0,29	0,21	0,32	0,42	0,34	0,45	0,37	0,35	0,40	0,25	0,35
Soil test		41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
code		V/1	V/2	V/3	V/4	V/5	V/6	V/7	V/8	V/9	V/10	VI/1	VI/2	VI/3	VI/4	VI/5	VI/6	VI/7	VI/8	VI/9	VI/10
pH (KCl)		7,65	7,57	7,51	7,39	7,34	7,35	7,38	7,44	7,47	7,49	7,59	7,47	7,53	7,59	7,57	7,55	7,51	7,48	7,49	7,43
SP	%	29	30	33	32	31	32	33	29	34	34	32	31	30	26	33	31	34	35	36	31
Total salts	m/m%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CaCO ₃	m/m%	17,0	17,0	3,0	4,0	4,0	4,0	3,0	8,0	9,0	14,0	9,0	9,0	9,0	10,0	12,0	10,0	10,0	7,0	5,0	2,0
Humus	m/m%	1,36	1,42	2,20	2,26	2,39	2,19	2,29	2,45	2,03	2,04	1,85	1,82	1,73	1,63	1,68	1,85	2,01	2,03	2,01	2,06
NO ₃ -N	mg/kg	2,3	2,7	4,2	3,0	4,3	4,6	4,5	6,1	3,8	2,8	4,5	5,9	3,2	5,6	5,0	4,2	5,7	5,4	3,2	3,7
P ₂ O ₅	mg/kg	176	196	189	192	177	194	189	197	172	148	264	248	262	215	197	209	195	212	194	140
K ₂ O	mg/kg	178	202	228	184	209	245	254	273	217	162	284	261	206	333	291	321	295	267	263	238
Mg	mg/kg	100	91	125	109	117	126	122	130	88	81	95	85	76	125	105	100	118	115	108	133
Zn	mg/kg	0,87	1,10	1,22	1,42	1,29	1,36	1,41	1,42	1,01	1,11	1,50	1,37	1,29	1,26	1,06	1,09	1,26	1,40	1,02	1,28
Cu	mg/kg	3,14	3,29	3,50	3,44	3,34	3,39	4,20	3,15	2,54	3,05	3,44	2,81	2,50	2,77	2,18	2,50	2,16	2,95	2,56	4,06
Mn	mg/kg	10,1	7,7	14,7	28,9	34,3	38,0	40,6	53,0	11,3	10,3	9,7	14,1	10,9	10,1	11,4	12,1	13,4	16,2	18,7	61,5
B	mg/kg	0,20	0,23	0,29	0,26	0,28	0,28	0,26	0,38	0,24	0,20	0,27	0,25	0,25	0,21	0,26	0,23	0,28	0,25	0,25	0,28

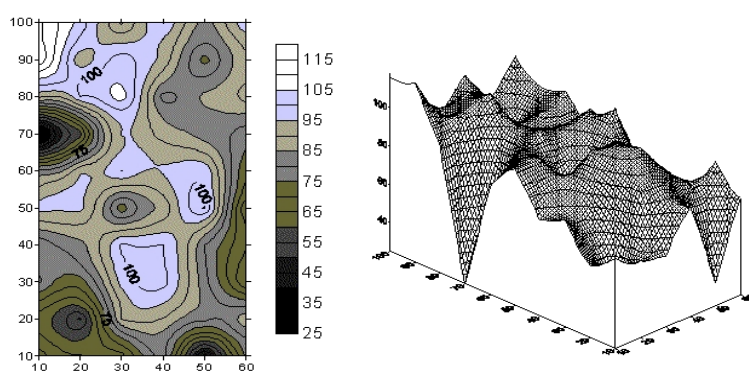


Figure 1: Sugar beet yield t/ha

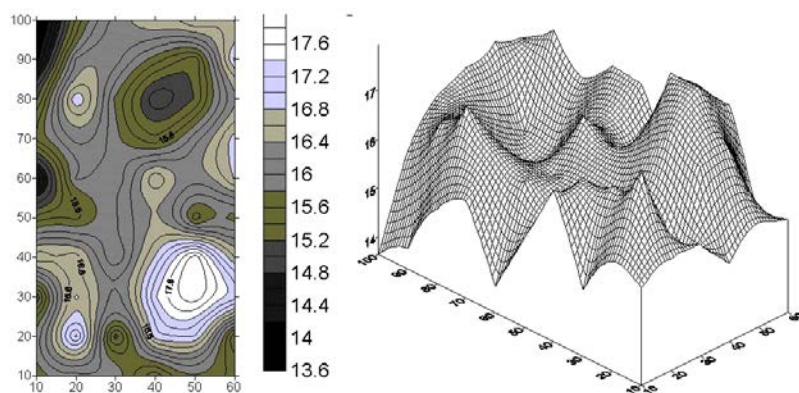


Figure 2: Sugar content (digestion%)

Similar large differences were observed in soil analysis results. Fig. 3 represents changes in CaCO_3 %. Fig. 4 those of nitrate-nitrogen and Fig. 5 those of AL-K content within the plot. Similar variability is found in all the measured and calculated parameters.

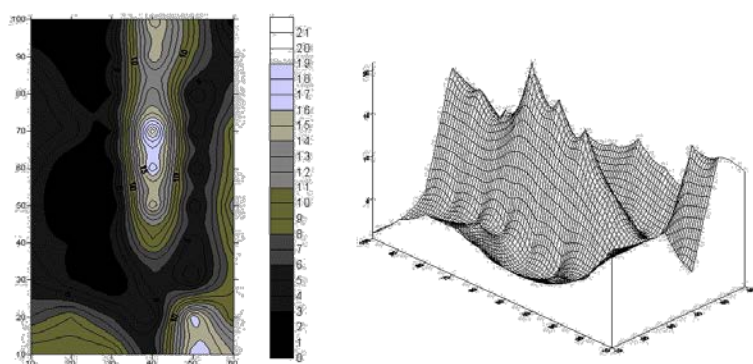


Figure 3: Calcium carbonate % (Scheibler)

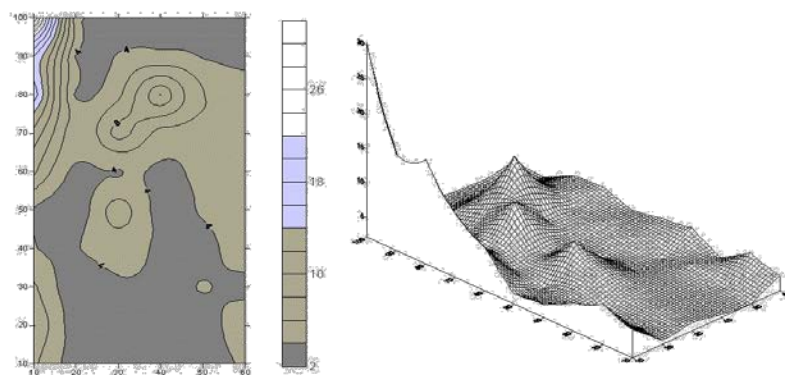


Figure 4: Nitrate-nitrogen mg/kg

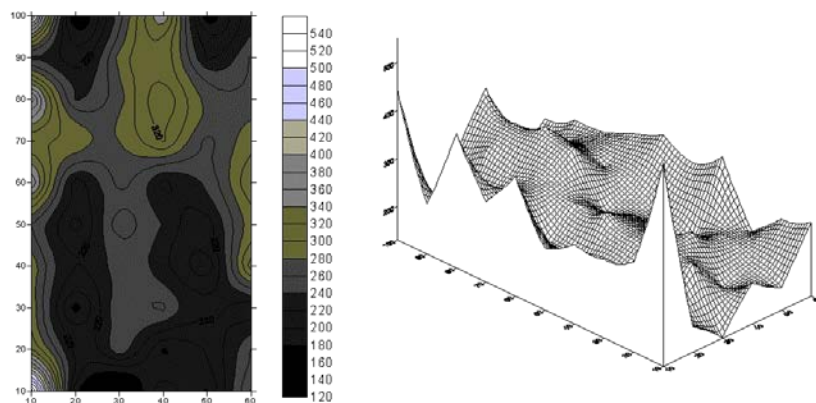
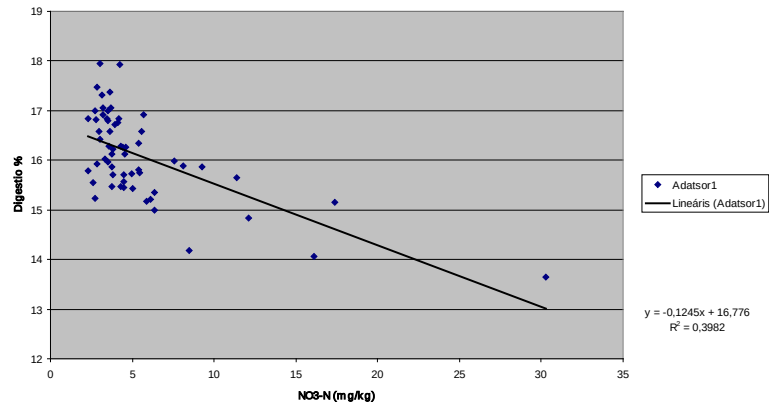


Figure 5: AL-K content K_2O mg/kg

As theoretically the measured differences could also be attributed simple failures in plant production technologies correlation was studied between soil analysis results and yield indices. A simple linear regression is used here to show tendencies of correlation. Detailed statistical data are dealt with in another lecture /Tamás, J. – Buzas, I.: Spatial analysis of point datasets to explore sugar beet variability).

Of the numerous correlation the effect of soil N and K contents on yield quantity and quality are especially important. As shown in Fig. 6 there is a convincing negative correlation between nitrate-N content and sugar content while practically no correlation ($R^2=0,013$) was found between the nitrate-N content and yield quantity (Fig. 7).In the same time, an increase in soil nitrate content spoils the thick juice purity quotient to a great extent which results in reducing the reception price of sugar beet (Fig. 8).

Figure 6: Nitrate-nitrogen content of the soil mg/kg and sugar content (digestion%)



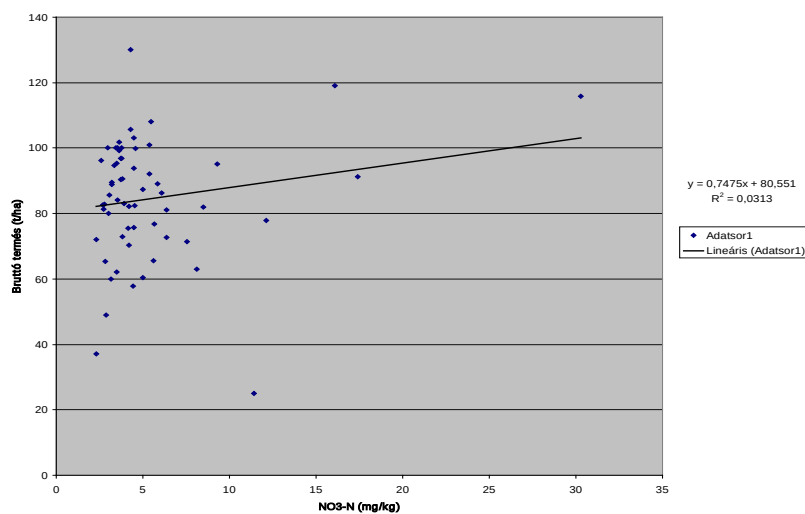


Figure 7: Nitrate-nitrogen content of the soil mg/kg and sugar beet yield t/ha

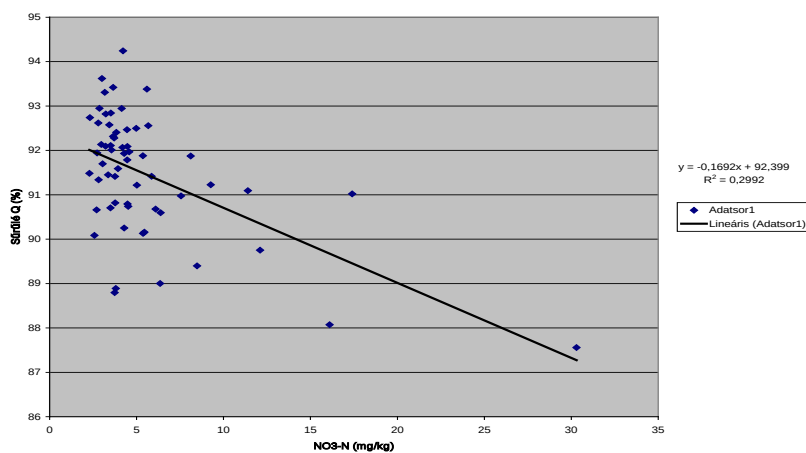


Figure 8: Nitrate-nitrogen content of the soil mg/kg and thick juice purity (Q%)

This soil well supplied with K, an increase in soil AL-K content did not increase sugar beet yield (Fig. 9), its effect, however, on white sugar content is still noticeable (Fig.10).

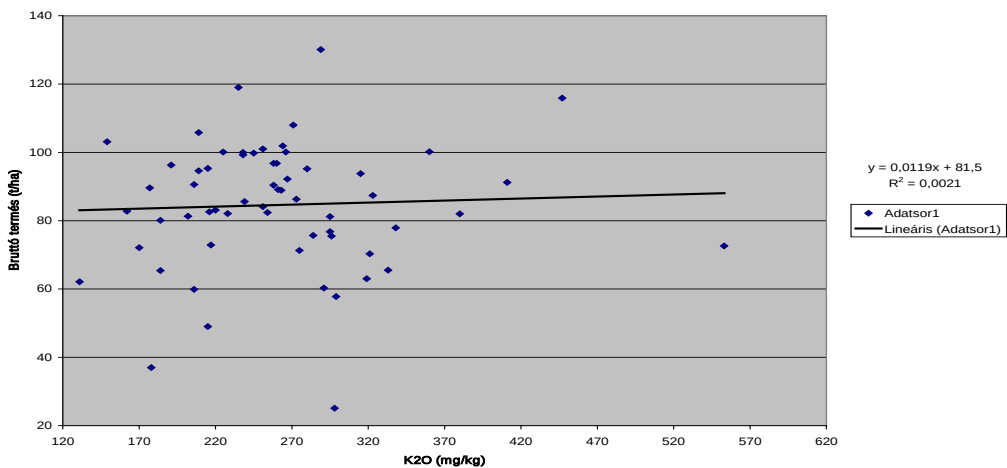


Figure 9: Soil AL-K content (K₂O mg/kg) and sugar beet yield t/ha

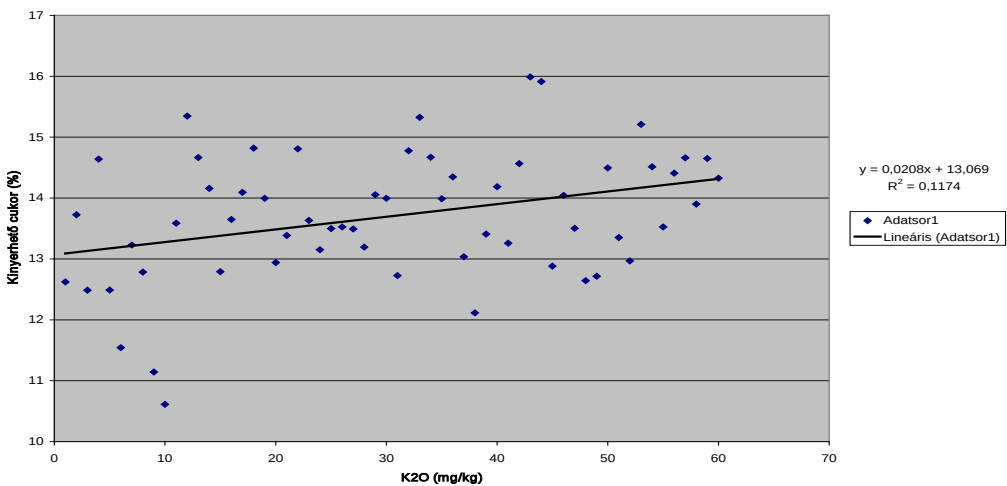


Figure 10: Soil AL-K content (K₂O mg/kg) and white sugar content %

Test results show clearly the correlation between pH (or calcium carbonate) and availability of microelements and heavy metals. For example: Fig. 11 shows the 0.05 mole EDTA+0.1 mole KCl soluble Cu and Fig. 12 that of Cd as affected by pH.

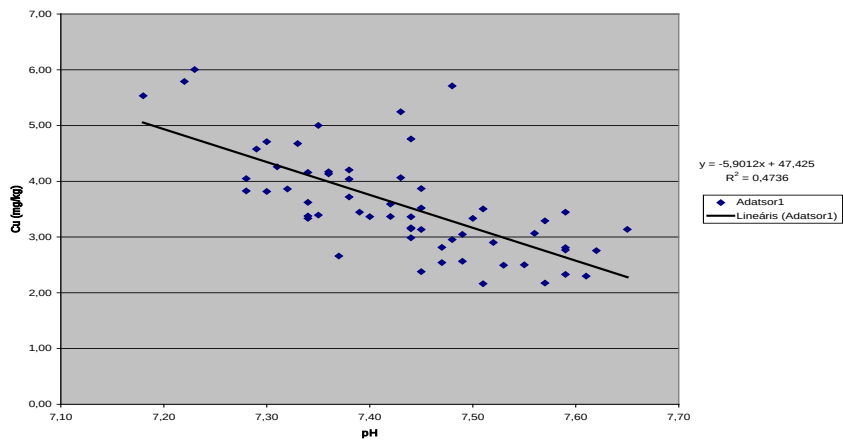


Figure 11: pH and 0.05 mole EDTA+0.1 mole KCl soluble Cu

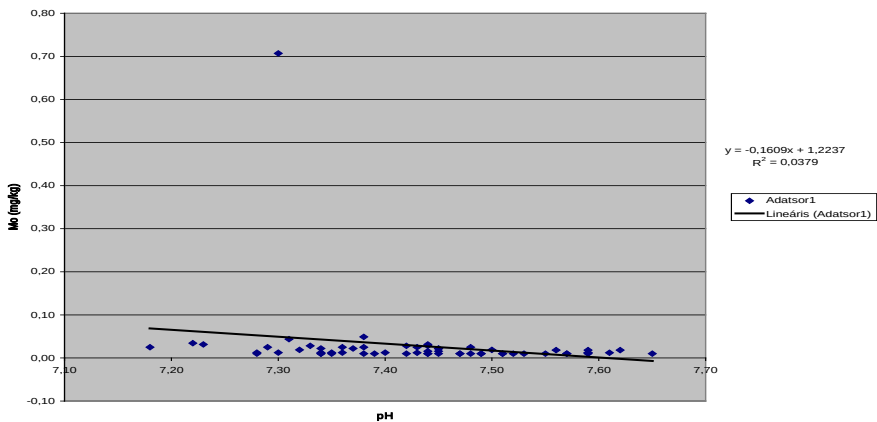


Figure 12: pH and 0.05 mole EDTA+0.1 mole KCl soluble Cd

Its generally known that in contrast to most microelements, Mo-availability is improved by increasing pH. As shown in Fig. 13 no positive correlation was found between pH and 0.05 mole EDTA+0.1 mole KCl soluble Mo-content.

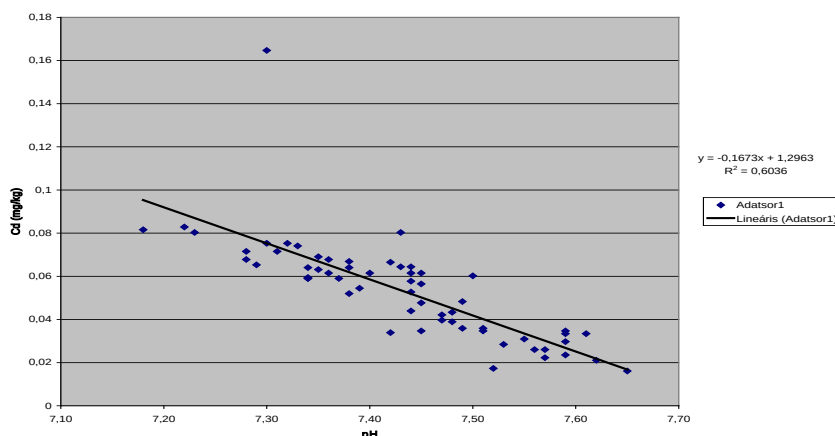


Figure 13: pH and 0.05 mole EDTA+0.1 mole KCl soluble Mo-content.

Discussion

Correlation between yield and soil characteristics and between certain soil analysis data can be followed by systematic sampling even within a heterogeneous plot.

An increase in soil nitrate content involves a decrease in sugar content and the thick juice purity while it does not affect root yield.

The effect of K on increasing sugar content is seen clearly even in this soil well supplied with K. An increase in pH and calcium carbonate content, respectively, decreases clearly the microelement and heavy metal content extracted by 0.05 mole EDTA+0.1 mole KCl solution. However, no positive correlation was found between pH and the extracted Mo content. It would be worth while to test if this general solvent can be used to characterise Mo availability in a soil fairly supplied with Mo.

References

- Poel, van der P.W. – Schiweck, H. – Schwartz, T.(1998): Sugar technology. Dr. Albert Bartens KG, Berlin.
- Tamás, J. (2001): Precíziós mezőgazdaság elmélete és gyakorlata. Mezőgazdasági Szaktudás Kiadó, Budapest.
- Buzás I. - Kulcsár L. (1999): Tápanyag-gazdálkodásunk és a cukorrépa-termesztés. Cukoripar LII. 2. 64-70.
- Buzás I. (2000): Impact of soil and nutrient management on sugar beet yield and quality in Hungary. in: Balanced plant nutrition in sugar beet cropping systems for high yield and quality (Ed. I. Buzás - A. E. Johnston) Proc. of workshop of Beta R.I.-IMPHOS-IPI. INDA 4231 Kiadó Budapest 22-61.
- A káliumellátás szerepe a sikeres cukorrépa-termesztésben. INDA 4231 Kiadó Budapest 2001.

LONG-TERM EFFECTS OF K FERTILIZATION ON PARAMETERS OF SOIL FERTILITY

A. Gransee¹ and T. Popp

Germany

Abstract

The ammonium fixation was tested in a soil with a different potassium application for 50 years. The clay fraction of the plot with no K fertilization was able to fix triply as much $^{15}\text{NH}_4^+$ compared to the clay minerals of the soil with an annual K application of 160 kg K/ha. The fixed $^{15}\text{NH}_4^+$ was not longer available for the roots of barley plants. The ^{15}N concentration in the plants from the soil with no K fertilization was significantly lower compared to the concentration in plants from the soil with long term K fertilization. However the omitted K fertilization had long-lasting effects on the N dynamic in the soil as well. The total N content in the clay fraction was double as much in the non K fertilized plot compared to the soil with K fertilization. The N was not in the nitrate or the organic form because both were removed during the extraction process. Therefore the higher N content in the K fertilized soil was due to not exchangeable NH_4^+ ions fixed instead of potassium in the intermediate layers of the clay minerals. Probably this can influence the N supply of the plants, because applied NH_4 is not available when the need of the plants is high.

Introduction

A forward-looking use of fertilizers has to take into account the long term effects of nutrients on the stability of soil fertility beside the necessary feed of the plants. But it is not only a one way of nutrients from the soil to the plant roots but the nutrients are a part of the soil structure at the same time. Thus they affect the parameters of the soil fertility to a great extent. Especially the potassium ion is important for the stability of the clay fraction due to its fixation in the intermediate layers of clay minerals. These minerals are the prerequisite for parameters of soil fertility like the cation exchange capacity and the gas and water balance of the soil. An omitted potassium application implicates not only an efficiency reduction of other nutrients particularly of nitrogen but can limit the uptake of nitrogen directly. An insufficient potassium fertilization causes an increase of the K^+ fixation in the soil. This means that the plants can take up the needed potassium only by the exchangeable K^+ from the intermediate layers of clay minerals. The consequence of this process is a reinforced fixation of NH_4 ions in these sites (Tang Yan et al. 1996). The fixation of ammonium results from the entrapment of NH_4 ions in the interlayers of 2:1 clay minerals. The amount of fixed ammonium depend on the clay content and the degree of K saturation (Scherer, 1993). This ammonium fixation may have a significant impact on available N in addition to organic N (Feigenbaum et al. 1994). The fixed NH_4 pool appeared to

¹ andreas.gransee@kali-gmbh.com

be a slow-release reservoir, with fixed NH_4 release being slower than the rate of fixation (Drury and Beauchamp, 1991). This could be important for the sufficient supply of nitrogen of the plants in the case of ammonium fertilization. Thereby the fixation rate of ammonium was affected by exchange reactions with other cations. In certain soils K^+ was highly effective at displacing adsorbed NH_4 (Chappell and Evangelou, 2000).

Consequently the present study was designed to investigate the impact of a long term K fertilization on the fixation of $^{15}\text{NH}_4$ and the resultant uptake of nitrogen into the plants.

Material and Methods

The experimental field is located in the Central German arid zone. The average rainfall was 466 mm per year in the period from 1965 – 1995 with a variation from 258 mm to 620 mm. The tested soil was a Luvic Phaeozem with the following characteristics: C_t content 1.5 %, N_t content 0.12 %, pH 6.5. Stumpe et al. (1995) and Merbach et al. (1999) give a detailed characterization. The potassium experiment was designed in 1949. It has 4 annual K application rates. K0 is without any potassium fertilization, K1 = 40 kg K for cereals and 80 kg K for sugar beets, K2 = 80 kg K for cereals and 160 kg K for sugar beets and K4 = 160 kg K for cereals and 320 kg K for sugar beets. The crop rotation is: maize – spring wheat – sugar beets – spring barley.

For the greenhouse experiment plastic containers (20 cm high, 12 cm diameter) were filled with 1.5 kg soil from K0 and the K4 plots with 4 replications. The soil was mixed with water so that the water content was 70% of the water capacity of the soil. In each pots 10 Seeds of spring barley were sowed. The N fertilization was 75 mg N ($(\text{NH}_4)_2\text{SO}_4$) and 75 mg ^{15}N per pot ($(^{15}\text{NH}_4)_2\text{SO}_4$). The application of the other nutrients was optimal for the experimental conditions with the exception of K which was omitted. The cultivation period was 3 and 6 weeks respectively. After this time the plants were harvested and the N content (^{14}N and ^{15}N was measured in the plant material, in the bulk soil and in the clay minerals. For this purpose the clay minerals were extracted as described by Tributh (1991) and Whitton and Churchman (1987).

Results and Discussion

As shown in table 1 the total N contents in the soil were not influenced by the plants because 95 % of the N was in this soil in the organic fraction. But the biomass production of the plants differs among the two plots. The plants in the K4 soil had a considerably higher dry mass

compared to the plants in the K0 soil. This was due to the higher K supply in the K4 soil. Nevertheless the N concentration in the K4 plants was higher than the N concentration in the K0 plants. Due to the identic N supply in both plots (K0 and K4) a higher or at least the same N concentration in the K0 plants was expected. However the K4 plants could accumulate a 30% higher N concentration in spite of the dilution effect caused by the higher biomass production. This effect was amplified remarkably considering the ^{15}N content in the plants. Here the the ^{15}N concentrations in the K4 plants were even twice as much compared to the K0 plants after 3 weeks. After 6 weeks the concentrations in the K4 plants were still two-thirds higher than in the case of K0. The application of nitrogen was in the form of ammonium only and so we can assume that in the K0 soil particularly the NH_4 uptake was handicapped. Thus the plants were fed by the nitrate pool of the soil mainly. In contrast the K4 plants preferred the nitrogen applied in the ammonium form. Due to the low uptake by the plants the ^{15}N content in the K0 soil was still high at the end of the experiment.

Table 1: N concentrations in soils and plants subject to the long-term K fertilization 3 and 6 weeks after the application of $^{15}(\text{NH}_4)_2 \text{SO}_4$ (Relative figures K0 versus K4 in brackets).

	Dry matter	Soil		Shoots	
	(Shoot and root) g pot ⁻¹	N _t conc. mg N (100g) ⁻¹	¹⁵ N conc. mg N (100g) ⁻¹	¹⁵ N conc. mg N pot ⁻¹	¹⁵ N conc. mg N pot ⁻¹
K0 3 weeks	1.37	98	4.3 (100)	1.8 (100)	0.3 (100)
K0 6 weeks	2.97	93	2.7 (100)	2.2 (100)	0.4 (100)
K4 3 weeks	1.93	93	2.7 (63)	2.4 (132)	0.7 (227)
K4 6 weeks	4.03	96	1.3 (48)	3.0 (133)	0.7 (167)

It is evident that the plants could not utilize the high ^{15}N contents still remaining in the soil. Therefore we looked at the fixation of this nitrogen. The results are given in table 2.

Table 2: Nitrogen concentrations in various fractions in the soil after variation in the long-term K fertilization. , results in mg N (100 g soil)⁻¹ and mg ^{15}N (100 g soil)⁻¹ resp.

	Bulk soil		Clay mineral fraction	
	¹⁵ N total	¹⁵ N KCl extract	¹⁵ N total	N total
K0 3 weeks	4.3	1.2	0.6	53.2
K0 6 weeks	2.7	0.7	0.6	55.8
K4 3 weeks	2.7	1.2	0.2	27.3
K4 6 weeks	1.3	0.9	0.2	29.0

As shown in the table 2 the clay mineral fraction of the K0 soil contains triply as much ^{15}N than the those of K4 soil. A remarkable share of the applied ^{15}N was fixed in this clay fraction in a relatively short period. The dynamic of this process is evident in the high ^{15}N content of the KCl extract of the K0 soil. The ^{15}N was fixed so strong that the plant roots were not able to take it up. However the nitrogen was not yet part of the clay mineral interlayers. The lower ^{15}N concentration in the K0 plants confirm this assumption. The total N concentrations given in table 2 show the long-term effects. The N content in the K0 soil was twice as much compared to the K4 soil. The nitrate and the nitrogen in organic forms was removed during the analytic procedure of clay mineral extraction. Therefore the additional N in the K0 soil can only be NH_4 ions. These ions were fixed nonexchangeable in the interlayers of the clay minerals in place of K^+ ions. Experiments with the indirect measurement of ammonium fixation at the same site show that negative potassium balances led to a reinforced ammonium fixation till 40 cm soil depth (Garz et al., 1993).

This can influence the N supply and the N uptake of the plants probably. The N fertilization use ammonium to an increasing extent to prevent or at least to minimize the loss of nitrate into the ground water. An omitted K fertilization causes a reinforced fixation into the interlayers of clay minerals. Even if this is only a short-term effect, the nitrogen is possibly not available for the plants during the the period of intensive plant growth and intensive N demand. Therefore a sufficient fixation with potassium is the prerequisite for an optimal availability of ammonium for the plants. Further investigation have to focus on this interesting aspect.

References

- Chappell M. A. and V. P. Evangelou, 2000. Influence of added K^+ on ammonium selectivity/mobility by soils with vermiculite behavior. *Soil Sci.* 165: 858-868.
- Drury C. F. and E. G. Beauchamp, 1991. Ammonium fixation, release, nitrification, and immobilization in high- and low-fixing soils. *Soil Sci. Soc. Am. J.* 55: 125-129
- Feigenbaum S., A. Hadas, M. Sofer and J. A. E. Molina, 1994. Clay-fixed labeled ammonium as a source of available nitrogen. *Soil Sci. Soc. Am. J.* 58: 980-985.
- Garz J. , H. Scharf, H. Stumpe, H. W. Scherer and W. Schliephake 1993. Der Einfluss der Kaliumdüngung auf einige chemische Bodeneigenschaften in einem Dauerversuch auf Sandlöß-Boden. *Kühn-Archiv* 87: 42-52.
- Merbach W., L. Schmidt and L. Wittenmayer, 1999. Die Dauerdüngungsversuche in Halle. Beiträge aus der Hallenser Pflanzenernährungsforschung. B. G. Teubner, Stuttgart and Leipzig.
- Scherer H. W. 1993. Dynamics and availability of the non-exchangeable $\text{NH}_4\text{-N}$ – a review. *Eur. J. Agron* 2: 149-160.
- Stumpe H., J. Garz and W. Schliephake, 1995. Das Versuchsfeld der Landwirtschaftlichen Fakultät in Halle und seine Dauerversuche. *Mitt. Dt. Bdkdl. Ges.*
- Tang Yan, Feng Ke and Yin Shixue, 1996. Preferential fixation of ammonium to potassium by soils. *Pedosphere* 6: 35-38.
- Tributh, H.1991. Qualitative und quantitative Bestimmung der Tonminerale in Bodentonen. In: Identifizierung und Charakterisierung von Tonmineralen. Eds. Tributh, H and G. Lagaly, *berichte der deutschen Ton- und Tonmineralgruppe* e.V: 37-85
- Whitton, J. S. and G. J. Churchman, 1987. Standard methods for mineral analysis of soil survey samples for characterization and classification in New Zealand. *NZ Soil Bureau Scientific report*: 79

LATE NITROGEN FERTILIZING OF WINTER WHEAT WITH THE AIM OF QUALITY IMPROVEMENT BASED ON PLANT DIAGNOSTICAL ANALYSES

L. Hangyel, Mrs. M. Hangyel Tárczy and L. Szabó

„Fleischmann Rudolf” Research Institute of the Szent István University
College Faculty of Economics and Agriculture, Hungary

Introduction

The cultivation and productivity of the wheat production is an item of high priority of the plant production. The high quality of the produced wheat is the base of the market competitiveness of the Hungarian farmers. The potential productivity of the varieties at disposal obtained as result of the work of the plant breeders is to be realised by using the adequate agricultural technology. One of the determinant factors of the yield is the nitrogen re-supply and fertilising. The technology of fertilisation is to be adapted not only to the soil characteristics but also to the other determining factors (variety, soil cultivation, plant care, plant protection) and the climatic conditions of the given year.

In the case of using not corresponding doses of fertilisation or in some years with favourable climatic conditions the wheat can use the most of the available nitrogen quantity before the coming. In this case despite of the basic fertilisation and top-dressing early in the spring a lack of nitrogen can come into being after the earing. A complementary nitrogen top-dressing following shortly the generative phases of the plant development may help to avoid this lack. The late nitrogen top-dressing made in the period between the end of thick growing and earing serve mostly the quality improvement.

Material and Method

We are making small plot trials and also take farm field samples and make measurements since 1996 for determining the relationship between the nitrogen supply of wheat and its quality parameters. The aim of our experiments is to evaluate the impacts of the late complementary nitrogen top-dressing based on plant diagnostic measurements. We also look after the possibilities of application of the results in the development of the technology.

Results of the trials

- The optimal nitrogen quantity given for realising the yield is not always enough for the realisation of the variety characteristic protein and gluten content (Figure 1)
- There is a strong correlation ($t_p = 0,1 \%$) between the values of the quality parameters and the measured nitrogen in the leaf in the phenologic period of growing thick and earing which can be proved statistically. (Table 1. Figure 2)
- The measured values can be used for the evaluation of the quality f yield and also for establishing the necessity and dose of a complementary late nitrogen fertilisation.. (Table 2)
- A precision instrument for field measurements can be useful – after the corresponding calibration – as diagnostically tool for an environment friendly technology of fertilisation. (Figure 3; Table 3)

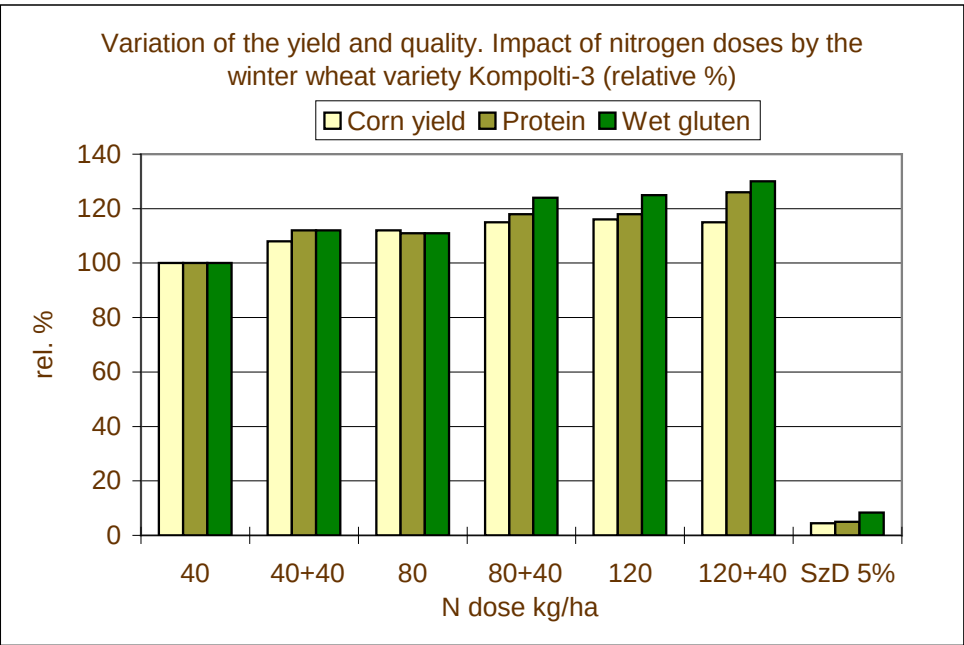


Figure 1

Table 1: Relationship between the measured leaf-nitrogen and the quality parameters by the winter wheat variety Kompolti-3

State EC 31

Parameter	Analysed variables (X;Y)	
	Leaf N % & Protein %	Leaf N % & Wet gluten %
Value of r	0,7572	0,7016
Square of r	0,5733	0,4923
Corrected square of r	0,5687	0,4869
Standard error	0,7677	2,1385
Number of observations	96	96
Value of F	126,29	91,16

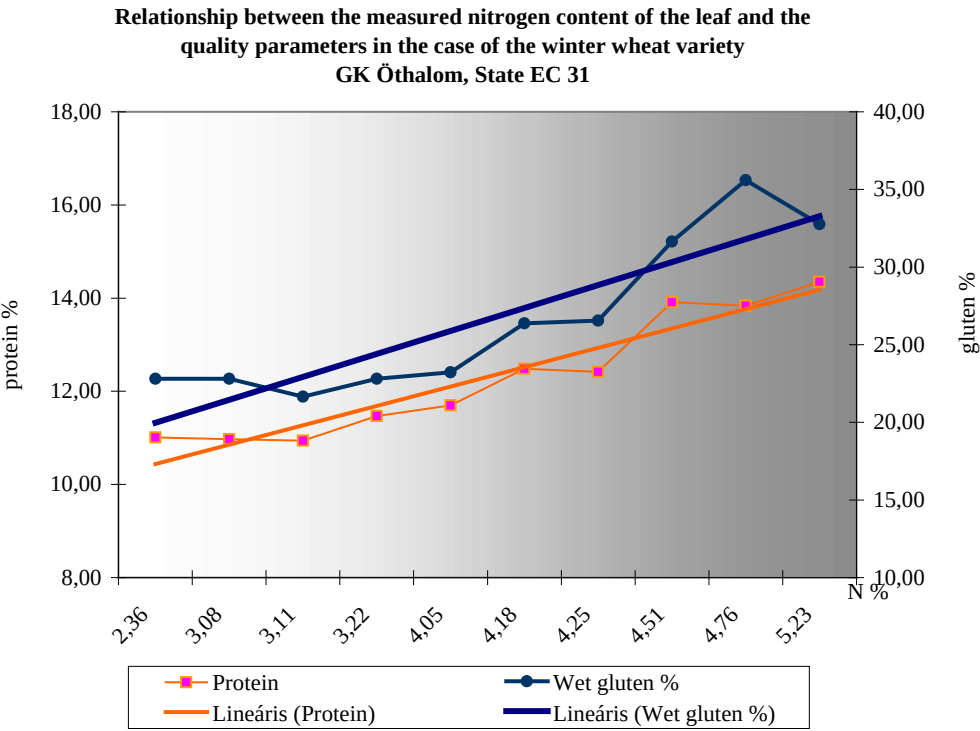


Figure 2

Table 2: Impact of late top-dressing on the quality of winter wheat

Kompolti – 3, 1998; 1999; 2000, 2002				
N-content Of leaf (%) State EC 31	Complementary N dose (kg/ha)	Yield mass (kg/ha)	Protein content (%)	WET GLUTEN CONTENT (%)
4,21	0	4722	14,27	30,08
	20	4920	14,46	32,03
1998	<i>Szd</i> 5%	342	0,69	1,30
3,61	0	4822	12,72	26,13
	46	5767	14,52	29,95
1999	<i>Szd</i> 5%	334	0,35	0,49
3,58	0	3947	13,9	30,7
	54	4187	15,4	34,1
2000	<i>Szd</i> 5%	396	1,22	2,88
3,66	0	4308	12,66	29,55
	67,5	4637	14,55	35,03
2002	<i>Szd</i> 5%	317	0,83	1,79
Jubilejnaja-50				
3,31	0	2832	10,78	20,95
	50	3607*	11,96*	24,51*
4,51	0	4106	12,43	25,96
	50	4407	13,85*	31,64*

* Significant increase on the level $t_p = 5\%$

Figure 3: Relationship between the N-tester values and nitrogen content by the variety MV - 21. State EC 31

<i>Coefficients</i>	
Centre section (a)	102,857
N % (b)	139,442

<i>Regression statistics</i>	
Value of r	0,9304
Square of r	0,8657
Corrected square of r	0,8637
Value of F	425,65
Observations	68

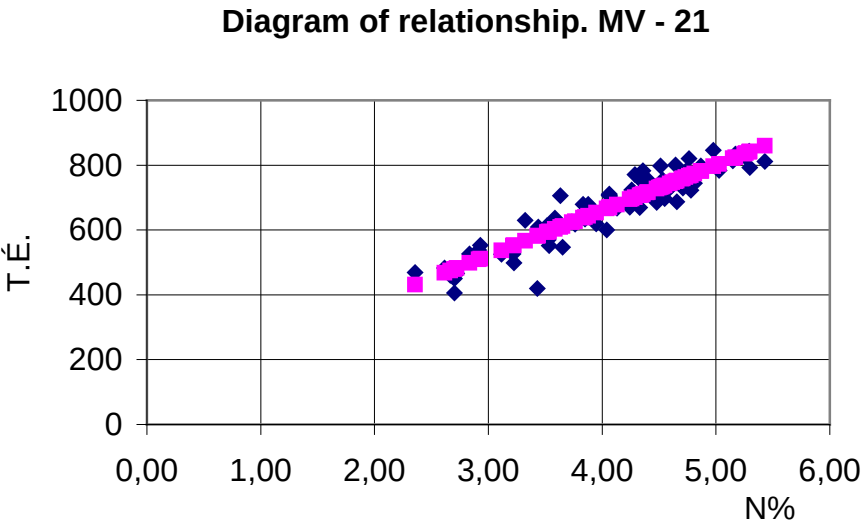


Table 3: Evolution of nitrogen content, N-tester values and quality parameters. Farm field data.
State EC 31

Jubilejnaja - 50	N %	N-tester values	Protein %	Wet gluten %
	3,09	459,00	9,76	17,70
	3,73	482,00	9,88	17,96
	4,45	497,00	12,69	28,65
	3,96	530,00	12,16	27,36
	4,18	568,00	12,11	27,29
	4,66	570,00	12,65	30,93
	4,42	583,00	10,25	21,52
	4,66	594,00	13,32	31,14
	5,22	631,00	14,41	32,14
GK Öthalom	2,36	280,00	11,01	22,80
	3,08	360,00	10,97	22,80
	3,11	449,00	10,94	21,66
	4,05	460,00	11,70	23,23
	4,18	520,00	12,48	26,38
	4,25	530,00	12,42	26,56
	4,51	560,00	13,91	31,64
	4,76	610,00	13,00	35,60
	5,23	630,00	14,35	32,77

Summary

In our trials in small pots and large field small plots between 1996 and 2002 using also farm data we have analysed the possibilities of forecasting the winter wheat quality and the determination of the necessity of a complementary nitrogen fertilisation by applying the data of plant analyses. We started the preparation of the calibration of an instrument for large field use in the qualification of the state of the Hungarian wheat varieties. The data of leaf samples taken in the period of unicular node and start of earing were useful for determining the protein and gluten content of the grains and for the optimisation of the complementary nitrogen doses.

References

- Mergenthaler, N.: The Dynamic of Nutrient Supply and Rational Nutrient supply by Winter Wheat. Agroinform, 1978. 31. p.
- Bergman, W.: Possibilities and Tasks of Plant and Leaf Analyse in the Fertilisation. Melioration – irrigation and Nutrient Management, 1987, No. 1. 48 –58 . p.
- Kádár, I.: Application of Plant Analyses in the Consulting for Fertilisation focusing on the Cultures of Wheat – Maize – Potato – Sugar beat. Research Results for the Practice. Nutrient Management. MÉM. 1988, 14-23. p.
- Bockman, O.C.– et. al.: Pflanzenernährung und Landwirtschaft. Norsk Hydro a.s, Oslo. 1990.
- Ragasits, I.: Wheat Cultivation. Edition Mezőgazda. 1998.
- Hangyel, L.- Bácsfalvi, Z. –Bartha, Sz.: Impact of Nitrogen Fertilisation on the Quality of Winter Wheat. II. Scientific Days for Environment Management of the Plane. Mezőtúr, 1999 10. 7-8. Lecture and publication. Tome 2
- Milata, P.: Co je Hydro N Tester ? [www. leadingfarmers.cz](http://www.leadingfarmers.cz)

PERFORMANCE OF UREA AND MULTI-NUTRIENT SUPER GRANULES ON RICE

S. A. Haque

Department of Soil Science, Bangladesh Agricultural University
Mymensingh-2202, Bangladesh

Abstract

Two field experiments were carried out under different agro-ecological zones of Bangladesh such as, Old Brahmaputra Floodplain at Bangladesh Agricultural University (BAU) farm, Mymensingh and Madhupur Tract at farmers' field in Madhupur to determine the response of super granules of urea (USG), Urea-DAP and NPK on HYV rice. Soil under the investigation at BAU farm was silt loam in texture, mild acidic and in general poor in nutrient status, while soil at Madhupur was also silt loam in texture, strongly acidic in reaction and poor in nutrient status.

Fertilizer treatments used in the experiments were (1) Control (without any fertilizer), (2) Urea (70 kg N ha^{-1} from urea), (3) USG (52 kg N ha^{-1} from USG super granule), (4) Urea-DAP SG (52 kg N and $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ from Urea-DAP super granule) and (5) NPK SG (52 kg N , $20 \text{ kg P}_2\text{O}_5$ and $20 \text{ kg K}_2\text{O ha}^{-1}$ from NPK super granule). In treatments 2-3, P, K, S and Zn fertilizers were applied basal @ $40 \text{ kg P}_2\text{O}_5$, $40 \text{ kg K}_2\text{O}$, 20 kg S and 3 kg Zn ha^{-1} respectively. In treatment 4, K was applied as basal @ $40 \text{ kg K}_2\text{O ha}^{-1}$ along with S and Zn as in treatments 2-3, while in case treatment 5, S and Zn were applied basal as in treatments 2-3. Each treatment was replicated thrice in a completely randomized block design. Test crops used were HYV rice, BR-30 at BAU farm and BR-11, at Madhupur farmer's field. The experiments were conducted in the wet season (July-November) of 2000.

Deep point placement of USG, Urea-DAP and NPK super granules had greatly increased grain yield of rice. The highest increase in grain yield was recorded in NPK followed by Urea-DAP and USG point placement. The maximum grain yield was obtained in NPK super granule treatment (6.23 t ha^{-1}), while the minimum grain yield was recorded in control treatment (3.41 t ha^{-1}). Similar trend of grain yield increases due to point placement of USG, Urea-DAP and NPK super granules over broadcast application of fertilizers were also recorded at Madhupur farmers' field. The maximum grain yield of rice was recorded in NPK super granule treatment (5.73 t ha^{-1}), while the minimum grain yield was obtained in control treatment (3.22 t ha^{-1}). Deep point placement of fertilizer super granules appeared highly promising on wetland rice.

Key Words: Urea, Urea-DAP, NPK, Super-granules, Rice

Introduction

Urea is the most dominant nitrogen fertilizer used for rice production in Bangladesh. The rice ecosystems also favour high losses (60-70% of N applied) of urea fertilizer. Because of agronomic superiority and cost effectiveness of deep-point placed urea super granule over split broadcast urea (BARC, 1985; Kumar, *et al.*, 1989; Savant and Stangel, 1990, Haque, 2000), use of USG has become attractive and being popularized in the country. An average of 15-20% yield increase of paddy with 25% less N in USG was reported to have been achieved in different areas of Tangail district in Bangladesh over split-applied N as prilled urea (Haque, 1998). The incremental benefit:cost ratios of hand deep-placed USG in line transplanted

rice have been found to be quite attractive and are usually >5 for small scale rice farmers (Haque,1998).

Multi-nutrient super granules such as USG with DAP was experimentally found to be sound for wetland transplanted paddy. Its application technology is similar to that of USG, which is already known to the farmers. Recent developments in USG agro-technology (Savant et al.) include use of USG/Urea containing Di-ammonium phosphate as a NP source for both rain-fed and irrigated transplanted rice. It has particular advantage in soils with high P-fixing capacity such as Red Terrace soils of Madhupur in Bangladesh (Haque, 2001). Use of deep placement of NPK super granules in rice is a recent development in multi-nutrient fertilizer technology in Bangladesh and first initiated in the present research work. Use of urea-DAP and NPK super granules in addition to USG are expected to ease up fertilizer handling by the farmers as well as improve efficiency of the applied fertilizers. Thus, the objective of the investigation was to increase the efficiency of applied fertilizer and boost up crop production through research trials on USG and multi-nutrient super granules such as Urea-DAP and NPK on rice, the major food crop of Bangladesh.

Materials and Methods

Two field experiments were carried out under different agro-ecological zones of Bangladesh such as, Old Brahmaputra Floodplain at Bangladesh Agricultural University (BAU) farm, Mymensingh and Madhupur Tract at farmers' field in Madhupur. The experimental site at BAU farm was medium high land and silt loam in texture. The soil had a pH 6.8, CEC 11.20 m.e.%, organic matter content 2.34%, total N 0.16%, available P 0.66 ppm, exchangeable K 0.12 m.e.% available S 4.0 ppm and Zn 12.81 ppm. The experimental site at Madhupur was high land with silt loam in soil texture. The soil had a pH 5.5, CEC 5.6 m.e.%, organic matter content 1.28%, total N 0.08%, available P 0.82 ppm, exchangeable K 0.04 m.e.%, available S 5.0 ppm and Zn 0.59ppm.

Fertilizer treatments used in both the experiments were (1) Control (without any fertilizer), (2) Urea (70 kg N ha^{-1} from urea), (3) USG (52 kg N ha^{-1} from USG super granule), (4) Urea-DAP SG (52 kg N and $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ from Urea-DAP super granule) and (5) NPK SG (52 kg N , $20 \text{ kg P}_2\text{O}_5$ and $20 \text{ kg K}_2\text{O ha}^{-1}$ from NPK super granule). In treatments 2-3, P, K, S and Zn fertilizers were applied basal @ $40 \text{ kg P}_2\text{O}_5$, $40 \text{ kg K}_2\text{O}$, 20 kg S and 3 kg Zn ha^{-1} respectively. In treatment 4, K was applied as basal @ $40 \text{ kg K}_2\text{O ha}^{-1}$ along with S and Zn as in treatments 2-3, while in case of treatment 5, S and Zn were applied basal as in treatments 2-3. TSP, MP,

gypsum and zinc oxide were used as the sources of P, K, S and Zn fertilizers. Super granules were placed at a depth of 7 cm centrally between 4 hills of rice plants 7 days after transplanting of rice seedlings. Each treatment was replicated thrice in a completely randomized block design. Test crops used were HYV rice, BR-30 at BAU farm and BR-11, at Madhupur farmer's field. The experiments were conducted in the wet season (July-November) of 2000.

Results and discussion

BAU farm:

Point placement of USG and multi-nutrient super granules had great impact on the yield contributing attributes of rice plants at BAU farm. Placement of USG almost doubled the number of effective tillers compared to the control treatment. Urea-DAP super granules had further increased the tiller numbers. The maximum number of effective tillers was obtained in NPK point placement (12.0). Similarly, length of panicles of the rice plants had positive effects of point placement of fertilizers over broadcast application. Number of filled grains was greatly boosted up in NPK as well as Urea-DAP super granules compared to the control treatment. In control treatment, the number of filled grains was 61.7, whereas in case of Urea-DAP and NPK super granules the filled grains panicle⁻¹ were 106.0 and 115.0 respectively. Again the increase of filled grains in NPK point placement was 86.4% compared to 35.3% as obtained in urea (inclusive of other nutrients) applied broadcast. 1000-grain weight also increased with point placement of fertilizer nutrients (Table 1).

Table 1: Effects of USG and multi-nutrient super granules on yield components of rice at BAU farm

Treatment	No. of effective tillers hill	Length of panicle (cm)	<u>No. of grains/panicle</u>		1000-grain wt (g)
			filled	unfilled	
Control	5.3	21.0	61.7	12.0	20.7
Urea	7.7	23.7	85.0	15.0	23.0
USG	10.3	26.0	96.0	17.7	26.3
U-DAP SG	11.7	27.0	106.0	16.3	26.6
NPK SG	12.0	27.3	115.0	13.3	26.6

Point placement of USG and multi nutrient super granules greatly increased grain and straw yields of rice. The grain yield increases ranged from 64.22-82.69% under point placed USG, Urea-DAP and NPK super granules over control, whereas in case of urea treatment the yield

increase over control treatment was only 27.56%. Among the USG and multi-nutrients treatments such as Urea-DAP and NPK super granules, the maximum grain yield increase was obtained in NPK super granule treatment (82.69%) and second highest yield increase (68.91%) was obtained in Urea-DAP super granule treatment. The maximum grain yield of rice (6.23 t ha⁻¹) was obtained in NPK super granule treatment, while the minimum grain yield (3.41 t ha⁻¹) was recorded in control treatment (Table 2). Maximum straw yield of rice was obtained in NPK super granule treatment (7.32 t ha⁻¹). The second highest straw yield of rice was obtained in Urea-DAP super granule treatment (6.57 t ha⁻¹), which however was statistically similar to that obtained in USG treatment (6.45 t ha⁻¹). USG and Urea-DAP super granule treatments produced significantly higher straw yields over urea treatment (Table 2).

Table 2: Effects of USG and multi-nutrient super granules on grain and straw yields of rice at BAU farm

Treatment	<u>Grain yield</u>		<u>Straw yield</u>	
	(t ha ⁻¹)	over control (%)	(t ha ⁻¹)	over control (%)
Control	3.41d	-	4.64d	-
Urea	4.35c	27.56	5.59c	20.25
USG	5.60b	64.22	6.45b	39.00
U-DAP SG	5.76b	68.91	6.57b	41.59
NPK SG	6.23a	82.69	7.32a	57.75

Figures in a column having common letters do not differ significantly at 5% level of significance.

Madhupur farmers' field:

Influence of point placement of nutrients over broadcast application of fertilizers on yield contributing attributes of rice plants were also recorded at Madhupur farmers' field. Point placement of USG greatly increased the number of effective tillers haill⁻¹ of the rice plants. The increase was more than 70% compared to the control treatment. Similar increase was obtained in Urea-DAP treatment. The maximum number of effective tillers was recorded in NPK point placement (12.3), which more than doubled the tiller numbers obtained in the control treatment (5.7). The maximum panicle length of the rice plants was also obtained in NPK point placement treatment, which was 27.3 cm compared to 19.7 cm obtained in the control. Increases in panicle length were much higher in point placement of USG and Urea-DAP treatment compared to both control and urea broadcast application. Number of filled grains was greatly boosted up in NPK point placed as obtained in BAU farm. The increase was 106.0% in NPK treatment compared to

44.7% as obtained in urea treatment applied broadcast. 1000-grain weight as well increased in NPK point placement treatment over urea broadcast application (Table 3).

Table 3: Effects of USG and multi-nutrient super granules on yield components of rice at Madhupur farmers' field

Treatment	No. of effective tillers hill	Length of panicle (cm)	<u>No. of grains/panicle</u>		1000-grain wt (g)
			filled	unfilled	
Control	5.7	19.7	55.0	14.3	20.3
Urea	8.0	22.0	78.3	19.3	24.7
USG	9.7	25.3	92.0	20.0	27.0
U-DAP SG	11.7	26.3	105.3	15.0	28.0
NPK SG	12.3	27.3	113.3	18.3	28.3

At Madhupur farmers' field, the grain yield increases due to USG and multi-nutrient super granules point placement ranged from 59.63-77.95% over control. In case of urea broadcast application, the yield increase the over control treatment was only 30.75%. Among USG and multi-nutrients treatments such as Urea-DAP and NPK super granules, the maximum yield increase was obtained in NPK super granule treatment (77.95%) and second highest yield increase (70.19%) was obtained in Urea-DAP super granule treatment (Table 4). The maximum grain yield of rice was obtained in NPK super granule treatment (5.73 t ha⁻¹), while the minimum grain was recorded in control treatment (3.22 t ha⁻¹). Maximum straw yield of rice was obtained in NPK super granule treatment (6.74 t ha⁻¹). The second highest straw yield of rice was obtained in Urea-DAP super granule treatment (5.95 t ha⁻¹), which however did not significantly differ from that of USG (5.69 t ha⁻¹) and urea (5.45 t ha⁻¹) treatments. The minimum straw yield (4.36 t ha⁻¹) was recorded in control treatment (Table 4).

Table 4. Effects of USG and multi-nutrient super granules on grain and straw yields of rice at Madhupur farmers' field

Treatment	<u>Grain yield</u>		<u>Straw yield</u>	
	(t ha ⁻¹)	over control (%)	(t ha ⁻¹)	over control (%)
Control	3.22d	-	4.36c	-
Urea	4.21c	30.75	5.45b	25.00
USG	5.14b	59.63	5.69b	30.50
U-DAP SG	5.48a	70.19	5.95b	36.47
NPK SG	5.73a	77.95	6.74a	54.59

Figures in a column having common letters do not differ significantly at 5% level of significance.

Conclusion

Point placement of USG, Urea-DAP and NPK super granules greatly increased yield contributing attributes and yields of both rice grain and straw over broadcast application of urea with recommended rates of other fertilizer nutrients in both the experiments at BAU farm and Madhupur farmers' field. Point placement of multiple fertilizer nutrients in the form of Urea-DAP and NPK super granules appear more promising in economizing fertilizer nutrients uses and boosting up yield of rice, which is the major food crop of Bangladesh.

Acknowledgement

The author acknowledges the financial support provided by Bangladesh Agricultural Research Council to carry out the research work.

References

- Bangladesh Agricultural Research Council (BARC), 1985. Fertilizer nitrogen deep placement for rice. Proceedings of the Technical sessions, July 8-9, Dhaka, Bangladesh.
- Haque, S. A. 1998. Case study on USG in three villages of Tangail district, ATDP/IFDC, Dhaka. 40p.
- Haque, S.A. 2000. Impact of UMG/USG in rice cultivation. Proceedings of the Second National Workshop on Urea Super Granules (USG) and Sustainable Agriculture in Bangladesh. IFDC, Dhaka. p. 69-74
- Haque, S.A. 2001. A report on the efficiency of N and P placement technologies for rice production in different agro-ecological zones of Bangladesh. Adapting Nutrient Management Technologies Project (ANMAT). Supported by IFAD and implemented by IFDC. Dhaka, 22p.
- Kumar, V.; Shrotriya, G.C. and Kaore, S.V. (eds). 1989. Urea super granules for increasing nitrogen use efficiency. Indian Farmers and Fertilizer cooperative (IFFCO), New Delhi, p. 1-143.
- Savant, N.K.; Lazo de la Vega R. and Stangel, P.J. 1990. Recent advances in USG agro-technology for transplanted rice. Agro. Abs. 63p.
- Savant, N.K. and Stangel, P.J. 1990. Deep placement of urea super granules in transplanted rice: Principles and Practices. Fert. Res. 25: 1-83.

DRY MATTER ACCUMULATION AND NUTRIENT UPTAKE OF DUAL UTILIZATION FIBRE HEMP

I. Iványi and Z. Izsáki

Tessedik Sámuel College Faculty of Agricultural Water and Environmental Management, Szarvas, H-5541 P. O. B. 3., Hungary

Introduction

Fibre hemp production has gained considerable attention in recent times. The demands for different hemp raw material changes a lot according to versatile end-products. For this reason, it is necessary to revisit the technology of hemp production and to modify where it is required by the varying needs of end-products. According to the principle of precision agriculture the nutrient supply of different fibre hemp varieties changes depending on the production tasks.

Dioecious hemp varieties are not suitable for seed production because they have 50% male plants and therefore they have low seed yield. Monoecious hemp varieties have high percent of seed-producing plants so we can use them for dual utilization, seeds and stalks as mainproducts.

Traditional hemp production in Hungary happened for its bast fibre in plant stalk. Seed production was only for planting of seeds.

Monoecious varieties of hemp have never been cultivated in Hungary. So, after a long-term (from 1990 to 1998) fertilization experiment with dioecious Kompolti hemp which aimed to determine the effect of nutrient supply on quantity and quality of stalk yield, from 1999 we continued our research with monoecious.

Before we reported the effect of nutrient supply on: dry matter accumulation; 9 elements nutrient uptake and the quantity and quality ; the optimum time of diagnostic plant analysis; nutrient supply limit values; self-thinning and decreased plant density on the yield of Kompolti dioecious hemp variety (Iványi L. né 1998; Iványi-Izsáki 1998; Iványi 1999; Iványi-Izsáki 2000; Iványi-Izsáki 2001).

One of the important goals of agrochemical research for plant analysis purposes is to examine the optimal nutrient supply limits, nutrient ratios of crops, and interactions between different nutrients in the different developmental phases of the plant (Moller - Nielsen, 1976, Friis - Nielsen 1976, Sumner 1977, Debreczeni 1979, Elek - Kadar 1980, Kadar et al.1981, Izsaki 1988).

Results of these studies will enable the practical application of plant analysis with different targets, described by Bergmann - Neubert (1976), Buzas (1987), Kadar (1987) and Izsaki (1988) are as follow:

- diagnosis of nutrient deficiency and surplus,
- analysis of plant's nutrient supply and nutrient content in order to
- achieve high yield and good quality,
- confirmation of soil analysis,
- control of fertilization practice, fertilizer recommendation,
- yield and quality forecast,
- analysis of developmental problems.

The wide applicability of plant analysis methods is clear, but based on the limitations of its interpretation and employment, it can not substitute soil analysis. The results of soil and plant analysis should be built into the fertilization recommendation system (Amberger 1980, Kadar 1980, SarkadiI 1981, Beringer 1985).

From 2000 year we investigated the Chinese monoecious hemp variety as dual utilization test plant of our fertilization experiment. We already reported the effect of nutrient supply on THC (tetra- hydro- cannabinol) content and the influence of N supply on stalk and seed yield, oil content, protein content, amino acid content, 9 essential amino acid and 8 non essential amino acid content of hempseed on different density on the bases of the results of 2000 year experiment (Iványi-Izsáki-Bócsa 2001a, Iványi-Izsáki-Bócsa 2001b).

This paper is about the dry matter accumulation and nutrient uptake of Chinese monoecious hemp variety on different nutrient supply level as results of 2001 years experiments.

Materials and Methods

Fibre hemp fertilization and other agrotechnical experiments were undertaken in the south-east part of Hungary from 1990 to recent times on chernozem meadow soil. Soyabean and broad bean were grown prior to the hemp every year.

We applied four levels of N, P, K fertilizers in total combinations ($4 \times 4 \times 4 = 64$) to determine the stem yield. N fertilizers were applied at rates of 0, 80, 160 and 240 kg ha^{-1} . From P and K treatments the P_1 , K_1 aimed at the maintenance of sufficient nutrient supply level in the soil, whereas the P_2 , P_3 and K_2 , K_3 aimed at the development of the different nutrient supply level.

The soil phosphate and potassium levels in the cultivated layer were:

P₂O₅ mgkg⁻¹		K₂O mgkg⁻¹	
	in 2000. autumn		in 2000. autumn
P ₀	120	K ₀	232
P ₁	183	K ₁	354
P ₂	156	K ₂	352
P ₃	204	K ₃	373

The total area of the basic plots was 20 m², in split-split plot design and with three replicates.

Chinese monoecious hemp was planted in the first week of April in 2001. The seeding rate was 45 kg ha⁻¹ with a row space of 12,5 cm.

The weather in 2001 year was warmer, the annual precipitation was higher, (634 mm) than the average of the previous 75 years.

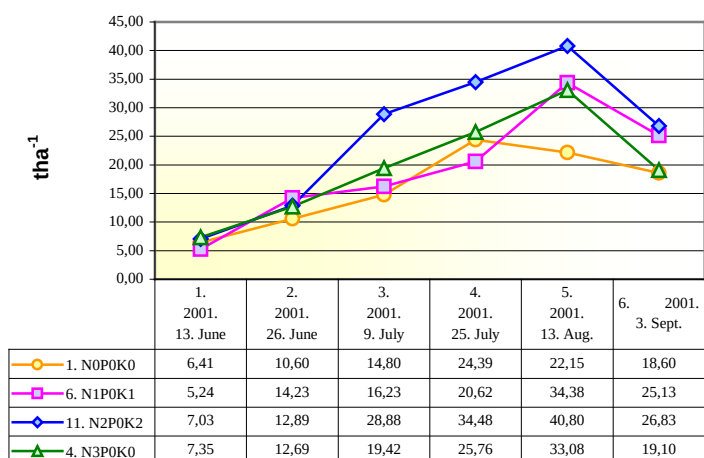
We did not use chemical protection except against *Psylloides attenuate* at emergency time, and we did not need to use any other cultivation during the growing season.

Total above ground plant organ samples of 2x1 m rows by plots were taken every second week, eight times during the growing season from 17 of May to 03 of September from selected 20 treatments. The data of the test were evaluated by analysis of variance according to Sváb (1981) methods.

Results

We achieve outstanding hemp yield in the 2001. Maximum stalk and leaf dry matter formed at middle of August, when the total above ground plant weight was 22,15 tha⁻¹ at controll treatment and 40,80 tha⁻¹ at the best N₂P₀K₂ treatment (Figure 1).

The 2001. year was very favourable for success of nutrients and suitable to determine the maximum and specific nutrient uptake because the warm and wet weather. At the time of maximum yield the control treatment gave 18,62 tha⁻¹ stem yield and 1,67 tha⁻¹ seed yield. The highest yield was at N₂P₀K₂ treatment: 34,75 tha⁻¹ stalk and 3,84 tha⁻¹ seed yield (Table 1.).



Sampling

Figure 1: Stalk+leaf dry matter accumulation of the Chinese monoecious hemp (2001, Szarvas)

Table 1. Some details of Chinese monoecious hemp yield at the time the maximum dry matter formation (Szarvas, 2001)

Treatments		Density mill. plant ha ⁻¹	Stem length (cm)	Stem diameter (mm)	Leaf dry matter (tha ⁻¹)	Stalk dry matter (tha ⁻¹)	Leaf+stalk dry matter (tha ⁻¹)	Seed yield (tha ⁻¹)
number	symbol							
1.	N ₀ P ₀ K ₀	1,16	211,43	7,50	3,46	18,62	22,15	1,67
2.	N ₁ P ₀ K ₀	1,20	241,53	8,96	3,94	20,29	24,60	1,42
3.	N ₂ P ₀ K ₀	1,30	246,74	8,16	4,26	21,89	26,16	1,31
4.	N ₃ P ₀ K ₀	1,36	236,18	7,46	5,00	28,08	33,08	1,78
5.	N ₀ P ₀ K ₁	1,26	214,64	7,26	4,28	21,82	26,35	2,45
6.	N ₁ P ₀ K ₁	1,20	232,81	8,26	5,15	29,25	34,38	1,59
7.	N ₂ P ₀ K ₁	1,16	228,25	8,46	4,51	25,09	29,56	1,8
8.	N ₃ P ₀ K ₁	1,16	230,11	8,36	4,23	25,01	29,25	1,48
9.	N ₀ P ₀ K ₂	1,36	228,51	7,50	3,72	25,90	29,62	1,55
10.	N ₁ P ₀ K ₂	1,30	235,78	9,66	4,28	23,98	28,23	1,76
11.	N ₂ P ₀ K ₂	1,06	234,26	9,13	6,05	34,75	40,80	3,84
12.	N ₃ P ₀ K ₂	1,20	237,05	8,60	3,72	25,90	29,62	2,36
LSD _{5%}	K ₀ N ₀ - K ₁ N ₀	0,442	44,960	1,741	1,425	6,519	7,453	-
	N ₀ K ₀ - N ₁ K ₀	0,219	31,956	1,621	1,498	5,495	6,625	-
Average		1,231	231,445	8,281	4,386	25,051	29,485	1,918

The nutrient uptake changed depending on the treatment. There were nutrient deficiency and nutrient surplus situations, also. So, we can determine the nutrient uptake the average of treatments. The Chinese monoecious hemp uptook nutrients to form 2 t_{ha}⁻¹ seed yield and 24 t_{ha}⁻¹ stalk and 4 t_{ha}⁻¹ leaf yield (Table 2.) :

Table 2: The maximum nutrient uptake of dual utilization hemp by parts of plant (2001, Szarvas)

Maximum nutrient uptake										
Parts of plant	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn
	kg _{ha} ⁻¹					g _{ha} ⁻¹				
stalk	89,28	21,52	190,91	90,32	28,96	39,99	6 48,47	4 69,40	614,40	1 29,15
seed	75,88	17,71	20,56	0,51	7,91	2,06	2 52,77	3 04,35	328,80	1 45,87
leaf	124,30	14,60	85,51	128,90	54,33	5,10	9 04,79	3 85,75	286,94	2 05,67
Total	289,46	53,83	296,98	219,70	91,20	47,15	18 06,03	11 59,50	1 230,10	4 80,69

Conclusion

The specific nutrient uptake for dual utilization Chinese monoecious hemp on sufficient nutrient content chernozem meadow soil (Table 3.) :

Table 3. The specific nutrient uptake for dual utilization Chinese monoecious hemp for 1 t seed yield (together with 12 t stalk and 2 t leaf yield)

Specific nutrient uptake									
N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn
kg _t ⁻¹					g _t ⁻¹				
144,7	26,9	148,5	109,8	45,6	23,5	903,0	5 79,7	615,1	2 40,3

For 1 t dual utilization hemp uptaken (together with 12 t stalk and 2 t leaf yield) 144,7 kg N-, 62 kg P₂O₅- and 178 kg K₂O.

This experiment was supported by Széchenyi National Research Program 2001.

References

- Amberger, A.: 1980. Grenzen der Düngung für Ertrag und Qualität. Die Dobenkultur, Wien. 31. 246-256.
- Bergmann, W.-Neubert, P.: 1976. Pflanzendiagnose und Pflanzenanalyse. VEB. Gustav Fischer Verlag. Jena.
- Beringer, H. 1985. Adequacy of soil testing for predicting fertilizer requirements. Plant and Soil, The Hague. 83. 21-37.
- Buzás, I.: 1987. Bevezetés a gyakorlati agrokémiába. Mezőgazdasági Kiadó, Budapest. (Introduction to practical agrochemistry)
- Debreczeni, B.: 1979. Kis agrokémiai útmutató. (Agrochemical handbook). Mezőgazdasági Kiadó, Budapest.
- Elek, É.-Kádár, I.: Állókultúrák és szántóföldi növények mintavételi módszere. (Sampling methods of trees and arable crops) MÉM-NAK. Budapest, 52.
- Iványi, L.né Gergely, I.: 1998. A tápanyagellátás hatása a rostkender szárazanyag-felhalmozására, tápelemfelvételére és termésére. The Effect of Nutrient Supply on Dry Matter accumulation. Ph.D. Thesis. Debrecen, 1998. 1-137. (In Hungarian with Abstract)
- Iványi, I.: 1999. Az okszerű tápanyagellátás- hozam és minőség összefüggései a rostkender (*Cannabis sativa* L.) termesztésében. Növénytermesztési Tudományos Nap. Növénytermesztés-Környezetvédelem. Magyar Tudományos Akadémia, Budapest. Relationship between nutrient supply- yield and quality of fibre hemp (*Cannabis sativa* L.) Crop production. Environment protection. Hungarian Scientific Academy, Budapest.
- Iványi, I.-Izsáki, Z.: 2000. Influence of nitrogen supply and P and K levels of the soil on dry matter accumulation-, macro-, medium- and micro nutrient uptake and quantity and quality of biomass yield of industrial hemp (*Cannabis sativa* L.) 12th International Symposium of the International Scientific Centre of Fertilizers (CIEC) 21-22 August 2000. Suceava-ROMANIA Proceeding 85-99.
- Iványi, I. –Izsáki, Z.: 1998. Some Agronomy Issues of Fibre Hemp. 2nd Balkan Symposium on Field Crops. Novi Sad, Yugoslavia. 429-432.
- Iványi, I. – Izsáki, Z.: 2001. Field Research in Hungary to Determine the Nutrient Requirements of Fibre Hemp. 12th International World Fertilizer Congress. August 3-9, 2001. Beijing, China Fertilization in the Third Millenium – Fertilizer, Food Security and Environmental Protection. Proceedings Vol. III: 1660-1668.
- Iványi, I. – Izsáki, Z. – Bócsa: 2001a. Results of agrotechnical research with dioecious and monoecious hemp varieties in Hungary. International Conference for Bast Fibrous Plants on the Turn of Second and Third Millennium. 18-22 September, 2001. Shenyang, China. Proceedings of the International Conference II/8.
- Iványi, I. – Izsáki, Z. – Bócsa, I.: 2001b. A ápanyagellátás és a tőszáma kapcsolata a Kompolti és a Kínai egylaki kenderfajták termésére. MTA II. Növénytermesztési Tudományos Nap. 2001. Budapest, november 26. Proceedings, 68-74.
- Izsaki, Z.: 1988. Összefüggés a cukorrépa tápláltsági állapota a termés mennyisége és minősége között növényanalízis alapján. Kandidátusi értekezés. Szarvas. 1-174. (Relationship between nutrient supply and yield quantity and quality of sugarbeet). Thesis of PhD.
- Kádár, I.: 1980. A növényanalízis alkalmazása az agrokémiail szaktanácsadásban és kutatásban. Agrokémia és Talajtan. 29. 323-344. (Utilisation of plant analysis in agrochemical advisori and research).
- Kádár, I. et al.: 1981. Diagnózis és Szaktanácsadás Egységes Rendszere (DRIS): új értékelési lehetőség a növénytermesztésben. Agrokémia és Talajtan. 30. 465-486. (The DRIS: new assesment possibly in crop production)
- Kádár, I.: 1987. A növénymintavétel alapelvei és technikája. Növénytermelés. 36. 395-404. (Methods and thecnich of plant sampling)
- Moller-Nielsen, J.-Friss-Nielsen, B: 1976. Evaluation and controll of the nutritional status of cereals. I. dry matter weight level. II. Pore-effect of a nutrient. III. Metods of diagnosis and yield prognosis. Plant and Soil, The Hague. 45. 317-337, 339-350, 647-658.
- Sumner, M.E.: 1997. Use of the DRIS system in foliar diagnosis of crops at high yield levels. Commun. Soil Sci. Plant anal. 8. 251-268.

THE IMPACT OF DURABLE FERTILISING ON THE SOIL CHARACTERISTICS DETERMINING THE SOIL FERTILITY AND YIELD

B. Kadlicskó, S. Holló, L. Szabó and L. Fodor

SZIE College Faculty of Economics and Agriculture, Gyöngyös, Hungary
„Fleischmann Rudolf” Research Institute, Kompolt, Hungary

The database of our experimentation is constituted from the yield analyse results of the long-term trials installed in Kompolt and Putnok in 1967 as part of the National Long-term Trials of Fertilising.

Introduction

The realisation of the plans and installation of the national standard long-term trials for fertilisation was made upon the disposition of the Ministry of Agriculture in 1965. The main aim of the planning was the realisation of an standard network of experiments in the different regions of the country on the main types of soil which – representing the micro- and macro-ecological characteristics – may constitute a base for the evaluation of the efficiency of the fertilisers introduced into the soil on one side and give informative data for the national planning of use of fertilisers on the other side.

The research within this program has been started in 1966 and 1967 on 26 trial fields. In our days this research is continued on only 9 places, two of them belonging to the Fleischmann Rudolf Research Institute of the College Faculty of Economics and Agriculture of the Szent István University.

Material and Method

Our trial fields represent the most frequent soils of the region, the main types of brown forest soils of Central and South - Eastern Europe. In long-term trials of 34 years we observe the fertilising reactions on two types belonging to the main type: on brown soils with clay alluviation in Putnok and the chernozem brown soils in Kompolt. In the region of the Northern Mountains the first represent about 346,6 thousand ha and the second with a little better quality about 219.7 thousand ha. The two types of soil represent together about 42,7 % of the whole area. Our observations consider a real base for fertilisation consulting of the farmers of the northern region.

From the results of winter wheat and maize yields of the years just following the soil analyses and taken of samples in 1999 (2000. 2001.) we analysed the followings:

- The correlation of humus, the $\text{pH}_{(\text{KCl})}$, P_2O_5 and K_2O content and cations. Determination of the existence and intensity of the relationship with the following factors:
 - o The volume of the nitrogen doses used in the trials
 - o The volume of the phosphorus doses used in the trials
 - o The volume of the potassium doses used in the trials and
 - o The system of mutual relations between the values of soil analyses (cations)
- The regression relation between the mentioned values and yield mass of winter wheat
- The regression relation between the mentioned values and the yield mass of maize
- The relation of the winter wheat and maize yield and the level of nitrogen and potassium fertilisation and soil amelioration on brown forest soil with clay alluviation and chernozem brown soils.

For analysing the relations we have used the results of the soil samples taken in 1999 from the upper soil (0-20 cm). By using correlation analyse for examining the variation of data sets by the application of long-term fertilisation. The results of the couples of sets are represented in the matrix of correlation. One half of the table is empty because the correlation of two analysed sets doesn't depend on the order of computation. The values on the diagonal are 1 because of the perfect correlation of the elements of a set with themselves.

Presentation of the results

The results of the data analyses - on the ameliorated parts of the trial fields - are presented in the Tables 1 and 2. For a better view of the table the strong relationship is presented with a grey background and the weak but appreciable relationship in bold letters. We accepted 0,2 as minimum value of the correlation for the still considerable relationship. Computed from the values of repetitions this represents a weak but still appreciable relationship.

On chernozem brown forest soil the increase of the nitrogen dose presents strong negative relationship with the $\text{pH}_{(\text{KCl})}$ values and the pH diminishing impact of the phosphorus is also appreciable. In the 33rd year of the trials the trend is further diminution. The fertilising treatments of the very acidified brown forest soils with clay alluviation didn't have influence on the values of pH. The acidification became very grave even in the case of the application of the minimum dose of nitrogen (100 kg/ha) and didn't change by using a higher level of nitrogen and phosphorus.

On both types of soil the applied dose of potassium and phosphorus presented strong correlation with the AL-soluble P_2O_5 and K_2O . The simultaneous effect of the two fertilisers is also to observe (phosphorus gives positive correlation with the AL-soluble K_2O content of the soil and reciprocally the relationship is also positive). The registered effect cannot be separated from the systematic impact of the treatment – thus the application of a greater dose of phosphorus needs mostly the application of an increased dose of potassium. These considerations are to be taken into account by the relationship between nitrogen fertilising and the AL-soluble P_2O_5 and K_2O content of the soil which have presented a weak relationship on both types of soil.

The measured microelement content of the upper soil presents a complicated system of relations. The values depend on the type of soil and the actual values are influenced by the cumulated impact of the long-term trial treatments.

The soluble aluminium increased by the fertilisation of both types of in positive relationship. The Fe content presents positive correlation with the phosphorus and potassium fertilisation only on brown soils with clay alluviation.

The negative correlation of the fertilising and the $pH_{(KCl)}$ values was stronger by re-acidification on ameliorated soils. This relationship is accentuated on the soils with clay alluviation.

The increase of the AL-soluble phosphorus and potassium quantity indicating the soil saturation with nutrients is of an even strong tendency like on the not-ameliorated control soils.

On chernozem brown forest soils decreased the Cu and Mn content by fertilisation with greater phosphorus and nitrogen doses. All the three fertilisers give positive correlation with the soluble Al, less with Fe. A likely tendency but weaker is to observe by the clay alluviated brown forest soils.

On the brown forest soils with clay alluviation in Putnok the yields of both indicator plants are in positive correlation with the applied quantity of fertilisers. This correlation in Kompolt is to be seen only by winter wheat. Maize has given nearly maximum of yield by a low level of fertilising still in unfavourable years.

The Figures 1 and 2 presents the impact surfaces on Putnok in crop rotation and by 36 years monoculture.

.

Table 1																		
x of correlation presenting the applied fertilising treatments, the measured values of the upper soil* and the yield**																		
OMTK Kompolt A-B 1733-34 trials on the ameliorated soils by liming																		
* = samples taken from the upper soil in 1999 (0-20cm) ** = maize grain yield in 2001 (shelled in mai)																		
computed from repetitions, without control winter wheat grain yield of 2000																		
Fertiliser treatments				VALUES OF THE ANALYSED SOIL PARAMETERS														Yield
	N	P ₂ O ₅	K ₂ O	pH	Humus	P ₂ O ₅	K ₂ O	Na	Mg	Cu	Zn	Mn	Al	Fe	B	Co	Pb	mass
Applied substances				(KCl)	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	
N	1																	
P ₂ O ₅		1																
K ₂ O			1															
pH _{KCl}	-0,377	-0,290	-0,089	1														
Humusz %	0,096	0,061	0,104	-0,090	1													
P ₂ O ₅ mg/kg	0,316	0,836	0,429	-0,316	0,211	1												
K ₂ O mg/kg	0,289	0,463	0,879	-0,140	0,161	0,321	1											
Na mg/kg	0,182	0,330	0,077	-0,181	0,062	0,218	-0,070	1										
Mg mg/kg	0,023	-0,081	-0,245	0,391	0,216	0,002	-0,295	0,045	1									
Cu mg/kg	-0,248	-0,207	-0,081	0,274	-0,180	-0,403	-0,214	-0,048	-0,055	1								
Zn mg/kg	-0,374	-0,204	-0,003	0,313	-0,055	-0,281	-0,129	-0,181	-0,139	0,776	1							
Mn mg/kg	-0,393	-0,466	-0,203	0,337	-0,055	-0,557	-0,260	-0,167	0,198	0,425	0,456	1						
Al mg/kg	0,380	0,537	0,384	-0,461	-0,096	0,340	0,150	0,607	-0,166	-0,087	-0,091	-0,140	1					
Fe mg/kg	0,123	0,232	0,202	0,011	-0,334	-0,016	-0,020	0,457	-0,067	0,146	0,095	-0,024	0,722	1				
B mg/kg	-0,043	-0,039	-0,084	0,111	0,383	0,202	0,124	-0,470	0,241	-0,230	-0,139	-0,135	-0,713	-0,872	1			
Co mg/kg	-0,142	-0,229	-0,109	0,167	0,375	-0,050	0,052	-0,476	0,333	-0,167	-0,040	0,236	-0,598	-0,679	0,726	1		
Pb mg/kg	-0,034	-0,011	-0,057	0,034	0,321	0,035	0,005	-0,260	0,201	0,351	0,267	0,192	-0,441	-0,649	0,622	0,459	1	
Maize yield	-0,300	0,081	-0,091	0,174	0,104	0,177	-0,054	0,109	-0,095	-0,061	0,080	-0,308	-0,246	-0,186	0,187	0,121	0,042	1
Winter wheat yield	0,700	0,778	0,531	-0,292	0,002	0,575	0,445	0,273	-0,145	-0,086	-0,163	-0,366	0,431	0,142	-0,028	-0,292	0,034	1

Table 2

The matrix of correlation of the applied fertilising treatments, the measured values in the upper soil* and yield **

OMTK Putnok A-B 1733-34 trials on ameliorated soils by liming

* = samples taken from the upper soil (0-20 cm)
computed from repetitions without control

** = maize grain yield (shelled in mai)2001
winter wheat grain yield in 2000

Fertilising treatments				VALUES OF THE ANALYSED SOIL PARAMETERS														Yield mass
N P ₂ O ₅ K ₂ O				pH	Humus	P2O5	K2O	Na	Mg	Cu	Zn	Mn	Al	Fe	B	Co	Pb	
Applied substances				(KCl)	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	
N	1																	
P ₂ O ₅		1																
K ₂ O			1															
pH _{KCl}	-0,433	-0,244	-0,397	1														
Humusz %	-0,102	-0,154	-0,036	0,171	1													
P ₂ O ₅ mg/kg	0,432	0,850	0,577	-0,226	-0,031	1												
K ₂ O mg/kg	0,178	0,513	0,867	-0,314	0,083	0,554	1											
Na mg/kg	0,120	0,102	-0,086	-0,134	-0,010	-0,005	-0,017	1										
Mg mg/kg	-0,077	-0,019	-0,030	0,207	-0,133	-0,064	-0,137	-0,289	1									
Cu mg/kg	-0,088	-0,167	0,033	-0,025	0,378	-0,111	0,212	0,210	-0,542	1								
Zn mg/kg	-0,153	-0,096	-0,089	-0,003	0,277	-0,022	0,080	0,076	-0,420	0,720	1							
Mn mg/kg	-0,196	-0,018	0,123	0,231	0,432	0,188	0,403	-0,025	0,003	0,447	0,433	1						
Al mg/kg	0,240	0,267	0,277	-0,035	0,514	0,266	0,414	0,139	-0,397	0,503	0,360	0,399	1					
Fe mg/kg	0,188	0,222	0,176	-0,118	-0,240	0,175	0,129	-0,010	-0,174	0,005	0,135	-0,054	0,060	1				
B mg/kg	0,100	0,126	0,137	0,133	-0,042	0,069	0,207	-0,196	-0,083	-0,058	-0,349	0,089	0,131	-0,051	1			
Co mg/kg	-0,193	-0,171	-0,343	0,299	0,220	-0,165	-0,273	0,049	0,153	0,090	0,196	0,219	0,207	0,053	-0,206	1		
Pb mg/kg	0,013	0,006	0,126	-0,124	-0,672	-0,016	-0,004	-0,091	0,464	-0,442	-0,443	-0,334	-0,669	-0,073	-0,082	-0,411	1	
Maize yield	0,220	0,251	0,250	-0,274	-0,160	0,249	0,278	0,286	-0,331	-0,037	-0,124	-0,101	0,191	0,247	0,078	-0,197	0,007	1
Winter wheat yield	0,392	0,755	0,680	-0,172	-0,046	0,749	0,525	-0,246	0,298	-0,301	-0,254	0,060	0,038	0,015	0,176	-0,131	0,121	1

Summary

We have analysed the impacts of the long-term fertilising and liming on the soil characteristics and the winter wheat and maize yields using the data of the database constituted from the long-term trials of fertilising of chernozem brown forest soils and brown forest soils with clay alluviation of the National Network of Long-term trials since 1968.

For examining the relations we used the results of soil analyses taken in 1999 from the upper soil (0-20 cm). Using correlation analyse we examined the changes of the data sets by fertilisation. The data of the set couples are presented in the matrix of correlation.

On both types of soil are the applied quantities of potassium and phosphorus in strong correlation with the measurable AL soluble P_2O_5 and K_2O . The positive impact of the two fertilisers is also to observe. The measured levels of microelements in the upper soil present a complicated relationship. The values depend on the types of soils and the actual values are influenced by the cumulated effect of the long-term fertilisation.

The soluble aluminium content increased on both types of soil in positive relation. The Fe content presents positive correlation with the phosphorus and potassium fertilisation only on brown forest soils with clay alluviation.

The relations of yield and fertilisation are presented on the impact surfaces.

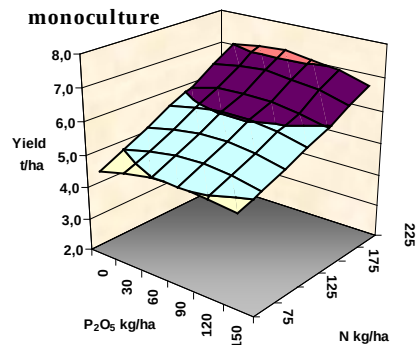
References

- Cruse R. M.-Szabó L.-Fodor L.** (2001): Sustainable nitrogen fertilisation in the crop production. In. Economic and Manageal Aspects of Sustainable Development of Agriculture. Conference Papers, I. Sec. (ed.: Gozora V.) Slovak Agr. Univ., Nitra. 1122-1128.p.
- Debreczeni B.- Debreczeni Bélánné** (1994): Reasearch of fertilising 1960-1990. Academic Editions. Budapest. 1994. 410 p.
- Fodor L.-Cruse, R. M.-Szabó L.** (2001): Energy balance of nitrogen fertilisation in sustainable corn production. Congress Guide and Abstracts, 12th World Fertiliser Congress Beijing. 244.p.
- Hangyel L.-Kadlicskó B.**(2000): Analyse of the necessity of sustainable liming and impact of systematic liming on brown forest soils. XIV. National Conference for Environment Protection. Siófok, 2000 09. 19-21. Conference publication.197-206 p.
- Holló S. – Lukendics Gy.** (1998): Possibilities of rational use of fertiliser in the winter wheat production. Practicai Agroforum, IX. évf. 13. sz. 30-36. p.
- Holló S.** (1998): Relationship between fertilising and liming on chernozem brown forest soils (Kompolt) In.: Relations of fertilising, soil acidification and liming on the soils of the National Network. Kompolt - Karcag Commission of the Network OMTK. Commission of soil acidity. 181-216. p.
- Holló S. – Kádár I.** (1998): Impact of fertilising and liming on soil fertility (Kompolt, chernozem brown forest soil) In.: Relations of fertilising, soil acidification and liming on the soils of the National Network. Kompolt - Karcag Commission of the Network OMTK talajain.. 217-224. p.
- Kadlicskó, B - Hangyel, L.**(1999): Impacts and long-term effects of liming on the very acidified soils. XIII. National Conference and Exhibition for Environmental Protection. Publication 119-117 p.

- Kadlicskó B. – Hangyel L.**(2000): Impact of acidification respectively of liming on soil characteristics and on the results of plant production by haplic alisol soils. CERECO 2000. The 3rd International Conference on Carpathian Euroregion Ecology. Miskolc, 2000. 05. 21-24. Konferencia kiadvány.
- B. Kadlicskó - G. Fülek**y(1997): Protection of the soils against acid impact in the microregions of northern Hungary. CERECO-97 The Second International Conference on Carpathian Euroregion Ecology. June, 1-4, 1997. Miskolc.
- Kadlicskó B. – Krisztián J.**(1998): A meszezéses talajjavítás eredménye és tartamhatásának értékelése agyagbemosódásos barna erdőtalajon. IV. Nemzetközi Agrárökonómiai Tudományos Napok., Gyöngyös 1998. Volume 2. 151-157.p.
- Kadlicskó B. – Hangyel L.**(2000): Impact of acidification respectively of liming on soil characteristics and on the results of plant production by haplic alisol soils. CERECO 2000. The 3rd International Conference on Carpathian Euroregion Ecology. Miskolc, 2000. 05. 21-24. Konferencia kiadvány.
- Szabó L.** (1997): Sustainable agricultural development – sustainable agricultural production. Alternative methods of management (Biotermesztés) II., Sillabus, Phare, GATE College Faculty of Agriculture, Gyöngyös, 1-70. p.
- Szabó L.** (1999): Estimation the erosion of micro-element contaminating agents in different soil types. 10th International Soil Conservation Organization Conference May 23-27. 1999, West Lafayette, Indiana USA, 77-82. p.
- Szabó L.** (1999): Environmental aspects of nutrient supply. In.: Fülek Gy.: Tápanyaggazdálkodás, mezőgazdasági kiadó, Budapest, 675-695. p.

Figure 1: Results of maize experiment - monoculture in Putnok in 2000

**Putnok, C-1733 maize trial
monoculture**



Results of the computing of the second degree impact surface

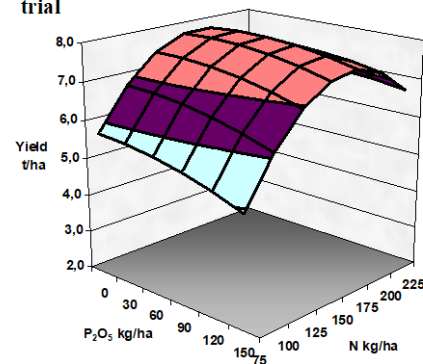
Parameter Coefficients		Statistics of regression	
b ₀	0,385	value of r	0,659
b ₁	93,509	square of r	0,434
b ₂	-3,674	Corrected r ²	0,340
b ₁₁	-291,621	Standard error	0,622
b ₂₂	-31,183	Observations	36,000
b ₁₂	36,263		

Analyse of variancy

	<i>fg</i>	<i>SQ</i>	<i>MQ</i>	<i>F</i>
Regression	5	8,9128	1,7826	4,6028
Difference	3	11,6183	0,3873	
Total	8	20,5311		

Figure 2: Impact surfaces of maize yield in crop rotation on brown forest soil

**Putnok, A-1734 maize
trial**



Results of the computing of the second degree impact surface

Parameter Coefficients		Statistics of regression	
b ₀	3,545	value of r	0,787
b ₁	13,826	square of	0,619
b ₂	10,865	Corrected r ²	0,555
b ₁₁	7,041	Standard error	0,519
b ₂₂	-51,897	Observations	36,000
b ₁₂	-23,615		

Analyse of variance

	<i>fg</i>	<i>SQ</i>	<i>MQ</i>	<i>F</i>
Regression	5	13,1174	2,6235	9,7446
Difference	30	8,0767	0,2692	
Total	35	21,1941		

ROLE OF FERTILIZATION AND HYBRIDS FOR IMPROVEMENT OF MAIZE GROWING ON K-DEFICIENT SOIL

V. Kovacevic, D. Banaj, M. Antunovic and G. Bukvic

Faculty of Agriculture, University J. J. Strossmayer in Osijek, Croatia

Introduction

Potassium (K) is an essential element for plants. Low K supplies have been found in some hydromorphic soils of the Eastern Croatia. Based on our earlier investigations, by adequate K fertilization and by choice of resistant maize hybrids is possible to overcome this problem (Bertic et al., 1989; Katusic, 1992; Kovacevic, 1994; Kovacevic and Vukadinovic, 1992; Kovacevic et al. 1997, 2000). In this study was tested response of maize to fertilization with muraite of potassium (KCl) on two hydromorphic soils characterizing moderate K supplies. Growth retardation and inclination maize to stalk lodging (SL) at maturity stage were the main reasons for conduction of these trials.

Materials and Methods

The field trials

Five maize (*Zea mays* L.) hybrids (OsSK444, OsSK458, OsSK552, Bc5982 and Florencia) were grown on Gundinci soil during two growing seasons (2001 and 2002). Two ameliorative rates of K (KCl form) were applied (500 and 1250 kg K₂O/ha) on ordinary fertilization at beginning of April 2001. Experimental plots measured 165 m² and 28 m², for fertilization and hybrid, respectively (the experiment A).

Two maize hybrids (OsSK444 and OsSK552) were grown on three levels of fertilization (control, 1500 and 3000 kg K₂O ha⁻¹, respectively) on Bebrina soil. Ameliorative fertilization was made at end of April 2002. Experimental plots measured 76 and 36 m², for fertilization and hybrid, respectively (the experiment B).

For both trials, maize was sown at end of April/beginning May on planned plant density 58310/ha (distance of plants in row = 24.5 cm; interrow spacing 70 cm). Maize was harvested manually at beginning October. In the second year of the experiment A, residual effects of ameliorative fertilization were tested and experimental plots fertilized uniformly in level of ordinary fertilization.

Grain yields were calculated on 90% realization of planned plant density and 14% grain moisture basis.

Share of SL at maturity stage was determined on level fertilization and hybrid only by addition of plants number from four replicates.

Soil characteristics

Moderate supplies of plant available K are characteristics of both experimental soils. Very high level of plant available P were found in the surface layer of the soil B (Table 1).

Table 1: Chemical properties of the experimental soils

	pH		Humus (%)	mg 100 g ⁻¹ (AL-method)	
	H ₂ O	KCl		P ₂ O ₅	K ₂ O
The Gundinci soil (the exp. A)	7.95	7.18	2.63	22.2	14.2
The Bebrina soil (the exp. B)	7.71	6.78	3.77	78.7	12.6

Weather conditions

In general, under our environmental conditions, low yields of maize are in connection with shortage of rainfall and higher air-temperatures during July and August (Kovacevic and Josipovic, 1998). Data of Weather Bureau Osijek were used for weather characteristics of the individual growing season. Excess of rainfall in June (239 mm) and September (195 mm), their shortage in July and August (total 84 mm), as well high air-temperatures in August (22.7°C), are main characteristics of weather during growing seasons of maize in 2001. Rainfall quantities (164 mm in July and August) and temperature regimes during the growing season 2002 were favourable for maize growing. However, in both tested growing seasons, rainfall quantities in Osijek were higher in comparison with 30-year mean (May-September: 478, 473 and 320 mm, for 2001, 2002, and 1971-1990, respectively).

Results and Discussion

In the first year of testing grain yields of maize increased for 9% and 14% as affected by application 500 and 1250 kg K₂O/ha, respectively (the experiment A). Differences of yields among the hybrids were from 10.55 to 11.34 t/ha (Table 2). Yields of two hybrids (OsSK444 and OsSK458) were higher (average 11.18 t/ha) in comparison with remaining three tested hybrids (average 10.70 t/ha). Yield increases of individual maize hybrids under influences of applied fertilization were in range from 5.4% (Florenca) to 28.3% (OsSK458). These results were in detail shown in the previous study (Kovacevic et al. 2002). In the second year of testing

was found considerable residual influences of KCl fertilization on maize yields. For example, average yield increases were 16% and 24% by application 500 and 1250 kg K₂O/ha, respectively. Also, considerable differences of yields were found among the hybrids in range from 9.74 to 10.84 t/ha. The hybrids OsSK552, Bc5982 and Florencia yielded higher (average 9.96 t/ha) in comparison with OsSK444 and OsSK458 (average 9.96 t/ha). Also, response to KCl fertilization was specific for tested hybrids. For example, similar yields were found for the Florencia, and significant yield increases for 16.7% (OsSK552), 30.1% (Bc5982), 35.7% (OsSK444) and 37.8% (OsSK458), respectively.

Table 2: Yields of maize as affected by KCl fertilization (the experiment A)

Fertilization (A) in spring 2001 (kg K ₂ O/ha)	Grain yield of maize hybrids (t/ha)					
	OsSK 444	OsSK 458	OsSK 552	Bc 5982	Pioneer Florencia	Mean (A)
	The growing season 2001					
Control	10.39	9.66	9.44	10.13	10.81	10.09
500	10.97	11.97	11.13	10.71	10.44	11.04
1250	11.70	12.39	11.07	11.13	11.39	11.54
Mean (B)	11.02	11.34	10.55	10.66	10.88	10.89
LSD 5%	A: 0.84		B: 0.47		AB: 1.15	
LSD 1%	1.27		0.62		1.67	
	The growing season 2002 (ordinary fertilization only)					
Control	8.34	8.66	9.63	8.79	10.21	9.13
500	9.56	9.96	11.65	11.09	10.88	10.63
1250	11.32	11.93	11.24	11.44	10.48	11.28
Mean (B)	9.74	10.18	10.84	10.44	10.52	
LSD 5%	A: 0.45		B: 0.69		AB: 1.18	
LSD 1%	0.69		0.91		1.61	

Adequate K nutrition is important factor of maize resistance to diseases, including diseases promoting SL at maturity stage. Frequency of SL in the first year of testing was 42% on the control treatment and 18% under conditions of 1250 kg K₂O/ha application, while depending on the hybrid, these differences were from 7 to 41%. Two corn hybrids could be designated as resistant (OsSK444 and Florencia: mean 10% SL), while remaining three hybrids are susceptible (OsSK552, OsSK458 and Bc5982: mean 38%). Under environmental conditions of the second year of testing SL incidences were lower, means 2% and 12%, for the control and ameliorative KCl fertilization, respectively (Table 3).

Table 3: Stalk lodging (SL) at maturity stage (the experiment A)

Fertilization	Stalk lodging at maturity stage (%)					
in spring 2001 (kg K ₂ O/ha)	OsSK 444	OsSK 458	OsSK 552	Bc 5982	Pioneer Florenia	Mean
The growing season 2001						
Control	6.8	67.0	78.7	40.2	18.4	42.2
500	9.9	26.1	21.0	30.6	8.8	19.3
1250	4.7	24.1	23.1	28.4	9.6	18.0
Mean	7.1	39.1	40.9	33.1	12.3	
The growing season 2002 (ordinary fertilization only)						
Control	2.2	21.3	19.0	12.2	3.3	11.6
500	1.4	13.2	14.4	8.1	1.9	7.8
1250	0.3	3.8	3.9	2.5	1.3	2.4
Mean	1.3	12.8	12.4	7.6	2.2	

As affected by application KCl, maize yields were increased for 26% (1500 kg K₂O ha⁻¹) and 42% (3000 kg K₂O ha⁻¹) in comparison with the control (the experiment B), while between two tested hybrids yield differences were non-significant. Also, share of SL was depended on the hybrid and fertilization (Table 4).

Table 4: Influence of KCl fertilization and genotype on maize yield and stalk lodging (SL) at maturity stage (the experiment B) - the growing season 2002

Fertilization	Grain yield (t ha ⁻¹) of maize			Stalk lodging at maturity stage (%)		
(factor A)	Maize hybrid (B)		Mean (A)	Maize hybrid		Mean
kg K ₂ O ha ⁻¹	OsSK444	OsSK552		OsSK444	OsSK552	
Control	6.41	7.24	6.83	13.5	31.7	22.6
1500	8.74	8.49	8.62	0	0	0
3000	9.68	9.72	9.70	0	0	0
Mean (B)	8.28	8.48		4.5	10.6	
LSD 5%	A: 0.45	B: n.s.	AB:			
LSD 1%	0.69		n.s.			

By our earlier studies were also found considerable influences of ameliorative KCl fertilization on maize yields because they increased for 52% (Bertic et al. 1989), threefold (Kovacevic et al. 1990), 120% (Katusic 1992) and fourfold (Kovacevic and Vukadinovic, 1992) in comparison with the control. Similar problems of K nutrition were found on chernozem loamy calcareous soils in Hungary (Kadar, 1992; Kadar et al. 1991).

Conclusions

Ameliorative fertilization by KCl considerably influenced on maize yields on two hydromorphic soils caharcterizing moderate supplies of plant available K. Differences of yields

among maize hybrids were found in both year of testing but they were also under environmental influences because the last ranged OsSK552 hybrid in the first year of testing was the first ranged hybrid in the next year. However, concerning response of individual hybrids to KCl fertilization, results are similar in both years of testing as follows: response Florencia was the lowest, while OsSK458 responded by the highest yield increase. In the second experiment, both tested hybrids (OsSK444 and OsSK552) had similar yields.

References

- Bertic, B., Vukadinovic, and Kovacevic V. (1989): Excess of magnesium uptake in maize plants as promoting factor of potassium deficiency. *Magnesium-Bulletin* 11 (1): 25-27.
- Kadar I. (1992): A novenytaplalas alapelvei es modszerai (Principles and methods in plant nutrition). Magyar Tudomanyos Akademia, Talajtani es Agrokemiai Kutato Intezete, Budapest.
- Kadar I., Csatho P. and J. Sarkadi J.(1991): Potassium fertilization in Hungary: Response of maize and other crops. *Acta Agronomica Hungarica* 40:295-317.
- Katusic V. (1992): Gnojdba kalijem na hipogleju naglasene fiksacije kalija (Potassium fertilization on K-fixing hypoglay). Master thesis. Univerza v Ljubljani, Biotehniska fakulteta, Agronomija.
- Kovacevic V. (1994): Excess of Mg as a factor of K deficiency in maize (*Zea mays* L.) plants. In: *Magnesium 1993*. John Libbey and Company Ltd. London.p. 89-97.
- Kovacevic V., Antunovic M. and Zdunic Z. (2002): Role of potassium fertilization and inheritance for resistance of corn to stalk lodging. In: 13th International Symposium of the CIEC (International Scientific Centre of Fertilizers, June 10-13, 2002; Gaziosmanpasa University Tokat, Turkey (in press).
- Kovacevic V., and Josipovic M. (1998): Weather and soil limitations for corn growing in the Eastern Croatia. M. Fifth Congress of ESA (European Society for Agronomy), 28 June - 2 July, 1998, Nitra, The Slovak Republic. Short Communications, Volume II. P.157-158.
- Kovacevic V., Kadar I., and Brkic I. (2000): Response of corn to potassium deficiency. In: *Plant Nutrition for the next millenium - nutrients, yield, quality and teh environment* (Abstract of Xth International Colloquium forthe Optimization of Plant Nutrition, April 8-13, 2000; Cairo, Egypt. p.205-206.
- Kovacevic V., Katusic V. and Vukadinovic V. (1990): Nutritional stress of maize (*Zea mays* L.) growing on a gleysol of east Croatia. In: *Plant nutrition, physiology and applications*. Kluwer Academic Publishers, Dordrecht, Netherlands. p.607-610.
- Kovacevic V. and Vukadinovic V. (1992): The potassium requirements of maize and soyabean on a high K-fixing soil. *South African Journal of Plant and Soil* 9:10-13.
- Kovacevic V., V. Vukadinovic, and B. Bertic. (1997): Response of maize to soil stress and fertilization on strong K-fixing soil. In Ando T., Fujita K., Mae T., Matsumoto H., Mori S. and Sekiya J.(ed) *Developments in Plant and Soil Sciences, Vol. 78: Plant Nutrition for Sustainable Food Production and Environment*. Kluwer Acad. Publ., Printed in Japan. p. 315-316.

IMPORTANCE OF 0,01 M CACL₂ SOLUBLE ORGANIC NITROGEN IN THE CHARACTERISATION OF N-SUPPLY IN THE TREATMENTS OF WESTSIK'S CROP ROTATION EXPERIMENT

J. Lazányi, J. Loch and P. T. Nagy

University of Debrecen, Centre of Agricultural Sciences, Hungary

Typically, most N in soils occurs in organic form. The amount of organic-N in soils is influenced by climate and topography. It is also influenced by vegetation. In Hungary, equivalent soils developed under prairie had twice the organic-N of soils developed under forest. The amount of N is also influenced by the particle size (more accumulating in fine-grained material) and the amount of mineral nutrients (especially phosphorus) in the soil. Agricultural practices have reduced the N content in the plow layer from their estimated virgin condition.

Soluble organic matter (SOM) in the soil plays an important role in the chemistry of carbon, nitrogen, and phosphorus. Present state of knowledge on the formation and fate of soluble organic matter and its response to organic matter mineralisation in changing environmental condition is still fragmented and often inconsistent despite the intensive research. Its effects on soil productivity and yield is still very uncertain and requires further research, as most of the information available today is the result of studies on forest ecosystems. The aim of this paper is to present data on soluble organic nitrogen (SON) from the soil of Westsik crop rotation experiment.

Introduction

Mineralisation of organic matter is an important nitrogen pool in sandy soil where reserves of mineral nitrogen are low. Sandy soils are generally well drained and crops do not profit much from mineral nitrogen reserves, as nitrate leaching is high and NH₄⁺ binding capacity is low. Németh et al. (1988) have shown that organic nitrogen fraction extracted by EUF is a reliable indication of mineralisation during the growing season. According to Tipping (1998) SOM exists as a part of soil organic matter and controlled by carbon inputs from plant, manure and from microbiological biomass. It is also generally accepted that the process is dominated by soil biota and involves physical and chemical alteration of organism matter during decomposition. Both biotic and abiotic controls are involved in the formation of soluble organic nitrogen.

Controls of SOM have been studied in many laboratory experiments, but very few have focused on the dynamics of SOM under field conditions. Even less information is available on SOM

dynamics in soils and ecosystems. It is also not clear whether SOM originates primarily from recent organic matter or from relatively stable humus in the lower part of cultivated soil profile. Zsolnay 1996 suggested that humified organic matter is the major source of SOM. Qualls and Haines 1991 measured high levels of SOM in the soil samples collected just after the litter fall and found higher variation in fluxes of SOM in the upper part of soil.

The rhizosphere and soil microbial biomass are also considered as potentially important source of SOM as high microbial activity can result from the input of readily available organic material. Williams and Edwards (1993) have shown that microbial metabolites constitute a significant proportion of SOM and the carbohydrate fraction of SOM is chemically different from that of plant residues. Corrie et al. (1992) suggested that litter production and humus content presumably increase SOM concentration and fluxes. Although the period of maximum litter fall and SOM leaching do not generally coincide, it is probable that SOM dynamics in soil are related to the amount of recent litter and organic matter in the soil. Recent findings emphasise the turnover of organic carbon (SOC), organic nitrogen SON and phosphorus SOP in soil as major pathways of element recycling. Mengel et al. (1999) reported 35-45 kg/ha 0,01 M CaCl_2 extractable soil organic matter. Recent studies have showed that soluble organic nitrogen varied seasonally between 8-20 kg/ha in coarse sand and 15-30 kg/ha in sandy loam. Minimum value was measured in winter the maximum value in summer.

Under continuous arable cropping, Murphy et al. 2000 measured 7-18 kg/ha SON after 8 years of grass lay in the 0-25 cm soil layer, which accounted for 33-60 % of the total soluble nitrogen. Even higher SON was measured by Appel and Mengel 1990 in a soil profile of 0-90 cm after ploughing up grassland long-term experiment. Appel and Mengel 1992 found correlation between SON and N mineralisation and suggested that SON extracted by 0,01 M CaCl_2 solution is a reliable indicator of organic nitrogen available for mineralisation and plant uptake. Groot and Houba 1986 found a significant correlation between organic nitrogen and microbial biomass in the soil, where mineralisation and microbial immobilisation of N is related to temperature and nutrient amendment. Detailed information was reported on the analysis of 0,01 M CaCl_2 soluble organic nitrogen by Lazány, Loch, Jászberényi (2002 a,b), while this paper presents data on a three year study of treatments of Westsik's crop rotation experiment.

Material and Methods

The crop rotation experiment was established in 1929 to study the effects of different organic matter amendments. The experiment, consisting of 15 treatments, makes it possible to study

sustainability of agricultural production under different applications of green, straw and farmyard manure treatments, to study the ecological impact as well as economical aspects of different production methods. One of the main practical objects of the Westsik's crop rotation experiment was to measure the long-term effects of different organic manure and inorganic fertilisers on rye and potato production. One part of the treatments covers the control treatments where fallow or organic manure was applied without fertilisers. The second group shows the effects of different straw manure treatments. The third group is used to study forage production and farmyard manure treatments. One group is used to compare the different utilisation of lupin main crop and a further one is to study the method of production and application of lupin green manure as second crop.

Soil samples were collected in the vegetation period of potato just before flowering. Samples were taken with soil auger from the depths of 0-20, 20-40, 40-60 cm and 6 elementary samples were united as a representative sample. No elemental samples were collected from the 1 m of the stripe between the parcels. Soil samples were collected from 9 different places in a treatment 20 m to study within plot variation. Before grinding, soil samples were cleaned from plant remains and other possible dirt, and were stored in paper bags in dry place until the examination.

Results and Discussion

Organic matter is vital to sustainable use of soil and the effective utilisation of crop residues and manures are central to organic farming. It helps to maintain soil structure and water-holding capacity. It has central role in soil fauna and nutrient cycling. Currently, advice on nitrogen use in Hungary employs an index system based on soil parameters and crop management. The objective of the current study is to evaluate relevant soil management data, and measurements of 0.01 M CaCl_2 soluble organic nitrogen in the root profile, for prediction of long-term effects of organic matter treatments and fertilizers. The data used in the study were derived from the years 2000-2002.

Table 1: 0.01 M CaCl₂ soluble organic nitrogen in the soil of Westsik’s crop rotation experiment (mg/kg)

Depth 0-20					20-40				40-60			
FK	2000	2001	2002	mean	2000	2001	2002	mean	2000	2001	2002	mean
F-1	2.21	1.87	2.09	2.05	2.36	1.34	1.83	1.84	1.67	0.72	1.47	1.28
F-2	2.20	2.51	2.04	2.25	1.96	2.42	1.69	2.02	1.54	1.89	1.33	1.59
F-3	2.84	2.22	3.01	2.69	2.87	1.59	2.52	2.33	2.19	1.03	2.23	1.82
F-4	2.20	2.88	3.53	2.84	2.08	2.54	2.87	2.50	1.34	1.64	2.28	1.75
F-5	3.31	6.21	4.00	4.51	3.20	5.39	3.63	4.07	2.17	3.91	2.52	2.87
F-6	4.30	4.40	4.75	4.48	4.04	4.47	4.50	4.34	2.79	3.27	3.11	3.06
F-7	3.47	3.37	3.47	3.44	3.40	2.72	3.27	3.13	2.19	1.99	2.89	2.36
F-8	4.84	4.54	4.65	4.68	4.74	4.28	3.82	4.28	2.87	2.47	2.80	2.71
F-9	2.96	2.57	3.35	2.96	3.01	1.37	3.12	2.50	1.99	0.53	2.38	1.63
F-10	3.63	3.62	3.68	3.64	3.51	2.00	3.87	3.13	2.51	1.09	3.21	2.27
F-11	4.28	4.25	3.59	4.04	4.22	4.43	3.67	4.11	3.10	3.22	2.59	2.97
F-12	4.12	3.32	2.94	3.46	4.11	3.06	2.55	3.24	3.33	1.52	2.23	2.36
F-13	4.37	3.76	4.47	4.20	4.14	3.75	4.09	3.99	2.96	2.29	3.28	2.84
F-14	4.39	3.06	2.99	3.48	4.20	2.29	2.62	3.04	2.42	1.30	2.36	2.03
F-15	2.78	2.56	2.55	2.63	2.51	2.27	2.19	2.32	1.57	1.34	2.23	1.71
Mean	3.46	3.41	3.41	3.43	3.36	2.93	3.08	3.12	2.31	1.88	2.46	2.22

The treatments of Westsik crop rotation experiment were intended to increase soil fertility by different organic matter amendments as the original purpose was to evaluate the cumulative effects of organic matters on light sandy soil with a long history of arable cropping.

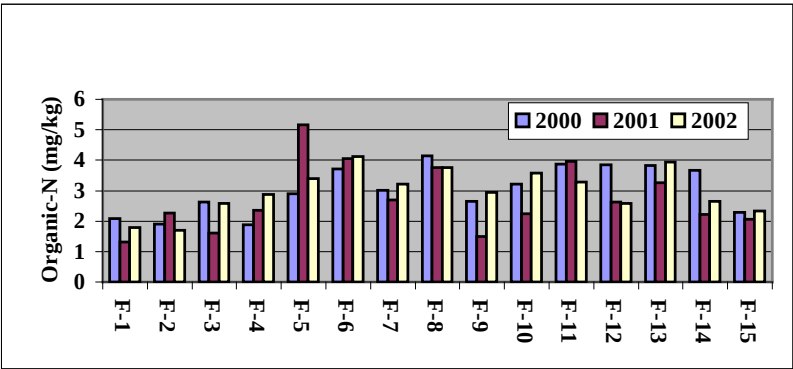


Figure 1: Yearly variation in soluble organic nitrogen content in the treatment of Westsik’s crop rotation experiment (mg/kg soil)

The F-1 block received no fertilizers and organic material treatment, except for the rye and potato roots and straw incorporated into the soil. The fallow in this block was a green one and the plant material produced was ploughed into the soil. The F-2 block represents green manure treatment, where lupin was grown as a main crop and incorporated into the soil 4-5 weeks after flowering. The phosphorus and potassium fertilizers in this treatment were applied the previous

autumn before the lupin was sown. The F-3 represents lupin root manure treatment, where lupin was grown for grain and the total organic material, except for the grain, was incorporated into the soil. Blocks F-4 - F-7 represent straw manure treatments. In the F-4 block the rye straw was applied as mulch. In blocks F-6 and F-7 straw manure was fermented without nitrogen and in block F-6 with nitrogen addition. The straw manure was incorporated into the soil 4-6 weeks before the sowing of rye.

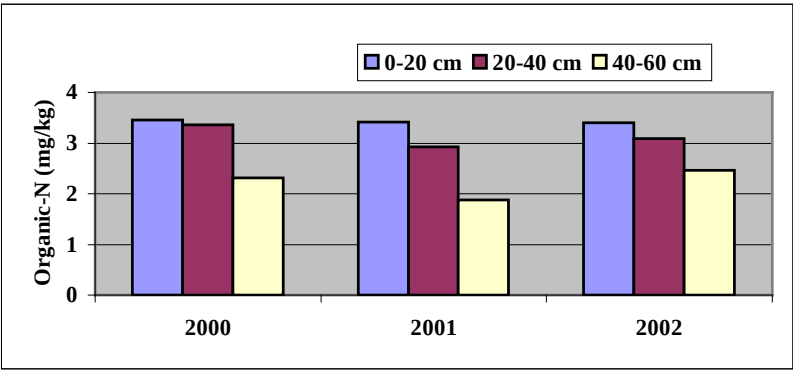


Figure 2: Yearly variation in soluble organic nitrogen content in the soil of Westsik’s crop rotation experiment (mg/kg soil)

F-8 is the only block with 4 main crops, where lupin grew twice in 4 years; once as a main crop produced for grain, and once as a second crop produced after rye and before potato, for green manure. In the F-9 block, lupin was grown as a forage crop and harvested 2-3 weeks after flowering. Blocks F-10 and F-11 represent farmyard manure treatments without and with supplementary fertilizers respectively. In block F-12, lupin is grown after a green forage crop and sown in May. This block is also evaluated with farmyard manure treatments to measure the comparative effects of the two treatments. Blocks F-13, F-14, F-15 represent green manure treatments, where lupin is grown as a second crop after rye and before potato. The F-15 block received no supplementary fertilizers. The difference between blocks F-13 and F-14 can be found in the time of the incorporation of green manure.

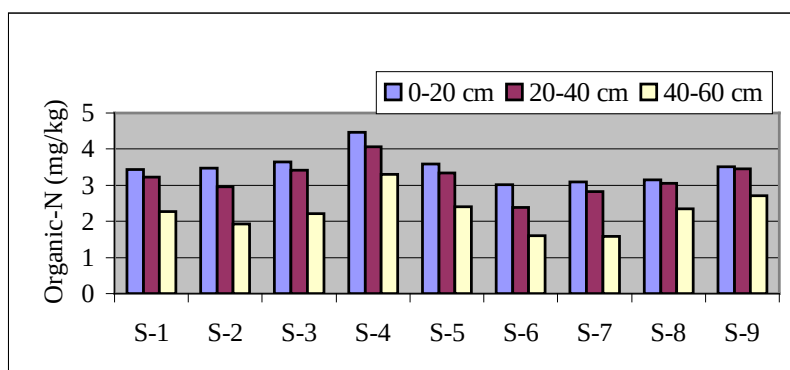


Figure 3: Within plot variation in soluble organic nitrogen content in the Westsik's crop rotation experiment (mg/kg soil)

F probe approved a significant difference between treatments, sampling place and years of examination with regard to the 0.01 M CaCl_2 soluble organic nitrogen (SON) content (Table 1, and Figure 1). Mean SON value in 2000 was 3,04 mg/kg in 2001, it was 2.74 mg/kg and in 2002, it was 2,98 mg/kg (Figure 2). 0.01 M CaCl_2 soluble organic nitrogen content varied between 1.73 mg/kg in F-1 and 3.96 mg/kg in F-6 treatments (Figure 1). Differences are also convincing between the sampling depths. Soluble organic nitrogen content of the soil was 3.43 mg/kg in 0-20 cm soil depth and 2.22 mg/kg in 40-60 cm soil depth (Figure 1). The variation in hundredth molar calcium-chloride soluble organic nitrogen content was higher in 40-60 cm soil depth. The variation between sampling sites also very characteristics to the experiment, which is situated on 2 sand dunes 200-250 m from a stream called Érpatak (Figure 3). 0.01 M CaCl_2 soluble organic nitrogen content was lower at the top of the sand dune and higher in the West side of the experiment, where soil erosion helps to increase soil organic matter content. Proportion of 0.01 M CaCl_2 soluble organic nitrogen content varied between 30-40 % (Figure 4).

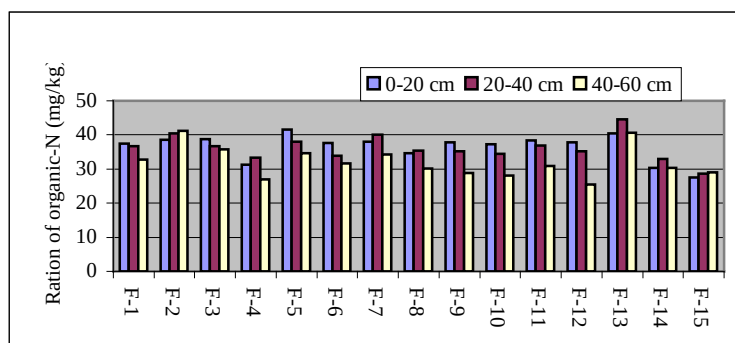


Figure 4: Proportion of soluble organic nitrogen versus total nitrogen in the treatment of Westsik's crop rotation experiment (%)

Present experiment was designed to study the correlation between the organic N fraction obtained by 0,01 M CaCl₂ solution and yield of potato in Westsik crop rotation experiment. Figure 5 shows a well defined correlation between SON and potato yield, where control plots and green manure treatments have lowest soluble organic nitrogen content and yield. Regression can be characterised with $y = 2.746x + 1.051$ equation, ($r^2 = 0.8547$).

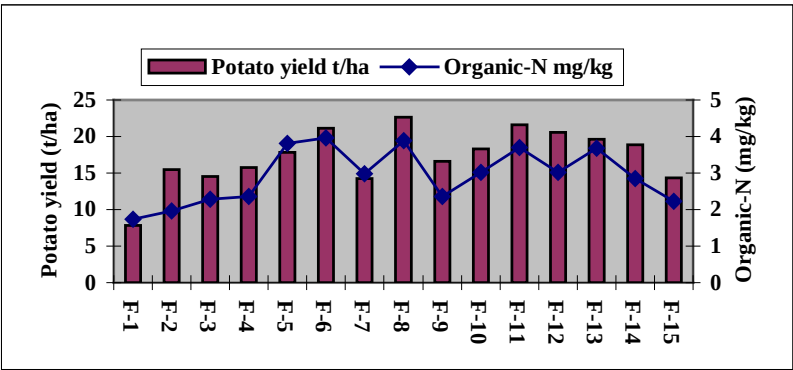


Figure 5: Soluble organic nitrogen and potato yield in the treatment of Westsik’s crop rotation experiment

The upper layer of sandy soil in Westsik crop rotation experiment contains 3000 kg/ha nitrogen, but most of it is in organic matter, and in the body of living soil microorganism. 0,01 M CaCl₂ soluble N represents only about 1% of total N in the soil and cycles rapidly. It is permanently supplied by the mineralisation of SOM and occasionally by fertilisers and atmospheric deposition. It is depleted by plant uptake, denitrification leaching and immobilisation by microorganism.

Present investigation conducted in Westsik’s crop rotation experiment has found a highly significant correlation between organic nitrogen extracted by one-hundredth molar calcium-chloride solution and potato yield. It has shown that soil organic nitrogen extracted by one-hundredth molar calcium-chloride solution is a reliable indicator of nitrogen available for mineralisation during the growing season. When precise nitrogen fertilizers recommendations are required, the method can supply additional information for environmentally friendly, sustainable agriculture.

References

- Appel, T., Mengel K. (1990):** Importance of organic nitrogen fractions in sandy soils, obtained by electroultrafiltration or CaCl_2 extraction, for nitrogen mineralisation and nitrogen uptake of rape. *Biology and Fertility of Soils*. 10. 97-101 p.
- Appel, T., Mengel K. (1992):** Nitrogen uptake of cereals grown on sandy soils as related to nitrogen fertilizers application and soil nitrogen fractions obtained by electro-ultrafiltration (EUF) and CaCl_2 extraction. *European Journal of Agronomy*. 1. 1-9 p.
- Currie, W. S., Aber, J. D., McDowell, W. H., Boone, R. D., Magill, A. H. (1996):** Vertical transport of dissolved organic C and N under long-term N amendments in pine and hardwood forest. *Biochemistry*, 35. 471-505 p.
- Groot, J. J. R., Houba, V. J. G. (1995):** A comparison of different indices for nitrogen mineralisation. *Biology and Fertility of Soils*. 19. 1-9 p.
- Lazányi, J., Loch, J., Jászberényi, I. (2002a):** One hundredth molar calcium-chloride soluble organic nitrogen in the soil of Westsik's crop rotation experiment. *Tartamkísérletek, tájtermesztés, vidékfejlesztés nemzetközi konferencia*. Debrecen. II. kötet 162-168 p.
- Lazányi, J., Loch, J., Jászberényi, I. (2002b):** An analysis of 0,01 M CaCl_2 soluble organic nitrogen in the treatments of Westsik's crop rotation experiment. *Agrokémia és talajtan*. 51. 1-2. 79-89 p.
- Mengel, K., Scheider, B., Kosegarden, H. (1999):** Nitrogen compounds extracted by electroultrafiltration or CaCl_2 solution and their relationship to nitrogen mineralisation in soil. *J. Plant Nutr. Soil Sci.* 162. 139-148 p.
- Murphy, D. V., MacDonald, A. J., Stockdale, E. A. (2000):** Soluble organic nitrogen in agricultural soils. *Biol Fertil Soils*. 30. 374-387 p.
- Németh, K., Bartels, H., Vogel, M., Mengel, K. (1988):** Organic nitrogen compounds extracted from arable and forest soils by electro-ultrafiltration and recovery rates of amino acids. *Biol Fertil Soils* 5: 537-539 p.
- Qualls, R.G. Haines B. I. (1991):** Geochemistry of dissolved organic nutrients in water percolating through a forest ecosystem. *Soil Soc. Am. J.* 55. 1112-1123 p.
- Tipping, E. (1998):** Modelling the properties and behaviour of dissolved organic matter in soils. *Mitteilg. Dtsch. Bodenk. Gesellsch.* 87. 237-252 p.
- Williams, B. L., Edwards A. C. (1993):** Process influencing dissolved organic nitrogen, phosphorus and sulphur in soil. *Chem. Ecol.* 8. 203-215 p.
- Zsolnay, A. (1996):** dissolved humus in soil waters. In Piccolo A. (ed.) *Humic Substances in Terrestrial Ecosystem*. Elsevier, Amsterdam, 171-223 p.

THE OPTIMIZING OF N-FERTILIZATION BY SOIL ORGANIC MATTER MINERALIZATION

Z. Lončarić, V. Vukadinović, B. Bertić and T. Teklić

Faculty of Agriculture in Osijek, University of J.J. Strossmayer in Osijek, Croatia

Abstract

Excess nitrogen (N) fertilization is both an unnecessary cost to producers and a pollution risk to groundwater. Appropriate N fertilization requires an accurate estimate of the mineralized from soil organic matter and residue of the previous crop.

The objective of this study was to determine the effects of the soil respiration intensity (SRI) as the indicator of soil microbial activity and humus mineralization, respectively. Therefore, the soil samples of five soil types in eastern Croatia were analyzed: the eutric cambisol, pseudogley, rigosol, amfigley and hypogley. The soil samples were taken from soil depths 0-25 and 25-50 cm. The SRI was determined at several moisture content (SMC; 60, 70, 80 and 100 % of field water capacity FWC) during 24 h, on three temperature level (9, 21 and 30°C). Also, the humus content (%) was determined, and the amount of released CO₂ was converted into the amount of mineralized humus (%) and nitrogen (kg/ha weekly and for whole year).

All tested soil samples showed lower humus content in the soil layer 25-50 cm as well as the SRI, compared to upper soil layer (0-25 cm). The increase of SMC resulted mostly by the increase of a difference between samples taken from upper and lower soil layer, measured at all temperature treatments. In general, the lowest SRI was at 9 °C, and the highest at 21 °C, excepting the eutric cambisol where the highest SRI was determined at 30 °C.

Based on the SRI, it could be appraised that the mineralization in eutric cambisol was 1.66 kg N/ha weekly at 21 °C and 60 % FWC, while it was 6.89 kg N/ha at 100 % FWC. If such conditions could be maintained whole year, that would be ranged 86.34-359.19 kg N/ha. Under condition of 60 % FWC in whole year, 1.92 % of humus content would be mineralized and 7.99 % at 100 % FWC. On other localities, the estimated amount of mineralized nitrogen in kg N/ha weekly was ranged as follows: 0.74-5.43 (amfigley) , 7.49-9.19 (hipogley), 6.55-9.03 (pseudogley) and 2.89-4.18 (rigosol), respectively. At higher temperatures and optimal humidity it increased to 58.34 kg N/ha weekly on amfigley, 57.40 kg N/ha on hipogley and 54.62 on pseudogley. Concerning that the soil was most of the year cold and wet in natural conditions, or warm and insufficient humid, such high mineralization rates could be expected only in short summer intervals.

The results showed doubtless influence of the soil moisture and temperature on the SRI but the relations between moisture and temperature were soil type specific.

Keywords: soil respiration, soil organic matter, mineralization, soil water content, soil temperature, optimazin N-fertilization

Introduction

According to many reports, excess nitrogen (N) fertilization is both an unnecessary cost to producers and a pollution risk to groundwater. Appropriate N fertilization requires an accurate estimate of the mineralized one from soil organic matter and residues of the previous crop. Soil

respiration is a process involving uptake of O_2 and release of CO_2 by living metabolizing entities in the soil (Anderson, 1982) and it can be measured in field or in laboratory. Rapid soil procedure for agricultural soil potential to mineralize C and N can be useful to avoid overfertilization. The objective of this study was to determine the influence of soil moisture and temperature on the soil respiration intensity (SRI) and the correlations between soil respiration, total C and N content and C/N ratio. At the same time, the intention was to predict amount of potential mineralizing N depending on soil temperature and moisture.

Materials and Methods

Five localities in eastern Croatia were chosen: Osijek, Krndija, Rakitovica, Našice and Vukojevci and the agrochemical and pedological analyses were done. The soil layers 0-25 and 25-30 cm were analyzed for physical and agrochemical properties. Analysed physical properties were soil bulk density, soil water holding capacity (Škorić, 1982) and soil texture. Conducted agrochemical analyses were pH (1 M KCl and H_2O), organic matter content, total carbon and total nitrogen content (Vukadinović and Bertić, 1988).

According to results of moisture contents, soil bulk density and soil water capacity, for all samples were made the next calculations: soil water content at 60, 70, 80 and 100 field water capacity (FWC) and amount of water (g) necessary to add to soil sample up to 60, 70, 80 or 100 FWC. Afterwards, the soil samples for soil respiration analyses were collected (shortly after wheat harvesting in July), field-moist samples were sieved to pass a 2-mm screen and analyzed moisture content (gravimetry). The previous calculations are equated according to soil moisture content and field-moist soil (100 g air-dried soil) samples are wetted in 500 ml bottle to 60, 70, 80 and 100 FWC (gravimetry). In the same bottle containing soil are placed the open glass bottle with 10 ml 0,2 M KOH solution. The 500 ml bottles with triplicated samples wetted to 60, 70, 80 and 100 FWC were hermetic closed and kept on 9, 21 or 30°C during 24 hours. Afterwards, in KOH solution was added 5 ml 20 % $BaCl_2$ solution, added few drops of the thymolphthalein indicator (1 % ethanol solution) and titrated the unneutralized alkali with standard 0,1 M HCl directly. As the blank sample a 100 g of wetted quartz sand was used. For the calculation of released CO_2 (mg) was used formula:

$$\text{mg } CO_2 = (a - b) \times F$$

a = ml of acid to titrate the blank sample alkali,

b = ml of acid to titrate the alkali in the CO_2 collectors from the treatment to the end point,

F = factor according to HCl strength (2,2 for 0,1 M HCl or 22 for 1 M HCl, as 22 is equivalent weight of carbon dioxide).

The statistic analyses for all data were done by analyses of variance and linear regression analysis using computer program (Ivezić and Vukadinović, 1985) created according to Snedecor and Cochran, 1987.

Results and Discussion

Soil types and soil analyses results

Soil types on analysed localities were eutric cambisol, amphigley, hypogley, pseudogley and rigosol. The water retention capacity of analyzed soils was medium, topsoil layer density was 1,55 (rigosol) – 1,63 kg dm⁻³ (amphigley and pseudogley) (Table 1).

Table 1: Soil physical properties

locality and soil type	depth (cm)	soil water holding capacity (cm ³ cm ⁻³)	soil bulk density kg dm ⁻³	soil texture
Osijek - eutric cambisol	0-25	40,2	1,56	clay loam
	25-50	38,6	1,61	clay loam
Krndija - amphigley	0-25	36,7	1,63	clay loam
	25-50	36,4	1,59	clay loam
Rakitovica - hypogley	0-25	40,8	1,59	sandy loam
	25-50	41,3	1,59	sandy loam
Našice - pseudogley	0-25	38,3	1,63	clay loam
	25-50	39,0	1,64	clay loam
Vukojevci - rigosol	0-25	42,3	1,55	clay loam
	25-50	37,9	1,54	sandy clay loam

Soil texture was clay loam except sandy loam on hypogley and sandy clay loam in the 25-50 cm soil layer on rigosol.

The lowest pH was on rigosol and indicated on liming requisite and the highest pH was on amphigley. The humus content of all analyzed topsoil layers were low or medium: 10,2 (Vukojevci) – 24,3 g kg⁻¹ (Rakitovica) and C/N ratio of topsoil layer 7,7 -13,2 (Table 2).

Table 2: Soil agrochemical properties

locality and soil type	depth (cm)	pH (H ₂ O)	pH (KCl)	humus g kg ⁻¹	organic C g kg ⁻¹	total N g kg ⁻¹	C/N ratio
Osijek - eutric cambisol	0-25	6,46	5,22	22,3	12,9	1,45	8,9
	25-50	6,65	5,40	17,7	10,3	1,25	8,2
Krndija - amphigley	0-25	7,89	7,40	16,7	9,7	1,05	9,2
	25-50	7,13	6,16	16,1	9,3	0,80	11,6
Rakitovica - hypogley	0-25	7,36	6,51	20,6	11,9	1,30	9,2
	25-50	7,77	6,76	14,9	8,6	0,80	10,8
Našice - pseudogley	0-25	7,09	6,41	17,0	9,9	0,75	13,2
	25-50	7,21	6,50	16,4	9,5	0,65	14,6
Vukojevci - rigosol	0-25	5,64	3,98	10,0	5,8	1,75	7,7
	25-50	5,47	3,88	4,9	2,8	0,70	4,0

Soil respiration results

The highest soil respiration intensity (SRI), depending on moisture and temperature, was determined on amphigley, pseudogley and hypogley and there were no significant differences between them. Significant lower SRI was on eutric cambisol inspite of the highest humus and total nitrogen contents. The lowest SRI was on rigosol (Table 3).

Table 3: Soil respiration intensity according to soil temperature and soil moisture

	9°C				21°C				30°C			
	60	70	80	100	60%	70	80	100	60	70	80	100
0-25 cm	%	%	%	%	%	%	%	%	%	%	%	%
Osijek	0,25	0,52	0,83	1,04	1,62	2,12	3,45	3,04	1,44	3,42	3,96	4,95
Krndija	0,11	0,16	0,81	0,29	3,74	5,54	7,27	8,7	3,63	4,82	5,99	7,43
Našice	1,02	0,98	1,14	1,35	4,34	5,56	6,56	8,17	3,33	4,13	4,79	6,07
Vukojevci	0,55	0,68	0,47	0,53	1,33	1,81	2,12	2,01	1,33	1,51	1,6	1,69
Rakitovica	1,17	1,35	1,13	1,1	6,12	6,93	7,26	8,43	4,96	5,88	6,53	7,53
25-50 cm												
Osijek	0,07	0,06	0,07	0,07	0,39	1,61	2,22	1,83	1,19	1,74	2,37	2,89
Krndija	0	0	0	0,2	1,54	3,1	3,91	3,99	1,31	1,63	2,39	2,77
Našice	0,11	0,35	0,36	0,54	3,49	4,52	5,97	8,03	2,05	2,85	3,2	4,52
Vukojevci	0	0	0	0	0,02	0,03	0,01	0,06	0,02	0	0,06	0,05
Rakitovica	0,47	0,84	0,91	0,89	5,28	5,93	6	6,52	3,64	3,82	3,98	4,29

There were significant correlation between carbon content and SRI on moisture 100% FWC on all temperatures (9°C: $r=0,737^*$, 21°C: $r=0,860^*$ i 30°C: $r=0,937^{**}$).

Soil respiration intensity was much lower in soil layer 25-50 cm then in top soil layer on all localities, and decreasing was most intensive with moisture and temperature increasing.

Temperature increasing from 9°C to 21°C resulted in higher SRI regardless to soil type or soil moisture, but the increasing was higher with higher soil moisture (Figure 1).

Temperature increasing from 21°C to 30°C resulted in higher SRI only on cambisol on both depths, but on other localities the influence of temperature rising was opposite.

Soil moisture increasing from 60 to 100 % FWC resulted in higher SRI on all localities and temperautres but on localitie Osijek with highest SRI on 80% FWC.

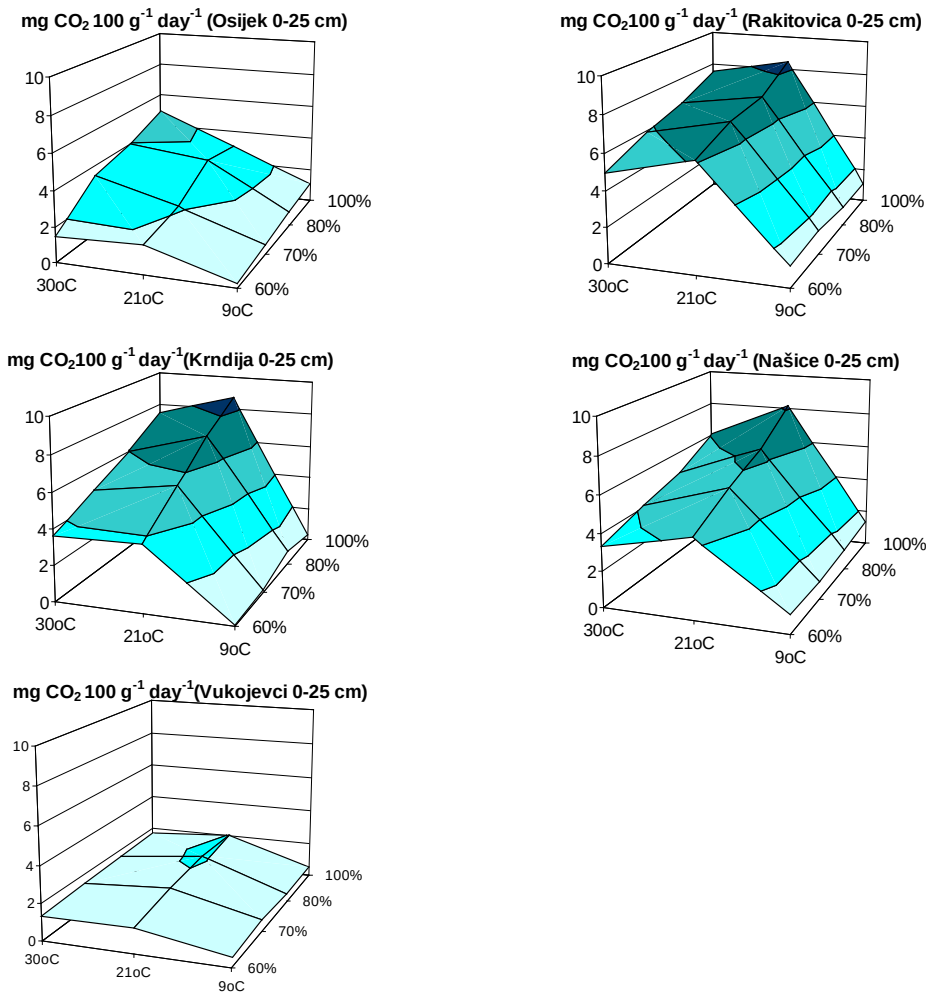


Figure 1: Soil respiration intensity in top soil layer (mg CO₂ 100 g⁻¹ soil 24h⁻¹)

Soil N mineralization prediction

Measured soil respiration can be expressed as a function of soil moisture and soil temperature:

$$\text{SRI}_{\text{FWC}, t} = (-0,027 \ t^2 + 1,3 \ t - 8,72 - 0,0085 \times \text{FWC}^2 + 1,475 \times \text{FWC} - 52)/2,35$$

in $\text{mg CO}_2 \ 100\text{g}^{-1} \ \text{day}^{-1}$. Estimated differences between soil types should be included in formula (Soil Factor SF), as well as soil bulk density (SBD) and CN ratio. According to that, the predicted amount of daily mineralized N (min_N) in top soil layer (0-25 cm) in kg N ha^{-1} is:

$$\text{min}_N = \text{SRI}_{\text{FWC}, t} \times \text{SF} \times \text{SBD} \times 6,82 / \text{CN}$$

Soil factor (SF) is calculated according to laboratory results of SRI and for hypogley and amphigley $\text{SF} = 1$, for pseudogley 0,82, for cambisol 0,48 and for rigosol 0,29. The formula listed above is calculated only for CN values between 7 and 15 as were the analyzed soil samples. Using this formula and different simulation models (Jeuffroy and Recous 1999, Vukadinović et al. 1994, Greenwood et al. 1987) it can be approximate that the mineralization in eutric cambisol was 1.66 kg N/ha weekly at 21 °C and 60 % FWC, while it was 6.89 kg N/ha at 100 % FWC. If such conditions could be maintained whole year, that would be ranged 86.34-359.19 kg N/ha. Under condition of 60 % FWC in whole year, 1.92 % of humus content would be mineralized and 7.99 % at 100 % FWC. On other localities, the estimated amount of mineralized nitrogen in kg N/ha weekly was ranged as follows: 0.74-5.43 (amphigley), 7.49-9.19 (hipogley), 6.55-9.03 (pseudogley) and 2.89-4.18 (rigosol), respectively. At higher temperatures and optimal humidity it increased to 58.34 kg N/ha weekly on amfigley, 57.40 kg N/ha on hipogley and 54.62 on pseudogley. Concerning that the soil was most of the year cold and wet in natural conditions, or warm and insufficient humid, such high mineralization rates could be expected only in short summer intervals.

Agroecological spring conditions in Osijek using mentioned simulation models and SRI data resulted in mineralization prediction 0,30 – 1 kg N ha^{-1} daily, Krndija 0,37 – 1,08, Rakitovica 0,49 – 1,55, Našice 0,45 – 1,28, and Vukojevcu 0,06 – 0,38 kg N ha^{-1} daily⁻¹. Greenwood et al. (1987) in their model calculated daily mineralization rate 0,22 – 0,88 kg N ha^{-1} .

Conclusion

There were clear correlation between soil respiration and soil moisture and temperature. The soil respiration analyses show that the temperature increasing from 9 to 21°C resulted in increasing of respiration of all analyzed soil types and moistures. However, this increasing was higher in the top soil layer and at the higher soil moistures. The temperature increasing from 21 to 30°C in most of analyzed soil types decreased the soil respiration. Soil moisture increasing from 60 to 100 % of field water capacity increased the soil respiration.

Soil respiration data can be used as a part of simulation models for mineralization prediction do to optimizing N fertilization recommendations. Results shows that the simulated N mineralization amount depends on soil type, temperature and moisture. In agroecological condition of spring in eastern Croatia under optimal temperature and moisture those amounts are from 0,38 kg N ha⁻¹ daily on most acid rigosol with low humus content to 1,55 kg N ha⁻¹ daily on hypogley with nearly neutral pH reaction and higher humus content.

References

- Anderson, J. P. E. 1982. Soil respiration. In: A. L. Page, R. H. Miller and D. R. Keeney (editors), *Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties*, 2nd Edition. American Society of Agronomy, Madison, Wisconsin, pp. 831-871.
- Greenwood, D. J., Verstraeten, L. M. J., Draycott, A. and Sutherland, R. A. 1987: Response of winter wheat to N-fertilizer: Dynamic model. *Fertilizer Research* 12: 139-156.
- Ivezić, M. and Vukadinović, V. 1985. Primjena mikroračunara u analizi varijance jednodimenzionalne i dvodimenzionalne klasifikacije. *Znanost i praksa u poljoprivredi i prehrambenoj tehnologiji* 15: 36-51.
- Jeuffroy, M. H. and Recous, S. 1999: Azodyn: a simple model simulating the date of nitrogen deficiency for decision support in wheat fertilization. *European Journal of Agronomy* 10: 129-144.
- Snedecor, G.W. and Cochran, W.G. 1987. *Statistical methods*. The Iowa State Uni, Ames.
- Škorić, A. 1982: *Priručnik za pedološka istraživanja*. Fakultet poljoprivrednih znanosti, Zagreb.
- Vukadinović, V. and Bertić, B. 1988: *Praktikum iz agrokemije i ishrane bilja*. Sveučilište u Osijeku, BTZNC, Poljoprivredni fakultet u Osijeku.
- Vukadinović, V., Lončarić, Z., Bertić, B. and Teklić, T. 1994: Computer modelling of organic matter production by wheat on heavy soils. *Proceedings of the 16th International Conference on Information Technology Interfaces (ITI '94)*, Pula, 14.-17. June 1994. pp. 295-298.

THE EFFECT OF N, P, K FERTILIZATION ON YIELD AND ON SHIFTS IN THE MAJOR SOIL CHARACTERISTICS

M. Sárvári, Z. Futó and E. Zsom

Centre of Agricultural Sciences, University of Debrecen
Debrecen, Hungary

Introduction

One condition of successful maize production is, that we know the specific reactions of hybrid maizes, to different agrotechnical factors. In this paper we analysed the results of maize experiments by the Department of Crop Sciences and Applied Ecology of the University of Debrecen, Centre of Agricultural Sciences during the period 1976-2000. Our main aims were to develop the technologies of maize, to increase the effectiveness of maize crop management, to work out and study the different crop models of different maize genotypes.

Further aim was to work out such new maize fertilizer methods and models which can reduce the harmful effects of fertilization, can maintain the soil fertility and can moderate the yield fluctuation (nowadays 30-50 %) (Figure 1.).

CORRELATION BETWEEN FERTILIZATION AND CORN YIELDS IN HUNGARY (1921-2000)

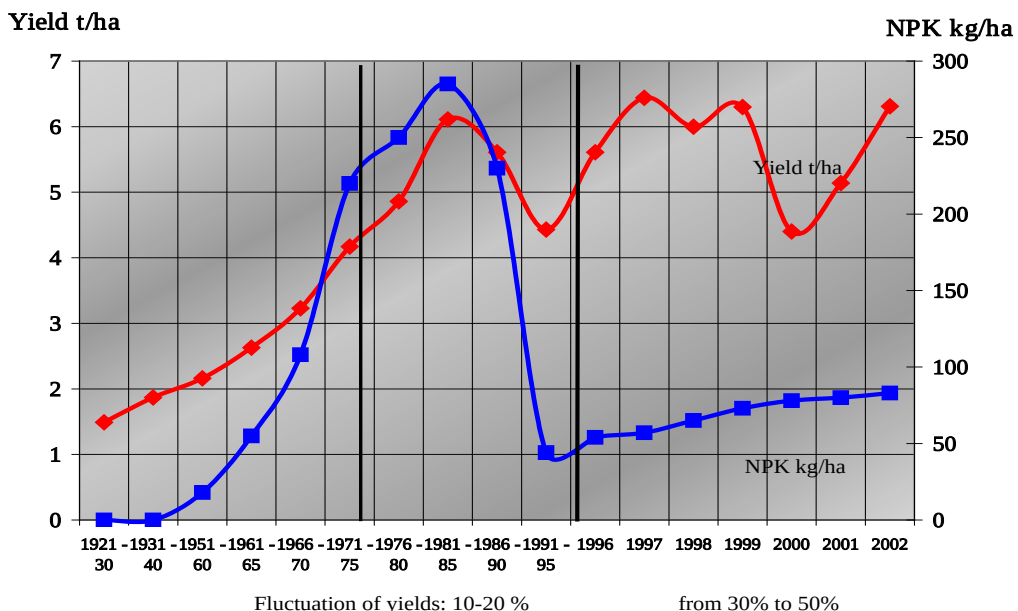


Figure 1

Kádár (1997) calculated the NPK balance for the years 1986-1990 and 1991-1995 on 6 million hectares of cultivated land in Hungary. It was found that during this century the N and K balance was only positive for 20 years, between 1970 and 1990, while the P balance was positive for 30 years (1960-1990), resulting in the accumulation of 800-1000 kg/ha N, P_2O_5 and K_2O per hectare of soil. As a consequence of this, the P and K supplies in the soil, the yields, and the nitrification of the groundwater increased in the 70s and 80s. The deficiency in the nutrient balance and the rate of fertilizer application dropped in 1991-1995 to the level recorded 30 years earlier.

Megyes et al. (2000) studied the effect of N-dose increase on the yield of maize hybrids and the environmental protection in a long-term experiment on calcareous chernozem soil. The results indicate that there is no justification for applying 240 kg N/ha, plus the corresponding P and K fertilizers, since this dose does not increase the maize yield significantly compared with the 120 kg/ha rate and in dry years may even lead to a substantial yield reduction. This rate of N fertilization is a potential source of danger from the point of view of environmental protection, since high doses of N fertilizer combined with irrigation multiply the quantity of nitrate leached from the root zone to pollute the groundwater.

Dobos and Nagy (1998) found out in the unfertilized treatment there was a significant difference in the dry matter content of the maximum vegetative mass in the years examined. In the fertilized treatment higher values were recorded each year than in the control plots, the fertilizer effect being 17-19 % in 1991, 1993 and 1994 and 22-28 % in 1992 and 1995.

Berzsényi and Gyórfy (1996) studied in a monoculture the yield of maize was lower in every case than in crop rotation. The yield-increasing effect of crop rotation was inversely proportional to the proportion of maize in the crop relation. Averaged over the fertilizer treatments, the yield-increasing effect was greatest in the Norfolk rotation (0.929 t ha⁻¹), followed by the alfalfa-maize-wheat triculture (0.664 t ha⁻¹), the wheat-maize diculture (0.324 t ha⁻¹) and the alfalfa-maize diculture (0.26 t ha⁻¹). The effect of year and crop rotation on the fertilization treatments was significant. It can be concluded from the experimental data that the application of stable manure and crop residues (maize stalks, wheat straw), supplemented by NPK, is an efficient method of fertilizing maize. Stable manure also improves yield stability.

Sárvári (2000) Considering the aspects of efficiency and environment protection, maize needs only N_{60-120} , P_{45-90} , K_{53-106} kg/ha active agent. With larger N doses than N_{60-120} kg/ha the quantity of NO_3-N reaches 150-200 mg/kg in the 100-120 cm soil profile which can result in marked environment pollution.

Materials and Methods

We analysed the results of maize experiments by the Department of Crop Sciences and Applied Ecology of the University of Debrecen, Centre of Agricultural Sciences during the period 1976-2000. The soil of our experimental projects was meadow soil. The soil could be characterized by high clay content and pour phosphorus and medium potassium contents. Among the soil characteristic parameters it's important that the phosphorus and potassium fixation are very high.

Main properties of the experimental field are shown in *table 1*.

Table 1

pH		CaCO ₃			AL old.	mg/kg	Humusz	Arany-f
H ₂ O	KCl	%	y ₁	hy ₁	P ₂ O ₅	K ₂ O	%	kötöttségi szám
7,0	6,4	ny.	5,0	4,4	40	130	4,2	52

In the last decade from ten years six years were dry and hot in our region. So the importance of crop-rotation is increasing and we have to intend to use appropriate crop rotation.

The water demand of maize is fairly moderate, but the sensibility of maize to drought is high among the field crops.

Results and Discussion

The yields of maize in monoculture crop rotation decreased by 1-3 t/ha in each dry year during my experiment (1983, 1990, 1992, 1993, 1994, 1995, 1998 and 2000 years). The most favourable fore crop of maize was wheat, medium was the biculture crop rotation and the worst crop rotation was the monoculture (*Figure 2*).

The fore crop determined the doses of fertilizers mainly influenced the doses of nitrogen. In triculture (peas – wheat – maize) crop rotation (after wheat fore crop) the optimum N-dose was 50-60 kg/ha, and in monoculture the optimum N-doses increased to 100-120 kg/ha (of course we had to apply appropriate phosphorus and potassium doses as well) (*Table 2*).

Figure 2

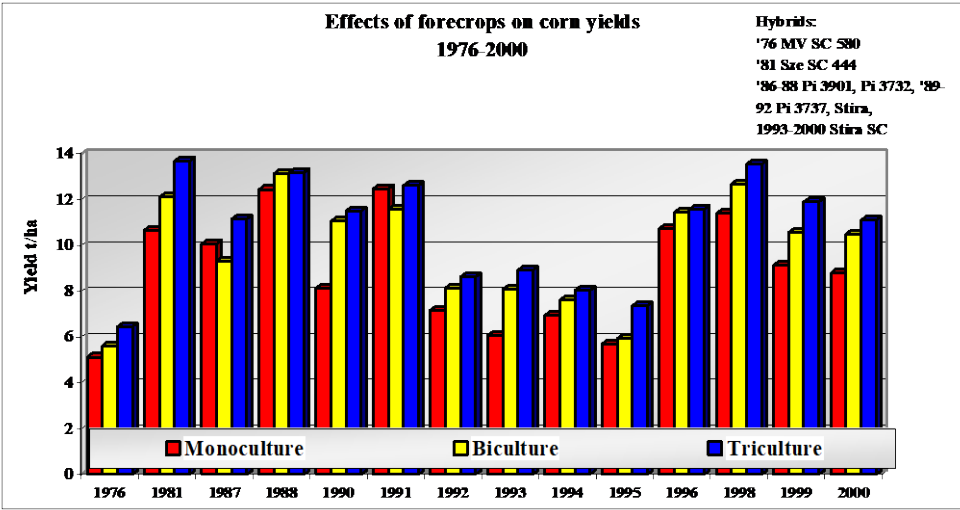


Table 2: Optimal fertiliser doses for corn kg/ha effective material

Forecrops	N	P ₂ O ₅	K ₂ O	TOTAL
Wheat (in triculture)	50-60	45	55	150-160
Wheat (in biculture)	60-80	45	55	160-180
Corn	80-100	90	110	280-300
Corn (in monoculture)	100-120	90	110	300-320

By using about 200-250 kg nitrogen fertilizer the NO₃ content of 100 and 120 cm soil layer varies between 10-50 mg/kg. We obtained lower NO₃ values in crop rotation experimental projects, the monoculture crop rotation was characterized by higher values (which means 125 and 175 mg/kg NO₃ content) (*Figure 3.*). In our long-term experiments the pH values decreased when we used high doses of fertilizers.

In monoculture crop rotation the soil fertility and the microbiological activity of soil is decreased. The yield decrease of maize in monoculture could be explained by the one side by the utilization of soil dispoñible water capacity. That's why we recommend crop rotation after 6-8 years of monoculture.

A lot of elements determined the harvest grain moisture of maize. Our experiments proved that with early planting time with optimum fertilizer doses and lower plant density maize lost water faster, so we could harvest the different maize genotypes at lower moisture.

The Cold-test values describe the different genotypes tolerances to Cold, so this parameter is very important determination of planting time. The hybrids marked by blue lines have high Cold-test values (94-96 %) and so these hybrids could be planted in earlier time (*Figure 4.*).

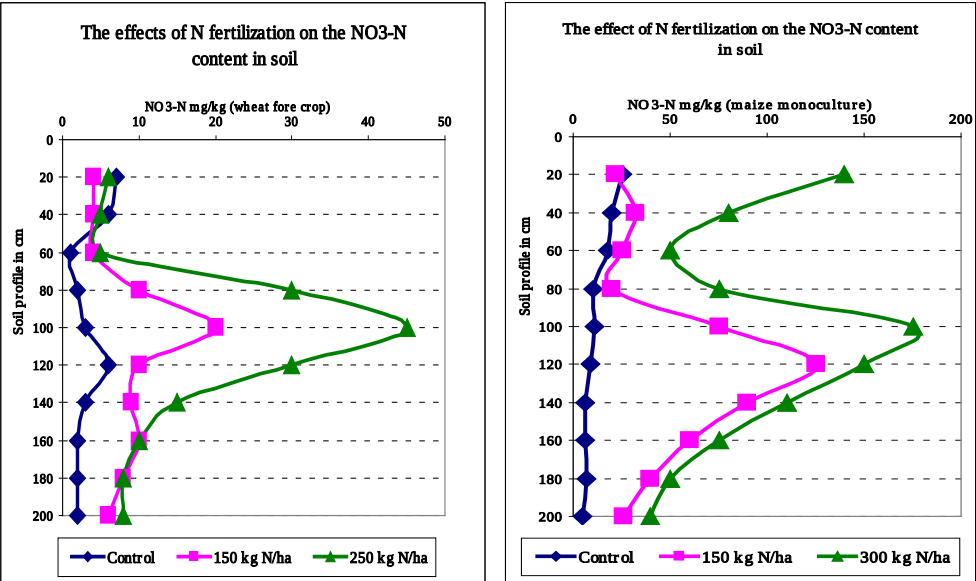


Figure 3

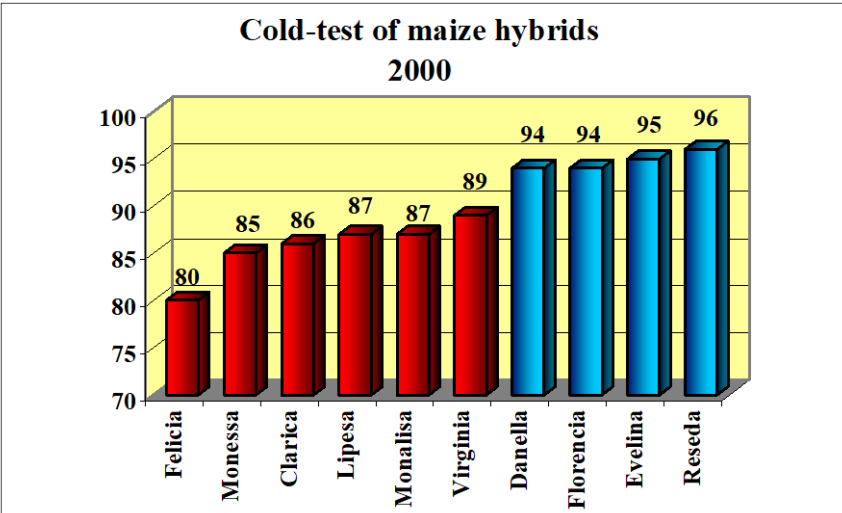


Figure 4

There is a strong correlation between the planting time and the yield of maize hybrids, but this interactive effect can be modified by the amount and distribution of precipitation in vegetation period. There is a stronger, even significant correlation between planting time and grain moisture at harvesting time.

At early planting time the grain moistures were less by 5-12 % lower compared to the late planting time, and 4-5 % lower compared to the optimum planting treatment (*Figure 5.*).

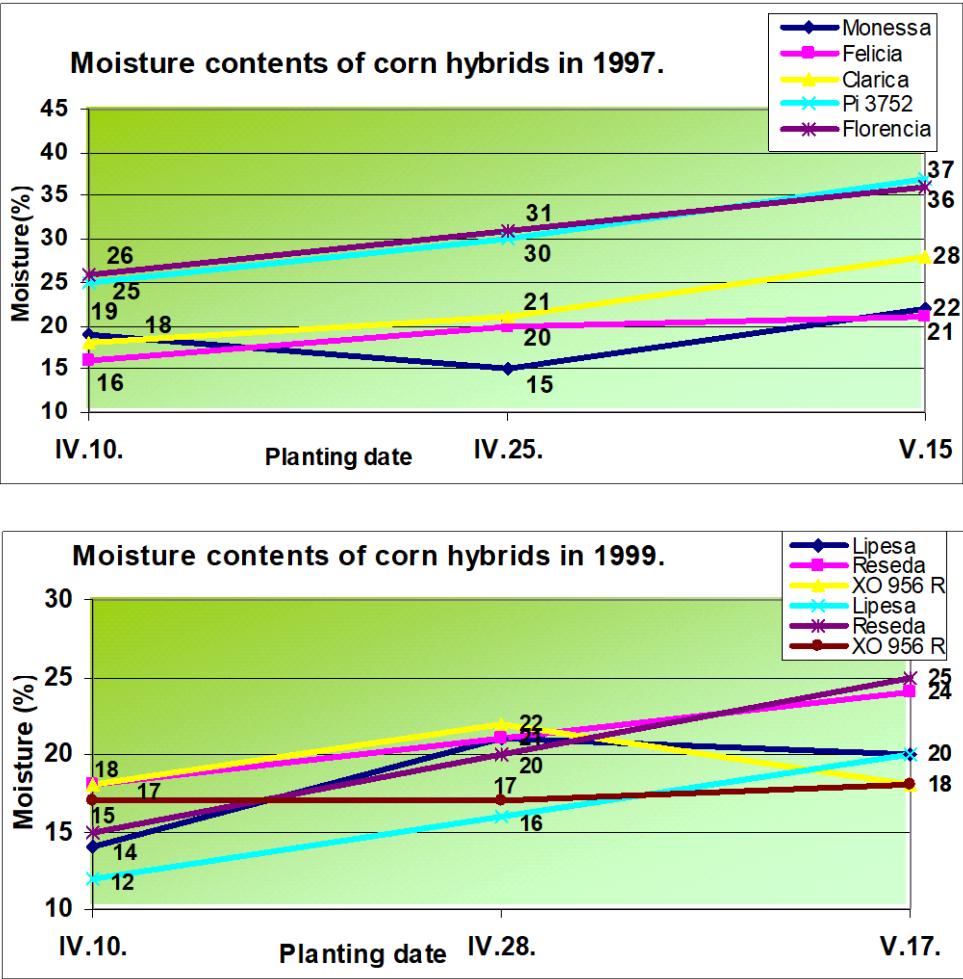


Figure 5

The optimum plant density depends on the genotype of hybrids, on agroecological conditions, on the effects of crop year, on the water- and nutrient supply and on the intensity of production. A 10 thousand plants/ha change in stock density can increase yields by 1,5-2 t/ha, but over the optimum level, yields are reduced.

There are big differences among the plant density of different maize hybrids. There are hybrids sensitive to higher plant density and there are wide and narrow optimum plant density hybrids (Figure 6.).

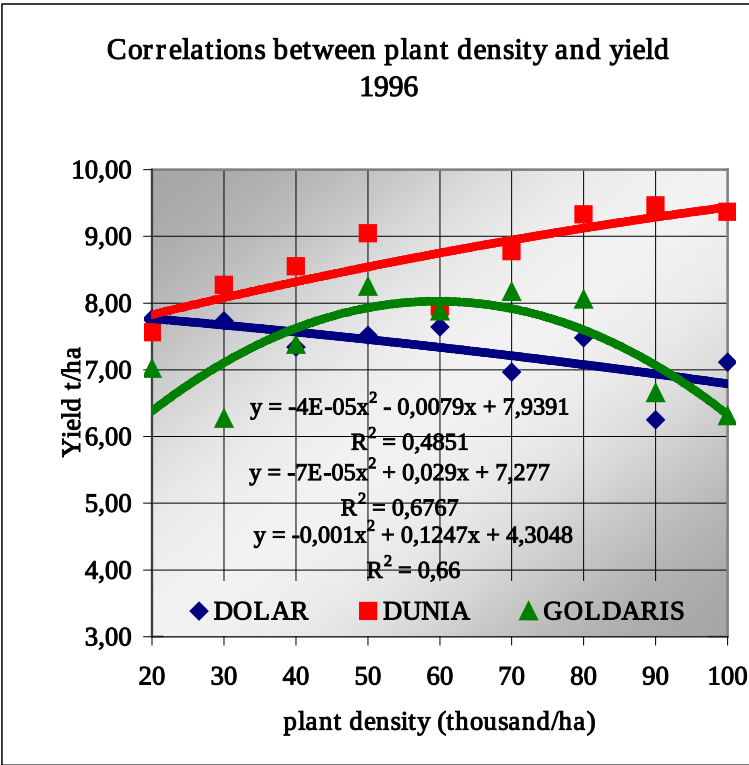


Figure 6

Considering the fact that the frequency of drought crop years increased and the usage of fertilizers dropped in the last ten years we suggest that the optimum plant density is 68-72 thousand/ha in the case of 200-300 FAO hybrids and 60-65 thousand/ha in 400-500 FAO hybrids.

To develop the genetical background of maize we continuously test the different maize hybrids by using special methods developed by Bocz (1974) and we evaluate the yield ability of hybrids, the natural nutrient utilization ability and the fertilizer-response of hybrids.

It is very useful for the practice that the new up-to-date hybrids combine the good natural nutrient utilization ability with good fertilizer utilization ability, so the modern maize hybrids can be characterized by good fertilizer response.

From the aspects of effectiveness and environmental protection the optimum fertilizer doses of maize hybrids are N 60-120, P₂O₅ 45-90, K₂O 53-106 kg/ha depending on fore crop and crop year (Figure 7.).

We can summarize our results by saying that we have to use hybridspecific technologies in maize production In the future we have to increase the level of inputs and have to apply the best appropriate hybrids and respecting to agroecological conditions we can better utilize the genetic yield potential.

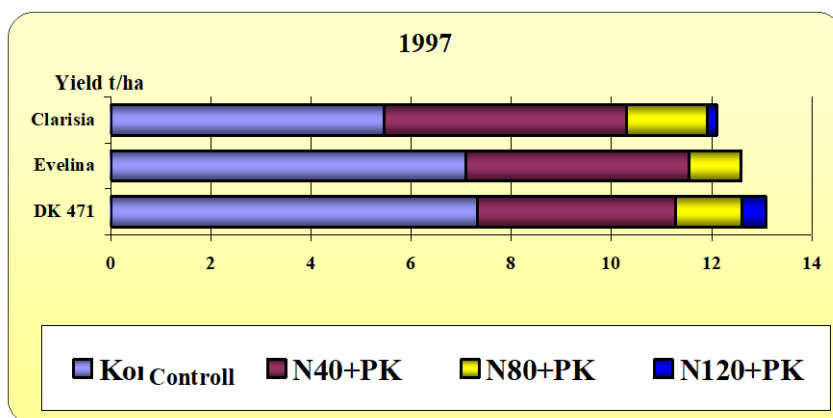


Figure 7: Yields and fertilizer responses of corn hybrids on a meadow soil (1997)

The quantity and quality of potato yield are also highly dependent on agrotechnique. When 165 kg/ha N, 55 kg/ha P₂O₅ and 220 kg/ha K₂O were applied, the yields of varieties Szákszorszép and White Lady exceeded 23 t/ha and 35 t/ha, respectively. Irrigation at given fertilizer doses could increase yield by 100 % at specific varieties.

In the future, more attention must be paid to soil testing, setting up a reasonable crop rotation, preserving soil fertility in the long run, efficacy and environmental protection.

References

- Berzsényi Z, Gyorffy B.: 1996: Effect of crop rotation and fertilization on maize yields and yield stability in a long-term experiment. *Növénytermelés*. Tom. 45 (3): 281-296. p.
- Bocz E. 1974: Crop production. *Mezőgazdasági Kiadó*. Budapest.
- Dobos A. Nagy J.: 1998. Effect of year and fertilisation on the dry matter production of maize (*Zea mays* L.) *NOVENYTERMELES* Tom. 47 No. 5 513-524. p.
- Kádár I.:1997. Nutrient management of Hungarian soils at the end of the 20th century. *Növénytermelés*. Tom. 46. No. 1. 73-83.p.
- Megyes A.-Rátónyi T.-Huzsvai L.-Szabó Gy.-Dobos A.-Sum O.:2000. Effect of mineral fertilisation on the yield of the maize (*Zea mays* L.) hybrid Dekalb 471 SC under irrigation and non-irrigated conditions. *Növénytermelés*. Tom. 49. No. 3. 307-315.p.
- Sarvari M. (2000):Development of variety-specific technologies in maize production. Soil, plant and environment relationships. p. 162-175.

THE INFLUENCE OF MANURE ON THE YIELD OF WHEAT- MAIZE AND FERTILITY OF SOILS

M. Ștefănescu

ARS Turda, Romania
scaturda@rdslink.ro

The main goal of any agricultural system should be increasing agricultural production and improving soil fertility. The contemporary agricultural system is centered upon the intensive use of soil in order to obtain increased yields both in quantity and in quality and soil fertility is often neglected. Increasing soil fertility is essential for the superior capitalization of all the links in the technological chain.

It is generally acknowledged that organic matter, especially humus, plays an important part in maintaining a high level of soil fertility. The main sources of humus are vegetable remains of crops, used fertilizers, especially organic ones.

The positive influence of organic fertilizers on soil fertility, on its production and quality has been demonstrated in the works of many researchers (Hera,Cr. and col., 1986,Patel, B.A. and col.,1992, Sarkadi,J.,1993,Ciobanu, Gh.,1999, Ștefănescu Maria,1999, Hoffman,J.,2001,Sattar, M.A. and col.,2001).

In our country, as the quantity of chemical fertilizers has continuously dropped in the last few years and the organic matter has recorded a descending tendency, it is necessary to use organic fertilizers, even more so considering the much greater frequency of weeding plants on the rotation, as apposed to the leguminous or fodder plants.

The objective of this paper is to present the results that were obtained in long- term experiments regarding the effect of organic and mineral fertilizers on certain indices of soil fertility, on the yield and quality of wheat and maize.

Material and Method of Research

Experiments were conducted in a stationary on the rotation haricot beans-wheat- maize. There have been made studies on manure, used both alone, in doses of 20, 40 and 60 t/ha and combined with mineral fertilizers (NP), in comparison with mineral fertilizers used alone and with the unfertilized trial

Trial have been planted in blocks of three repetitions, and the capitalization of the results has been achieved by the variance analysis method. The most productive cultivars and hybrids in the area have been planted.

After 30 years of experiments, in 1997, a laboratory analysis was performed in order to establish the influence of organic and mineral fertilizers on certain soil fertility indices.

Results

1.The influence of fertilization on certain soil- fertility indices

A prominent part in maintaining the fertility features of a soil is played by the deposit of organic matter. It is on important factor of physical and chemical improvement, being a means of stocking water and nutritional elements, a protection agent against certain unfavorable pedological phenomena (erosion, phosphorus blockage, etc.).

According to the great biologist Bronovski, quoted by Hera and col., “manure is still a fertilizer, not a miracle” The special part played by manure must be highlighted especially in preserving and increasing soil fertility, in protecting the environment, as it is an important component of a rational agriculture.

Organic and mineral fertilization, through its cumulative effect influences both the harvest (in quality and quantity) and the evolution of certain soil fertility indices.

On the clayey chernozem soil from Turda, during a 34 year experiment, organo- mineral fertilization on a rotation of two, then three years of haricot beans- wheat- maize has constituted an extremely efficient phitotechnical method with a view to increasing the fertility and the productivity of these soils.

From an analytical point of view, there has been noticed an increase of the total nitrogen content (Nt%) (table 1)

Table 1: The influence of organic and mineral fertilization on certain soil fertility indices

	PH Water	Nt%	PAL ppm	KAL ppm	Humus %	Cu ppm	Zn ppm	Pb ppm	Co ppm	Ni ppm	Mn ppm	Cr ppm	Cd ppm
N30P60	7,97	0,257	48,44	656	4,21	32,5	163,5	57,7	25,3	58,8	654,5	127,3	2,75
20tmanure +N120P50	7,89	0,257	63,97	646	4,26	35,3	181,3	62,8	28,8	66,8	764,3	134,8	3,03
40manure N80P30	8,10	0,266	67,25	684	4,26	34,7	151,3	55,8	26,8	61,8	731,8	141,3	2,82
60tmanure N50P25	7,99	0,293	80,24	729	4,36	33,8	165,6	58,2	27,3	61,5	767,8	137,3	2,76
20t manure/ha	7,98	0,286	91,82	748	4,32	32,27	169,2	62,0	26,3	62,0	706,6	131,2	2,73
40 t manure/ha	7,96	0,302	78,32	720	4,50	34,2	151,2	62,5	27,7	64,3	749,2	133,0	2,71
Unfertilized	7,95	0,230	49,98	663	4,04	33,3	153,5	64,3	27,8	64,0	742,6	126,6	2,88

The unfertilized version has recorded a total nitrogen content of 0,230 %, whereas, by mineral fertilization with 30 kg/ ha and 60 kg P₂O₅/ha in maize crops and 80 kg N+ 80 kg P₂O₅/ha in wheat crops, the total nitrogen content has augmented to 0,257% and in the trial fertilized with 40 t/ha manure per ha, the total nitrogen content has reached 0,302%, exceeding by 0,072% the unfertilized version.

The data presented in table 1 show that the soil reaction, both in the unfertilized trial and in the organically, mineral or organo - mineral fertilized trials was unaltered, neutral or slightly alkaline, propitious for the growth and the development of plant.

Under the influence of fertilizers, especially of organic ones, there has been an important increase in the content of phosphorus and potassium in soil. The highest content (from 78 to 91 ppm P and from 720 to 748 ppm K) has been recorded in parcels fertilized with manure, in a dose of 20-60 t/ha. The content for these trials has reached the level of very well supplied.

Fertilization with manure has influenced favorably the humus content of soil. In comparison with a content of 4,04% without fertilizers, chemical or organo - chemical fertilization has improved the humus content with up to 0,32%. A stronger mineralization of the organic matter has been recorded in the trial fertilized exclusively with mineral fertilizers (NP), reflected through the humus content, lower in percentage, of 4,21% in comparison with the trial fertilized with 60 t/ha of manure+ N₂₅P₂₅, where the humus content is 4,36%.

Mineral fertilization has had a positive influence on the quality and quantity of the wheat and maize crops, but it contributed less to the increase in humus content.

The microelement content, zinc and manganese, does not vary by large quantities as a result of fertilization. The presence of some of the heavy metals: Cu, Pb, Co, Ni, Cr, Cd, is noticed in concentration on clayey soils, like the chernozem from Turda; in these types of soils, on the one

hand sulphur and on the other hand the clay-humus compound have contributed to slow, but permanent accumulation of chemical elements.

2. The influence of fertilizers on wheat and maize yields

Researches conducted at the Agricultural Research Station in Turda, on a clayey chernozem soil, in long- term experiments, ever since 1967, highlight the importance of fertilization with manure in maintaining soil fertility, as well as in augmenting wheat and maize yields. The results obtained in the trials fertilized with fermented manure are similar to those obtained in the trials fertilized small quantities of mineral fertilizers (table 2).

Table 2: The Efficiency of Manure in the first year of use on Maize and the third year of use on Wheat (1991-2001)

The variant of fertilization on maize	MAIZE				The var. of fertil. on wheat	WHEAT			
	Q/ha	%	Dif.	Semnif		Q/ha	%	Dif.	Semnif.
N ₁₅₀ P ₆₀	60,71	150	20,1	xxx	N80P80	49,1	153	17,1	xxx
20t manure+N120P50	64,70	159	24,1	xxx	N120P80	51,5	160	19,5	xxx
40t manure+N80 P30	65,3	160	24,7	xxx	N80P80	50,3	157	18,3	xxx
60t manure+N50 P25	65,5	160	24,9	xxx	N80P80	51,3	160	19,3	xxx
20 t manure	63,2	156	22,6	xxx	N120P80	51,8	162	19,8	xxx
40 t manure	63,7	156	23,1	xxx	N80P80	52,3	163	20,3	xxx

The highest maize yield were obtained in the trials which received fermented manure combined with mineral fertilizers, and the most economical increases of yield were recorded for a manure dose of 20 t/ha. There are only slight differences in quantities between the trials fertilized with 40 t/ha or 60 t/ha of manure and those fertilized with 20 t/ha. The average increase of yields within the reference period has varied between 20,1 q/ha and 24,9 q /ha, i. e. 50-60% in comparison with the unfertilized trials.

The organo - mineral fertilization ensures both the immediate and the long-term needed nitrogen. Manure is a valuable fertilizer for wheat as well, especially on heavy, acid soils, with scarce physical features. Wheat also capitalizes well the subsequent effect of manure used on maize crops; in this way, any organizatory difficulty related to manure incorporating on wheat crops is eliminated.

As to wheat, fertilization with 80-120 kg N/ha +80 kg P₂O₅ /ha, against a background of maize fertilization with 20-60 t /ha, has ensured superior yields in comparison to the control (table 2). The growths obtained have varied between 17,1- 20,3 q/ha, i.e. 53- 62%. These result have emphasized the positive contribution of mineral fertilization against a background of the initial manure fertilization.

The high fluctuation in weather condition is reflected by the ample variation of yields. Production will be steadier when the difference between the maximum and the minimum yields during the experiment is lower.

During the reference period, pluviometer quotas manifested a big range of variability, going from very favorable years to very droughty ones, totally hostile to wheat or maize crops, with strong influences on the obtained yields (table 3). Between 1991- 2001, the biggest maize yield was obtained in 1992, when the quantity of rainfall reached a satisfying level in July- August, which is the grain filling period. The smallest yield was recorded in 1995, when the quantity of rainfall from July and August was 71,0 mm (8,0 mm in July).

Table 3: The production of maize and wheat according to weather condition

Var	MAIZE						WHEAT					
	Minimum			Maximum			Minimum			Maximum		
	Q/ha	Dif.	%	Q/ha	Dif.	%	Q/ha	Dif.	%	Q/ha	Dif.	%
1	41,5	9,7	130	69,8	22,2	147	31,1	12,6	168	77,1	25,6	150
2	50,8	19,0	160	74,8	27,2	157	32,1	13,6	174	84,0	32,5	163
3	51,9	20,1	163	75,6	28,2	159	31,6	13,1	170	78,4	26,9	152
4	53,5	21,7	168	74,2	26,6	156	31,0	12,5	167	81,4	29,9	158
5	50,1	18,3	158	69,8	22,2	147	31,5	13,0	170	82,0	30,5	159
6	53,6	21,8	169	70,4	22,8	148	30,3	11,8	164	83,9	32,4	163
7	31,8	Mt.	100	47,6	Mt.	100	18,5	Mt.	100	51,5	Mt.	100

In wheat crops, the smallest quantities were obtained in 1993, a very dry year with a long drought in Mai- June, when the total amount of rainfall was 63,8 mm as compared to 151,6 mm, the multiannual mean. The biggest yields and growths obtained by means of fertilization were recorded in 1995, a very propitious year for wheat crops, when the total amount of rainfall in May- June was 180,3 mm.

3. The influence of fertilizers on the chemical composition of the harvest

The chemical analysis of the harvest of 1997, presented in table 4, emphasizes a strong connection between the doses of used fertilizers and the chemical composition of the harvest for the two studied plants. It is noticed that there is a significant increase of the percentage of nitrogen and therefore of the protein. The highest growths were recoded in the trials which received organic and mineral fertilizers.

Table 4: The influence of organic and mineral fertilization on certain quality features of wheat and maize

Variant of fertilization on maize	Maize- first year of use				Variant of fertilization on wheat	Wheat- third year since organic fertilization						
	N %	P2O5 %	K2O %	Prot %		N%		P2O5%		K2O%		Prot
						grain	plant	grain	plant	grain	plant	
N ₁₅₀ P ₆₀	1,43	0,48	0,27	8,34	N80P80	1,96	0,53	1,04	0,16	0,45	1,02	11,42
20t manure+N120P50	1,78	0,63	0,28	10,38	N120P80	2,19	0,60	1,05	0,17	0,46	1,12	12,76
40t manure+N80 P30	1,81	0,59	0,28	10,55	N80P80	2,15	0,56	1,05	0,17	0,46	1,15	12,53
60t manure+N50 P25	1,83	0,61	0,27	10,66	N80P80	2,12	0,55	1,06	0,18	0,47	1,13	12,35
20 t manure	1,63	0,57	0,27	9,50	N120P80	1,93	0,54	1,03	0,17	0,46	1,05	11,25
40 t manure	1,68	0,59	0,28	9,79	N80P80	1,95	0,56	1,04	0,18	0,46	1,09	11,36
Nefertilizat	1,41	0,40	0,27	8,22	Nefertil.	1,84	0,51	0,91	0,15	0,45	0,98	10,72
DL5%=0.25	0.81	0.012	1.83		0.11	0.03	0.06	0.03	0.035			

Thus, nitrogen percentage has increased significantly from 1,41 when unfertilized to 1,83 when fertilized with 60 t manure + N₅₀P₂₅ . In wheat crops, the nitrogen content in the grain augmented from 1,84 to 2,12% when fertilized identically. Only by organic fertilization on maize, the nitrogen content in the grain of both plants is lower, i.e. 1,63-1,68% for maize and 1,93- 1,95% for wheat.

Under the influence of organic and mineral fertilization, the phosphorus content also increased significantly both in maize grains (from 0,40% to 0,63%) and in wheat straws and grains. The potassium content accumulated in grains and straws was not significantly influenced by fertilization.

Conclusions

Manure is a valuable fertilizer, with positive influence both on wheat and maize yields and on soil fertility.

On the clayey chernozem, in non- irrigated crops, manure must be directed mainly toward maize crops, as wheat efficiently capitalizes its prolonged effect.

For maize, the most economical fertilization is obtained in a dose of 20 t/ha of manure, but the highest yields have been obtained in the trials in which fermented manure has been used in combination with mineral fertilizers.

The use of fertilizers in stationary have also influenced the quality of wheat and maize crops, increasing the nitrogen and therefore the protein content.

The phosphorus content in maize grain and wheat straws and grain has suffered significant influence from the used fertilizers, and the potassium content has practically remained the same.

Systematic fertilization with manure has contributed to an increase of the humus content as well as the total nitrogen, phosphorus and mobile potassium content.

In future, the organo - mineral fertilization will represent an essential element of a modern and durable agriculture. Under any circumstances, the main concern should be to preserve the Earth and the environment, to use rationally one of the greatest riches of the planet, which is fertility. It is a fundamental duty of future generation.

Summary

In the paper, there are presented the results obtained at a.r.d.s:- Turda- Romania, in the period 1982-2002, concerning the influence of the manure in a long-term experiment in wheat and maize, on a clay - iluvial vertic chernozem under nonirrigation conditions.

The soil is typical of the forest steppe region in the plain of Transilvania, with good fertility, well supplied with total nitrogen (0,196%), with medium supplies of assimilable phosphorus (15-20 ppm P), high content of mobile potassium(250 ppm K) and organic matter (3,92%).

The experiment is made on the bean- wheat- maize rotation. The maize is fertilized with 20; 40 t/ha fermented manure and 20; 40; 60 t/ha fermented manure + mineral fertilizers; the wheat is fertilized only with chemical fertilizers in rates of 80-120 kg N/ha and 80 kg P/ ha.

According to the results of the last 20 years research a controlled organic fertilization is recommended firstly on maize, which utilizes small rates, 20-40 T /ha and then on wheat, which utilizes remnant effect on the fertilization. The average increases of yields within the reference period has varied between 20,1 q/ ha and 24,9 q /ha, i. e. 50-60% in comparison with the unfertilized plots.

The use of fertilizers in stationary have also influenced the quality of wheat and maize crops, increasing the nitrogen and therefore the protein content.

Systematic fertilization with manure has contributed to an increase of the humus content as well as total nitrogen, phosphorus and mobile potassium content.

References

- Ciobanu, Gh.**, 1999 – Influența îngrășămintelor organice și minerale asupra producției și calității grâului și porumbului. “ Agric. durabilă-performantă”.Ed. Agris-București, p.227
- Dincă, D., Cîmpeanu, Henriete, Tăbăranu, T.**, 1971- Influența îngrășămintelor minerale și organice asupra producției și calității la grâu și porumb pe solul brun roșcat de pădure. Analele ICCPT vol. XXXVII, seria B, p. 158.
- Hera, Cr., Eliade, Gh., Ghinea, L.**,1986 - Contribuții ale cercetării științifice românești privitoare la rolul materiei organice în fertilitatea și fertilizarea solurilor. Probl.de agrof. teor. și aplic. VIII(2) p.119.
- Hoffman, J.**, 2001- Assesment the long-term effect of organic and mineral fertilization on soil fertility. 12th WFC-Fertilization in the third millenium-Beijing.
- Patel,B.A., Patel, R.H., Amin, A.U.**, 1992 - Effect of combined application of organic sources and inorganic fertilizer on wheat. Crop Science, vol.11,nr.5.
- Sarkadi, J.**, 1993-Nutrient use efficiency of organ manures and mineral fertilizers in long-term experiments. Crop Science, vol.11,nr.5.

CHALLENGES CONCERNING FERTILIZER USE AND MANAGEMENT PRACTICES IN THE BANANA INDUSTRY IN SOUTH AFRICA

J.H. van der Waals, C. Kaiser and L. D. Stronkhorst

Department of Plant Production and Soil Science, University of Pretoria, Pretoria, 0002, South Africa.

Abstract

Currently one of the biggest threats to banana production in South Africa is Panama disease (*Fusarium oxysporum* Schlet. f.sp. *cubense* (E.F. Smith) Snyder and Hansen) - and it is most prevalent in the warm subtropical Mpumalanga lowveld area. Studies on the control of different species of *Fusarium* in crops other than banana indicated that soil pH, nitrogen (N) concentration, application and form (NO_3^- versus NH_4^+), as well as micronutrients played an important role in controlling or suppressing pathogenic infections. Very little research had been conducted up to the present on the relationship between Panama disease and fertilizer related management practices. Several workers have also raised concern that excessive amounts of N are being applied to bananas with subsequent environmental degradation. To investigate the link between fertilizer practices and Panama incidence, several trials (some on pilot scale) were implemented. These ranged from soil and foliar applications of micronutrients in winter (where leaf concentrations were deficient), through soil and water culture greenhouse trials, to field surveys of soil characteristics. Preliminary results from the micronutrient trials indicated that combinations of several nutrients applied as leaf sprays had a positive effect on plant vigour. In contrast, simultaneous soil applications of these micronutrients to other plants had detrimental effects and in some cases resulted in attrition. Results from the soil and water culture trial indicated that N concentration and form had significantly different effects on growth of the plants and this is mainly attributed to rhizosphere influences in the soil. An integrated management plan, which manipulates plant nutrition, is envisaged to control the incidence of Panama disease of bananas in South Africa and as a consequence will minimize leaching of excess nutrients such as N into the environment.

Introduction

Currently one of the biggest threats to banana production in South Africa is Panama disease (*Fusarium oxysporum* Schlet. f.sp. *cubense* (E.F. Smith) Snyder and Hansen – referred to as Foc hereafter). It is most prevalent in the warm subtropical Mpumalanga lowveld area close to the town of Kiepersol. In this area almost 30 % of banana fields (> 1000 ha) have been lost to Panama disease (Viljoen, 2002). The soil-borne pathogen infects the roots of the plant and subsequently colonizes the rhizome. From here it produces copious amounts of spores and causes the blockage of the plant's vascular system. In South Africa the disease symptoms are most severe just after winter when the average minimum temperature is 11°C (Viljoen, 2002).

Studies on the cultural control of different species of *Fusarium* in crops other than banana indicated that soil pH played an important role in controlling or suppressing pathogenic infections (Woltz and Jones, 1981). Several workers (Sarhan and Sharif, 1986; Duskova and

Prokinova, 1989; Höper *et al.*, 1995) found that high pH suppressed disease severity in a variety of crops. The addition of lime has also been found to suppress the disease (Peng *et al.*, 1999). The role of Ca in the suppression of Fusarium wilts has however been discounted by Jones *et al.* (1989) They concluded that it is the increased pH associated with the application of liming products that suppresses disease severity.

Numerous nutrients have been listed as having a suppressive effect on chlamydospore germination of Fusarium wilts. These include Ca compounds and phosphate salts (Huang *et al.*, 1989) as well as high K applications (Woltz and Jones, 1981). The availability of Fe (and other micronutrients) plays an important role in the germination of chlamydospores and this availability can be directly linked to pH (Chuang, 1991). In trials where different Fe chelates were added to the soil, the disease was less severe in the treatments where the complexes had very high stability constants (Scher and Baker, 1982) therefore rendering the Fe less available for chlamydospore germination.

The levels and type of N-fertilizer applied also play an important role in the incidence of Fusarium wilts. High levels of applied N generally increase (Woltz and Jones, 1981) and low levels retard disease severity (Schneider, 1990). Furthermore, the application of NO₃-N decreases disease severity but the application of NH₄-N increases disease severity even in soils that are suppressive to Fusarium wilt (Woltz and Jones, 1981). The authors of this paper are of the opinion that this effect is an influence on the rhizosphere pH and that the pH effect, as discussed previously, applies.

Very little research has previously been conducted on the relationship between Panama disease and fertilizer related management practices. Viljoen (2002) lists the conclusions of trials that were conducted mostly by farmers. It is not clear whether these trials were properly randomised or included adequate control treatments.

The predominant soils that are used for banana cultivation in the area range from high clay content red soils (Fe rich) derived from dolerite and diabase to coarse sandy soils derived from granites. Most soils have an influence of both parent materials with the higher potential soils dominated by a dolerite/diabase influence. Ironically, the higher potential soils are also the soils with the highest Panama incidence and therefore are removed from the banana production cycle first. Often bananas are replaced by avocados.

During visits to different farms and through consultation with farmers it was found that several of the management practices applied in the area are a cause for concern. High levels of K are used but this seems to be in line with recommendations. The use of N, however, is very high in

some cases when compared to removal factors. Some farmers have mentioned that they have applied farmyard manure up to 100 tons ha⁻¹ during the establishment of banana orchards and that inorganic fertilizers equal to recommended rates are used simultaneously. In fertilizer recommendations there is no provision made for N returned to soil through large quantities of decaying plant material. The excessive N applications seem to be confirmed by farmers' observations that when plants with Panama disease are taken out of production (and N applications are halted) many of the plants produce normally the following year without any fertilizer amendments. Excessive N in the soils is also the cause of fruit quality problems when bananas are replaced with avocados.

Several workers have raised concern that the excessive amounts of N being applied to banana possibly leads to environmental degradation. Irrigation dams in the area are fed by runoff and groundwater from the plots where the bananas are produced. The water from these dams usually contains high levels of NO₃⁻ as well as Fe – an element that several farmers have tried unsuccessfully to remove from the water by different means.

Viljoen (2002) states that if a solution is not found, continued production “will be difficult, if not impossible”. He further states that there is currently no cure for Fusarium wilt of banana in South Africa. Tolerant cultivars are also currently not acceptable to the local market in terms of taste. In the light of these statements, as well as the literature available on Fusarium wilt of other crops, it was decided to investigate the role of different plant nutrients under local conditions on the vigour of banana plants in Foc infested soil.

Trials

To investigate the link between fertilizer practices and Panama incidence, several trials (some on pilot scale) were conducted.

Soil and foliar applications of micronutrients

Different micronutrients and combinations thereof were applied to the soil and the leaves of banana tissue culture plantlets in a Fusarium wilt “hotspot” in the Kiepersol area. In this area the disease is most prominent just after the winter months, probably due to the recommencement of growth after the winter stress period. The treatments consisted of commercially available element chelates of Mg, Cu, Zn, and Fe and MgSO₄ and CaSO₄. These were applied to entire rows of twenty young banana trees on 13 August 2002. MgSO₄ and CaSO₄ soil applications were included in the treatments due to regularly occurring low Ca and Mg levels in plants in the area.

Chlorophyll fluorescence readings were taken as an average of three readings per leaf of the youngest fully expanded leaf on a monthly basis using a Minolta SPAD-502 leaf chlorophyll meter, from 15 September until 15 December and averages graphed for each of the above treatments. Simultaneously, plant height was recorded on the same day for each plant with ratings of 1 = 0-50 cm; 2 = 51-100 cm; 3 = 101-150 cm and 4 = 151-200 cm. Results were averaged and plotted over the same time period.

Results from the micronutrient trials (Kaiser and van der Waals, 2003) indicated that a combination of Mg, Zn, Cu, and Fe as a leaf spray had a positive effect on plant vigour compared to elements individually applied. Of the individually applied micronutrients Mg had the highest positive effect, but less so than the combination treatment. In contrast, the soil application of MgSO_4 had a very negative effect on plant vigour and in this treatment many plants appeared highly stressed (retarded growth and signs of yellowing). This trend was however not confirmed by the chlorophyll fluorescence readings that indicated no obvious differences between any of the treatments except the control.

Soil and water-culture greenhouse trials

Tissue culture banana plants of a highly susceptible cultivar (Williams) were planted in soil collected from a Fusarium wilt “hotspot” in the Kiepersol area. One plant was planted per pot and there were four replicates of each treatment. The trial consisted of one set of treatments that received lime and another which did not. The treatments consisted of three different ratios of NH_4^+ to NO_3^- as well as three increasing total N application rates. All the soil in the pots was inoculated with millet seed that had been infected with Foc at very high concentrations. A control treatment for each of the pH treatments was included and did not receive any additions of N or millet seed.

The water culture trial consisted of the same replicates as above but with two plants per pot. A Hoagland 2 nutrient solution was used and the pH as well as N-levels and ratios were manipulated. Air was bubbled through the solution to ensure adequate mixing as well as to prevent any possible rhizosphere pH differences developing around the roots. All the plants were harvested, rated for Fusarium wilt infection, and the above ground parts dried and weighed to determine dry-matter yield.

Results presented by Stronkhorst *et al.* (2003) indicated that the high nitrate and pH treatments had a beneficial effect on plant growth in the soil pot trial. In the water-culture trial however the high nitrate treatment had a detrimental effect on plant growth as opposed to the higher pH that benefited plant growth. The lower nitrogen application rates as well as the highest nitrate

application led to higher yields in the presence of Fusarium wilt in the soil pot trial. The same trend in terms of nitrogen rates was observed in the water-culture trials. A higher NH_4 ratio led to decreased yields in some of the soil treatments and higher yields in some of the water-culture treatments. Differences between the soil and water-culture trial in terms of NO_3^- to NH_4^+ ratios are ascribed to the alteration of the pH of the rhizosphere in the soil and a uniform pH in the water-culture trial. The rhizosphere therefore played an important role in the soil as opposed to the plant's preference of nutrient element in the water-culture trial.

Field survey of soil characteristics

Soils identified by farmers and other workers as “suppressive” and “conducive” to Fusarium wilt have been sampled randomly and also in grids. Preliminary assessment of the data revealed no trends in terms of pH, Ca, Mg, K, and Na concentrations or P concentrations. Different statistical approaches are currently being investigated as a means to identify and clarify subtle trends in soil characteristics. Further investigations into the physical properties are also being carried out.

Conclusions and Recommendations

Although it has received little attention in the past, an integrated management plan, which manipulates plant nutrition, is envisaged to control the incidence of Panama disease of bananas in South Africa. This will be investigated through the implementation of several field and greenhouse trials.

Present environmental legislation places the onus on the farmer and management practices will therefore have to be altered through extensive consultation with farmers. Regular monitoring of nutrient fluxes will be required and the importance of this aspect will have to be effectively communicated to the farmers and fertilizer companies.

References

- Chuang, T.Y., 1991. Soil suppressive of banana Fusarium wilt in Taiwan. *Plant Protection Bulletin* (Taiwan R.O.C.) 33: 133-141.
- Duskova, E., & Prokinova, E., 1989. Interaction between growing substrate composition and Fusarium wilt of carnation. In Vancura, V., & Kunc, F.J., (Eds.) *Interrelationships between Micro-organisms and Plants in Soil*. Elsevier Science, Amsterdam, p. 403-410.
- Höper, H., Steinberg, C., & Alabouvette, C., 1995. Involvement of clay type and pH in the mechanisms of soil suppressiveness to Fusarium wilt of flax. *Soil Biology and Biochemistry*, 27 (7): 955-967.
- Huang, J.W., Sun, S.K., & Hsieh, T.F., 1989. Characteristics of suppressive soil and its application to watermelon Fusarium wilt disease management. *Plant Protection Bulletin* (Taiwan R.O.C.), 31: 104-118.
- Jones, J.P., Engelhard, A.W., & Woltz, S.S., 1989. Management of Fusarium wilt of vegetables and ornamentals by macro- and microelement nutrition. In Engelhard, A.W., (Ed.), *Soilborne plant pathogens: management of diseases with macro- and microelements*. APS Press, St. Paul, Minnesota, p. 18-32.
- Kaiser, C., & van der Waals, J.H. 2003. Effects of different mineral element foliar sprays and soil application on Panama disease (*Fusarium oxysporum* f.sp. *cubense*) of bananas. Golden Jubilee Congress (Soil Science Society of South Africa, South African Society of Crop Production, Southern African Society for Horticultural Sciences), Stellenbosch, 20-23 January 2003.
- Peng, H.X., Sivasithamparam, K., & Turner, D.W., 1999. Chlamydospore germination and Fusarium wilt of banana plantlets in suppressive and conducive soils are affected by physical and chemical factors. *Soil Biology and Biochemistry*, 31: 1363-1374.
- Sahran, A.R.T., & Sharif, F.M., 1986. Integrated control of Fusarium wilt of pepper. *Acta Phytopathologica et Entomologica Hungarica*, 21: 123-126.
- Scher, F.M., & Baker, R., 1982. Effect of *Pseudomonas putida* and a synthetic iron chelator on induction of soil suppressiveness to Fusarium wilt pathogen. *Phytopathology*, 72: 1567-1573.
- Schneider, R.W., 1990. Influence of mineral nutrition on Fusarium wilt: A proposed mechanism involving cell water relations. In Ploetz, R.C., (Ed.), *Fusarium Wilt of Banana*. St. Paul, Minnesota, APS Press, p. 83-91.
- Stronkhorst, L.D., Viljoen, A., Claassens, A.S., Nel, B., & van der Waals, J.H. 2003. The effect of N-fertilization and pH on the incidence of Fusarium Wilt (Panama disease) of banana in greenhouse trials. Golden Jubilee Congress (Soil Science Society of South Africa, South African Society of Crop Production, Southern African Society for Horticultural Sciences), Stellenbosch, 20-23 January 2003.
- Viljoen, A., 2002. The status of Fusarium wilt (Panama disease) of banana in South Africa. *S. Afr. J. of Sci.*, 98: 341-344.
- Woltz, S.S., & Jones, J.P., 1981. Nutritional requirements of *Fusarium oxysporum*: basis for a disease control system. In Nelson, P.E., Toussoun T.A., & Cook, R.J., (Eds.) *Fusarium: diseases, biology, and taxonomy*. Pennsylvania University Press, p. 340-349.

USE OF MINERAL FERTILIZERS AND YIELDS OF MAJOR CROPS IN YUGOSLAVIA

P. Sekulić, R. Kastori and J. Vasin

Institute of Field and Vegetable Crops, Novi Sad, Union of Serbia and Montenegro

Introduction

The intensive growth of the world's population and the associated increases in food demand have made it necessary to permanently increase food production, i.e., to keep increasing the yields of cultivated crops. Average yields per unit area have increased significantly in recent decades. Average annual increases are estimated at 5 to 6%. When determining factors that contributed to such large advances in crop production, it becomes clear that the advances are primarily due to plant breeding, i.e., development of high-yielding varieties and hybrids, and the application of various chemicals, i.e., mineral fertilizers, pesticides, growth regulators, etc. The contribution of mineral fertilizers is estimated at 35%. The following example illustrates the importance of mineral fertilizers. In the years 1800, 1875, 1900, 1925, 1950, 1975 and 1982/83 in Germany, cereal production was 7.3, 12.0, 18.4, 22.8, 29.8, 44.4 and 54.7 dt/ha, respectively. In the same years, the use of mineral fertilizers ($N + P_2O_5 + K_2O$) increased at the following rate: 0, 3.1, 15.6, 43.9, 101.9, 233.5 and 267.5 kg/ha, respectively.

The above data as well as many others are a clear indication that the progress achieved in plant production has been predominantly but not exclusively due to the application of chemicals, especially the application of mineral fertilizers. On the other hand, the application of mineral fertilizers, herbicides and other chemicals has created a new set of problems, which seem to be coming to a peak.

Yields and application of fertilizers

In Yugoslavia, in spite of the edaphic and climatic conditions favorable for crop production, the average yields of major crops have been much behind the top yields achieved in the world. In part this was due to inadequate mineral fertilization.

In recent years, the average yields of the staple crops have stagnated at the level much below those achieved in West European countries (Table 1). Furthermore, the average annual yields have registered large variations, which were primarily due to weather conditions. Yields have also varied among regions. Because of favorable soil conditions and intensive cultural practices

applied, the yields in the northern part of the country, the Vojvodina Province, have been considerably higher than those obtained in the other parts of the country.

Table 1: Development of crop yields in Yugoslavia, in t/ha (2000 Statistical Yearbook of Yugoslavia)

CROP	1955	1965	1975	1985	1995	1996	1997	1998	1999	2000
Wheat	1.31	2.28	2.98	3.79	3.42	2.58	3.64	3.73	3.29	2.95
Corn	1.56	2.49	4.35	4.13	4.25	3.73	5.08	3.83	4.84	2.44
Sugarbeet	20.4	37.0	40.0	41.9	27.4	34.6	36.8	36.9	41.3	23.9
Sunflower	0.99	1.79	1.43	2.34	1.74	1.90	1.62	1.75	1.48	1.49

The main reasons for stagnant yields have been the insufficient application of organic fertilizers, mineral fertilizers and herbicides and inadequate soil cultivation and crop tending, caused by low prices of agricultural products and the resulting reluctance to invest in agricultural production.

Another reason for stagnant yields has been the insufficient utilization of the yield potentials of the genotypes used. It is estimated for some crops that the utilization of genetic yield potentials was below 60%.

The application of mineral fertilizers in Yugoslavia had been consistently lower in comparison with West European countries. The disintegration of the ex-Yugoslavia further reduced the application of all mineral fertilizers. In last 10 years, the application of mineral fertilizers was practically symbolic (Table 2). Simultaneously with the decline in the amounts of fertilizers applied, there occurred a disparity in the ratio among the N-, P- and K-fertilizers used. It was not uncommon that only N-fertilizer is applied.

Table 2: Application of mineral fertilizers and nutrients ratio in FR Yugoslavia

YEAR	ACTIVE SUBSTANCE, kg/ha of arable land			NUTRIENTS RATIO		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
1985	57.28	30.28	26.19	1	0.53	0.46
1991	29.63	12.55	11.32	1	0.42	0.38
1992	23.63	10.68	9.66	1	0.45	0.41
1993	15.82	3.29	3.08	1	0.21	0.19
1994	12.72	2.46	2.26	1	0.19	0.17
1995	12.51	2.87	3.08	1	0.23	0.24
1996	15.45	4.12	4.12	1	0.27	0.7
1997	18.36	5.36	5.57	1	0.29	0.30
1998	18.40	3.80	4.30	1	0.21	0.23
1999	15.76	3.15	3.38	1	0.20	0.21
2000	16.67	3.60	4.05	1	0.21	0.24

The soils of the Vojvodina Province, which make 40% of the national agricultural land, are highly fertile (chernozems, black soils, alluvial soils) and well provided with available potassium and to a degree with available phosphorus (Kastori, 2000). The previous statement may be confirmed by the results of a long-term stationary trial in which the application of nitrogen was the key determinant of yield level (Table 3). The favorable influence of nitrogen may explain the steady shift in the ratio of applied NPK fertilizers in favor of nitrogen (Table 2).

Table 3: Effect of different doses and ratios of NPK fertilizers on the yields of wheat, corn, sugarbeet and sunflower in a long-term experiment established in 1966 on the chernozem soil (Sarić and Jocić, 1993)

VARIANT kg/ha	AVERAGE YIELD OF GRAIN (t/ha) in the period 1966-1990				AVERAGE YIELD OF GRAIN (t/ha) in the period 1986-1990			
	Wheat	Corn	Sugarbeet	Sunflower	Wheat	Corn	Sugarbeet	Sunflower
Control	2.22	6.85	2.45	1.76	2.69	7.25	36.0	2.22
N ₁₀₀	4.71	10.30	27.0	2.21	4.61	10.16	43.5	2.58
P ₁₀₀	2.59	7.35	28.2	1.77	2.90	7.35	40.0	2.24
K ₁₀₀	2.13	6.30	25.1	1.67	2.68	7.04	37.0	2.19
N ₁₀₀ P ₁₀₀	5.69	10.73	39.5	2.23	5.49	10.31	51.7	2.64
N ₁₀₀ K ₁₀₀	4.46	10.79	26.9	2.12	4.70	10.44	44.8	2.57
P ₁₀₀ K ₁₀₀	2.62	7.48	27.7	1.69	2.85	7.22	39.3	2.25
N ₁₀₀ P ₁₀₀ K ₁₀₀	5.53	10.77	40.6	2.39	5.57	10.41	53.2	2.68

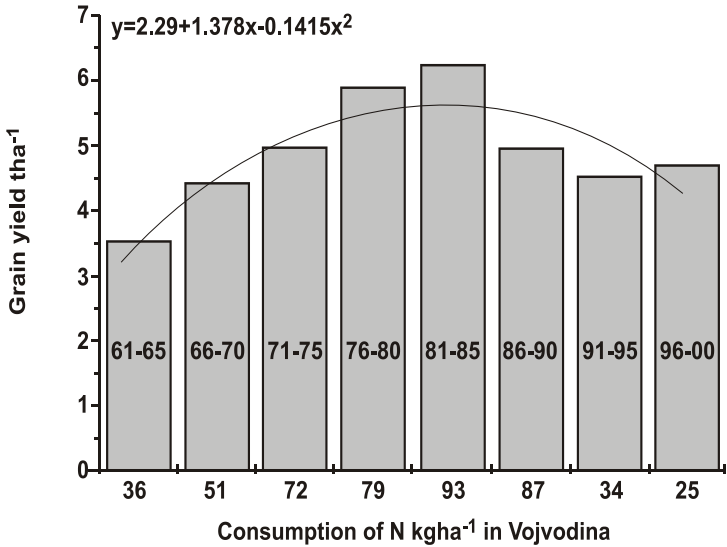
Among the crops grown, sugarbeets receive the highest amount of fertilizers, the soybean and sunflowers the lowest. Wheat is frequently only top-dressed with N-fertilizers. Mineral fertilization is more intensive in the Vojvodina Province than in the other parts of Yugoslavia. In the not-so-recent past, mineral fertilization was more intensive and more regular in the public sector than in the private sector.

There are no reliable data on the extent of use of organic fertilizers - there are only estimates which are frequently arbitrary. The animal production in Yugoslavia is underdeveloped. It has been estimated that there are only 0.4 heads of cattle per one hectare of arable land. The organic fertilizers in use are farmyard manure and semi-liquid manure. Composting and green manuring are not typically used.

The average yields of the major crops kept increasing till the mid-1980s. After that, they leveled off or even decreased, in spite of the introduction of genotypes with increased genetic yield potentials. Highest yields were obtained in years in which largest amounts of fertilizers were applied. That larger yield reductions were not suffered can be attributed to the high fertility of the soils in the main agricultural region of the country.

Figure 1 illustrates the above statement. There is a clear positive correlation between the applied doses of nitrogen fertilizers and corn yield in the last four decades. There is no doubt that the yield reductions were not exclusively due to a reduced use of mineral and organic fertilizers. The unrewarding economic position of agriculture discouraged the normal investing, which negatively affected the agricultural production.

Graph 1: Relationship between N consumption and corn yield (Starčević et al., 2003)



Nutrients balance

Because of the insufficient application of mineral and organic fertilizers, the balances of N, P and K in the cultivated land of Yugoslavia have become negative (Table 4). If this regrettable trend continues, and there seem to be good prospects for it, further reductions in crop yields may be expected. Reductions in the content of organic matter in soil have been confirmed. Paradoxically, in spite of the scant application of organic fertilizers, harvest residues (wheat straw, corn stalks) are frequently burned, although the practice is banned.

Table 4: Nutrients balance in the cultivated land of Yugoslavia in 1997 (kg/ha) (Čuvardić et al., 1999)

SOURCE	N	P ₂ O ₅	K ₂ O
Removal of nutrients by main product	55.0	26.7	40.8
Nutrients added with manure	26.7	13.4	32.1
Utilized nutrients from manure	8.0	4.0	19.3
N fixed by legumes	5.2	-	-
Nutrients added with mineral fertilizers	18.4	5.4	5.6
Total nutrients added	31.6	9.4	24.8
Balance	-23.4	-17.4	-16.0

Largest amounts of NPK fertilizers were used in the period 1984-1988. Their use was more intensive in the Vojvodina Province than in the other parts of the country - the average figures were 97 kg/ha N, 53 kg/ha P₂O₅ and 45 kg/ha K₂O. The average removals of nitrogen, phosphorus and potassium from soil by the yields of the three major crops (corn, wheat and sugarbeet, with the average yields of 6 t/ha, 5.2 t/ha and 45 t/ha, respectively) were 123 kg/ha N, 45 kg/ha P₂O₅ and 85 kg/ha K₂O. These figures show that the fertilization returned 79% of N, 118% of P₂O₅ and 53% of K₂O removed by yield (Starčević et al., 2003). In last 10 years, however, the returns were only 31% N, 26% P₂O₅ and 10% K₂O. In spite of the high fertility of the most important soil types in Yugoslavia, the long-term negative balance of soil nutrients (amounts removed vs. amounts returned) resulted in reduced soil fertility and lower crop yields.

Thanks to the limited application of mineral fertilizers and pesticides (0.7 kg of active matter per ha) as well as to the underdeveloped industrial sector, soils in the major agricultural regions of Yugoslavia are not contaminated with pesticides, heavy metals and other harmful substances (Kastori, 1993) and are thus suitable for the production of safe and biologically valuable food.

Production and economy of fertilizer use

Production of mineral fertilizers on the territory of Yugoslavia started in 1904. The first fertilizer in production was superphosphate. In recent years, the production of mineral fertilizers dropped significantly, especially the production of phosphorus fertilizers (Table 5). The utilization of the domestic capacities for the production of fertilizers is exceedingly low. The annual production (in 000 t) of ammonium, urea, calcium-ammonium nitrate, superphosphate, triple superphosphate, NPK, and mono/di-ammonium phosphate is 500, 90, 500, 430, 260, 1450 and 110 t, respectively.

Table 5: Production of nitrogen and phosphorus fertilizers in Yugoslavia (in 000 t)*

Fertilizer	Year								
	1965	1975	1985	1995	1996	1997	1998	1999	2000
N fertilizers(20% N)	332	824	321	337	414	439	359	166	323
P fertilizers (16.5% P ₂ O ₅)	773	803	570	17	84	64	49	16	61

* Official Gazette of Yugoslavia

In 1999, 42 mineral fertilizers of domestic origin were on the Yugoslavian official list of registered fertilizers - 10 N-fertilizers, 5 P-fertilizers and 27 NPK or complex fertilizers. The P- and K-fertilizers are marketed almost exclusively in the form of complex fertilizers.

In recent years, the economic situation of Yugoslavia has been characterized by relatively low prices of agricultural products and high costs of agricultural inputs. Consequently, the disparity between the prices of agricultural and industrial products kept increasing and the position of agriculture became increasingly difficult (Table 6).

Table 6: Wheat price parity against other products (wheat = 1)

PRODUCT	YEAR							INDEX 2002-03 vs. 1967-71 (%)
	1967/1971	1972/1976	1977/1981	1982/1986	1987/1991	1992/1996	2002/2003	
Diesel fuel	1.4	1.6	2.0	2.5	3.2	4.9	5.5	393
Edible oil	5.3	6.4	5.9	5.9	8.3	11.2	10.0	188
Crystal sugar	2.8	4.1	3.5	2.9	5.0	8.3	5.7	203
Tractor IMT 539	31,760	33,260	26,200	22,380	37,250	55,500	54,914	173
CAN	0.6	0.6	0.5	0.7	0.7	1.4	1.4	233
Urea	1.0	1.0	1.0	0.9	1.1	1.1	1.5	150
NPK	0.6	0.8	0.9	1.0	1.1	2.1	1.6	266

The parities calculated on the basis of the ratio - wheat purchase stock exchange price vs. retail prices of respective products.

The unfavorable parity between the prices of agricultural products and agricultural inputs in general, including mineral fertilizers, and the unsteady supply of mineral fertilizers are among the main reasons for the scant use of these fertilizers.

Conclusions

The use of mineral fertilizers has always been low in Yugoslavia. In recent years, their use dwindled to symbolic amounts, especially the use of phosphorus and potassium fertilizers. In consequence to this practise, the balance of soil nutrients was negative for a long period. It also explains the low yields of the major crops and the low utilization of the genetic yield potentials of the genotypes in cultivation.

A devastating combination of low prices of agricultural commodities and high agricultural inputs pesters the Yugoslav agriculture for years. Because of this problem, further emphasized by the general economic decline, the use of mineral fertilizers has dropped drastically. The domestic production of mineral fertilizers went down and the market suppliers frequently failed to respond adequately to the shortage.

The example of Yugoslavia shows convincingly that the nature of the problem of use of mineral fertilizers in the countries in transition and in the underdeveloped countries in general differs diametrically from the problems encountered in the developed countries, which revolve around excessive use and the associated ecological problems.

References

- Bogdanović, D., Ubavić, M., Dozet, D. (1993): Chemical properties and provision of essential macroelements in Vojvodina soils. 197-215. In: Kastori, R. Ed. Heavy Metals and Pesticides in Soil - Heavy Metals and Pesticides in Vojvodina Soils (in Serbian, English summary), Faculty of Agriculture, Institute of Field and Vegetable Crops, Novi Sad.
- Čuvardić, M., Bogdanović, D., Ubavić, M. (1999): The role of fertilization in sustainable agriculture (in Serbian, English summary). Review of Research Work of the Institute of Field and Vegetable Crops, Novi Sad, 32, 271-284.
- Kastori, R. (ed.) (1993): Heavy Metals and Pesticides in Soil - Heavy Metals and Pesticides in Vojvodina Soils (in Serbian, English summary), Faculty of Agriculture, Institute of Field and Vegetable Crops, Novi Sad.
- Kastori, R. (2000): The Soil Potassium Resources and the Efficiency of Potassium Fertilizers in Yugoslavia. International Potash Institute, Basel, Country Report 14, 1-26.
- Sarić, M., Jocić, B. (1993): Biological Potential of Plants Grown in an Agrophytocoenose Depending on Mineral Nutrition (in Serbian). Serbian Academz of Sciences and Arts, Vol. 68, Belgrade.
- Starčević, Lj., Latković, D., Crnobarac, J. (2003): Current status and possible direction of field crop production in Vojvodina (in Serbian, English summary). Review of Research Work of the Institute of Field and Vegetable Crops, Novi Sad, 38, 5-19.
- 2000 Statistical Yearbook of Yugoslavia (in Serbian). Federal Office of Statistics, Belgrade.

SOIL P STATUS AND THE FUNCTION OF INCREASING CROP YIELDS IN NORTH OF CHINA

Zhou Yimin¹, Jin Jiyun² and Sun Kegang³

¹Tianjin Soil and Fertilizer Institute of TAAS, Tianjin 300192, China

²PPI/PPIC, China Program, SFI/CAAS, Beijing 100081, China

³Henan Soil and Fertilizer Institute of HAAS, Zhengzhou 450002, China

Phosphorus is one of the major elements essential for crop growth. Northern China is characterized by soil phosphorus deficiency due to some influential factors such as soil parent materials, geographical and climatic conditions. About 75% of agricultural soil acreage of the arable lands has been showed P deficiency ^[1]. The First National Soil Survey and the Second National Soil Survey in the early 1980s had basically revealed that severe soil P deficiency existed and that crop yields were restricted by P deficiency in the northern China at that time. Soil P status has been improved significantly through large scale P fertilizer application in recent years and positive balance of soil P has occurred in some regions ^[2,3,4]. In recent years, systematic evaluation of soil nutrients and a lot of field experiments have showed that soil P is still the major limiting factor, following N, to crop yields in northern China ^[5]. Therefore, it is very important for the agriculture suitability development to pay more attention to the rational application of P fertilizers in order to improve fertilizer use efficiency of P fertilizers and soil fertility building-up. The paper summarized the research results from the northern cooperative group and reviewed the soil P status, the rational application of P fertilizers, and the crop response to P fertilizers in northern China

1. The soil P status and balance of arable lands in Northern China

1.1 The soil P status and balance of the plowed layer (0-20cm)

The results from “The Monitoring Sites for Soil Nutrients on Major Soils” in northern China ^[6] showed that the soil P balance became positive due to large amount of P fertilizer inputs in farmlands during the agricultural development in the 1980s and 1990s. Table 1, 2, 3 listed the results of the N, P and K inputs and outputs of the farmlands in the northern representative provinces in different years. Nitrogen and phosphorus fertilizer input has increased significantly with years, and the P input increased much markedly. The use of P fertilizers in 1990s was about 2-8 times more than that in 1980s. The contribution of organic manures to the P input was accounted by about 25%-30%. The heavy application of various P fertilizers was the cause of positive soil P balance.

The soil available P level in the plow layer (0-20cm) was generally increased with the heavy P application, which could be seen in Figure 1 showing the changes of available P level in plow layer of selected soils from Jilin and Shandong province and Xinjiang region. Compared to the 1980s, the average soil available P level was increased by 3-10 mg/kg.

Table 1: The farmland nutrient balance sheet in Heilongjiang province(×104 tons)

Year	Input			Output			Balance		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
1967-1979	10.8	5.7	1.0	11.8	8.1	10.2	-1.0	-2.4	-9.2
1980-1984	20.6	14.7	1.2	19.4	13.4	12.5	1.3	1.3	-11.3
1985-1989	32.9	18.7	1.8	20.4	13.2	16.1	3.5	5.5	-14.3
1990-1994	51.5	30.4	3.6	46.4	15.4	21.1	5.2	15	-17.5
1995-1997	62.8	40.2	6.1	56.0	18.5	26.4	6.8	21.7	-20.3

Table 2: The farmland nutrient balance sheet in Henan province(×104 t)

Year	Input						Output			Balance		
	Fertilizer			Manure								
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
1980	35.1	7.9	2.73	23.5	14.7	38.0	72.2	30.6	70.5	-13.6	-8.0	-29.8
1992	94.1	57.0	12.9	27.2	17.9	41.2	113.3	46.1	106.0	8.0	27.8	-52.5
1997	134.4	72.2	36.1	32.8	20.5	50.0	150.9	61.9	144.4	16.3	30.8	-58.4

Table 3: The farmland nutrient balance sheet in Shanxi province(×104 t)

Year	Input						Output			(In-out)/(out) (%)		
	Fertilizer and irrigation water			Manure and seed								
	N	P	K	N	P	K	N	P	K	N	P	K
1977	127.6	6.1	5.5	113.2	17.8	60.3	256.5	37.6	156.1	-6.1	-36.4	-58.0
1987	345.0	33.3	12.3	123.8	18.8	63.3	400.4	48.8	194.6	17.1	7.2	-61.2
1997	721.6	80.9	67.1	154.0	24.0	81.9	552.9	51.8	199.2	58.4	100.6	-25.2

1.2 The vertical distribution characteristics of soil phosphorus in the profile

The study in Yutian county of Hebei province conducted by Soil and Fertilizer Institute of CAAS found the obvious accumulation of P in the surface soil (0-20cm) in cinnamon soil and fluvo-aquic soil (Fig. 2). The P concentration in surface soil was 4.7 and 5.2 times higher than that in the 20-40cm and 40-60cm layer respectively, which should be associated with the slow mobility of P applied to soil surface layer and the P adsorption and fixation in calcareous soils in northern China. The subsoil P status remained at an extreme low level although the most of the applied P stayed in surface soil. The soil area proportion of P deficiency accounted for about 62.5% in the studied sites based on the surface soil P level. However, the severe P deficiency of subsoil layer was found in all studied sites, which showed the severe unbalanced distribution of soil phosphorus.

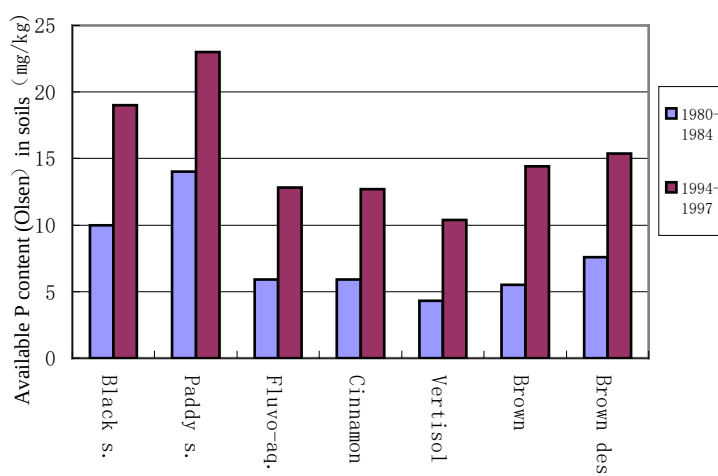


Figure 1: Soil available P level in major soils in northern China

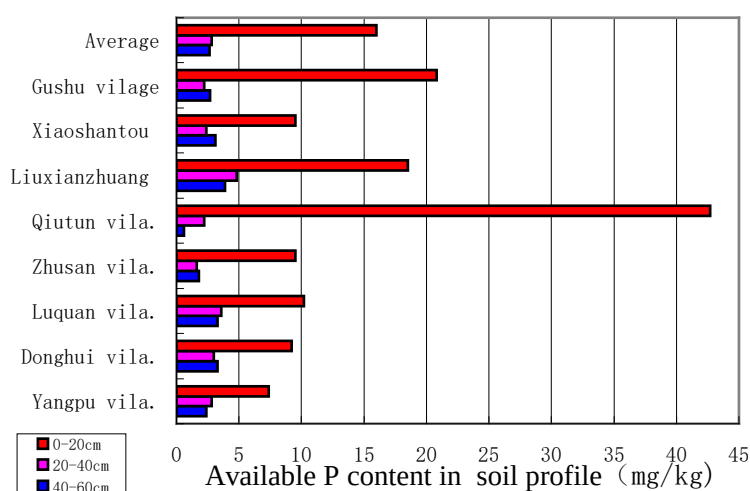


Figure 2: The profile distribution characteristics of soil phosphorus

1.3 The Effect of soil P deficiency on the crop growth

199 soil samples selected from more than 10 soil types in 13 northern provinces were studied with pot experiments using Systematic Approach for Soil Nutrient Evaluation. The results (see Table 4) showed that P, following N, was still the major soil nutrient factor restricting the crop growth. The average plant biomass in the soils with no P applied was only 49% of those with optimum nutrient treatments (OPT). The order of soil nutrients limiting the plant growth was $N > P > K > Zn > Fe > B > Mn > Cu$. The average plant biomass in control treatments (without any nutrients applied) with northeastern, north-central and northwestern soils was 32.9%, 38.6%,

and 25.0% of OPT treatments respectively, which showed the natural soil fertility in north-central region was the highest and northwestern soils had the lowest natural soil fertility (Fig. 3, 4, 5). The biomass without P fertilizer applied were 47.4%, 54. %And 43.6% of OPT treatments respectively for the northeastern, north-central and northwestern soils, which indicated that the soil P deficiency was more severe and the rational application of P fertilizers more important in regards of crop production in northwestern region.

Table 4: The soil nutrient evaluation of the soils in northern China (1992-1998)

Province	Samples	OPT	-N	-P	-K	-S	-Cu	-Fe	-Mn	-Zn	-B	CK
Heilongjiang	11	100	33.5	50.8	74.9	78.6	92.4	-	90.4	81.9	88.4	29.3
Jilin	23	100	32.2	38.9	85.3	78.1	92.4	87.3	88.2	87.8	103.0	36.4
Liaoning	12	100	46.3	52.5	75.9	81.9	77.6	85.7	98.0	81.1	83.3	-
Northeast	46	100	37.3	47.4	78.7	79.5	87.5	86.5	92.2	83.6	91.6	32.9
Hebei	18	100	62.8	68.1	87.6	84.9	87.1	83.6	89.4	87.2	72.8	52.2
Henan	32	100	28.3	33.9	81.7	71.5	83.4	84.4	85.2	81.4	85.3	24.2
Tianjin	56	100	41.5	61.3	71.0	81.9	80.4	83.7	83.1	76.1	-	44.3
Shandong	23	100	46.7	53.2	78.9	82.1	83.7	72.4	87.7	81.9	77.0	33.6
North-central	129	100	44.8	54.1	79.8	80.1	83.7	81.0	86.4	81.7	78.4	38.6
Shaanxi	13	100	41.7	33.8	80.0	70.5	78.0	79.1	78.3	77.0	78.7	-
Qinghai	7	100	39.5	45.5	77.9	-	81.0	86.2	72.1	72.5	81.8	-
Xinjiang	4	100	27.0	51.6	76.3	80.8	94.1	82.1	94.1	65.0	-	25.0
Northwest	24	100	36.1	43.6	78.1	75.7	84.4	82.5	81.5	71.5	80.3	25.0
Whole North	199	100	40.0	49.0	79.0	78.9	85.0	82.7	86.7	79.2	83.8	35.0

1.4 The soil P adsorption and fixation

The adsorption experiments with more than 60 soils by the Soil and Fertilizer Institute of Tianjin and Henan found that the soil adsorption and fixation of P accounted for 24%-57%(with an average of 36%) of P fertilizer applied. There was obvious difference in the amount adsorbed and/or fixed among soil types. The marked P adsorptions were observed by Shajiang black soils, paddy soils and clay fluvo-aquic soils. There was close correlation between the P adsorption and soil texture. A significant positive correlation was found between the soil available P level and the proportion of soil physical sand (1-0.01mm), and a negative correlation between the soil available P level and the soil clay (>0.01mm) content. There was also significant correlation between the slope of P adsorption curve and soil texture. The slope became smaller with the increase of soil clay content, which indicated the less release and less availability of P fertilizer applied in soils. The soil P adsorption characteristics should be

considered for rational P fertilizer application. A proper rate, timing and methods should be adopted on heavy soils.

Table 5: The P absorption in various soils of Henan province*

Soil type	Samples	Average adsorption to P applied (%)	Soil type	Samples	Average adsorption to P applied (%)
Shajiang black soil	4	53.2	Cinnamon soil	6	45
Sandy fluvo-alluvial soil	2	31.0	Yellow brown soil	1	32
Clay fluvo-alluvial soil	1	50.0	Brown soil	1	32
Loamy fluvo-alluvial soil	5	34.6	Paddy soil	1	57

* The percentage of adsorption and fixation accounted for total P applied to soil at addition rate at 320ug/ml.

Table 6: Correlation between the slope of P absorption curve and soil mechanical analysis

Slop of P adsorption curve	Mechanical analysis (mm)				
	1-0.01	0.01-0.05	0.05-0.001	>0.005	>0.001
P	0.583**	-0.488**	-0.446**	-0.575**	-0.468**

N=48

$r_{0.01}=0.354$

$r_{0.05}=0.273$

2. The effect of phosphorus fertilizer application on crop yield and the rational P application techniques

2.1 Crop yield response to P application

Table 7 listed the results achieved from P fertilizer experiments on various crop in the northern China. The soil available P levels of the soils under the experiments ranged from 3 to 16 mg/kg. The yields increased by one kg fertilizer P differed greatly on various soil types and under different soil fertility conditions. With P fertilizer application, the average of grain crop yields increased by 12.5%, with 8.7kg grain increase per kg P_2O_5 . The yield of winter wheat was increased by 11.5kg per kg P_2O_5 . On cotton and sweet potato, P fertilizer increased their yield by 20%and 26% respectively. These experiment results showed that soil P deficiency should still be very severe in the northern China and the P fertilizer application should play a key role in obtaining higher, stable crop yields.

Table 7: the yield response to P fertilizer on various crops

Province	Crop	Trials	Yield increase (%)	Yield gain (kg) per Kilo P ₂ O ₅	Optimum application rate (kg/ha)	Maximum yield (kg/ha)	NPK ratio N: P ₂ O ₅ : K ₂ O
Liaoning	Spring corn	7	7.3	9.1	150	12020	180:150:180
	Soybean	6	11.9	4.3	90	3980	60:90:120
	Sunflower	1	25.3	3.9	113	2172	113:68:113
Jilin	Rice	2	5.9	5.1	113	7162	225:113:113
	Spring corn	2	11.3	14.7	92	10625	195:92:75
Hebei	Winter wheat	4	38.7	12.1	180	6174	180:180:0
	Summer corn	4	22.0	10.7	120	7650	180:120:0
Henan	Winter wheat	7	17.2	6.8	150	6450	135:150:113
	Spring corn	2	6.1	5.5	150-225	10091	200:150:113
	Turnip	1	9.1	26.4	225	47499	200:225:113
	Sweet potato	4	32.6	27.5	75	21480	75:75:0
Shandong	Winter wheat	11	24.6	15.5	120	5895	225:120:113
	Summer corn	11	15.4	10.8	60	9540	225:60:113
Shanxi	Millet	6	32.7	16.5	78-97.5	2708	78:78:0
Tianjin	Summer corn	5	11.7	8.2	93	7290	195:93:52
Xinjiang	Cotton	20	20	1.73	75-135	120	In south: 250:130:75
Ningxia	Spring wheat	22	11.3	7.5	90-120	5408	180:90:0

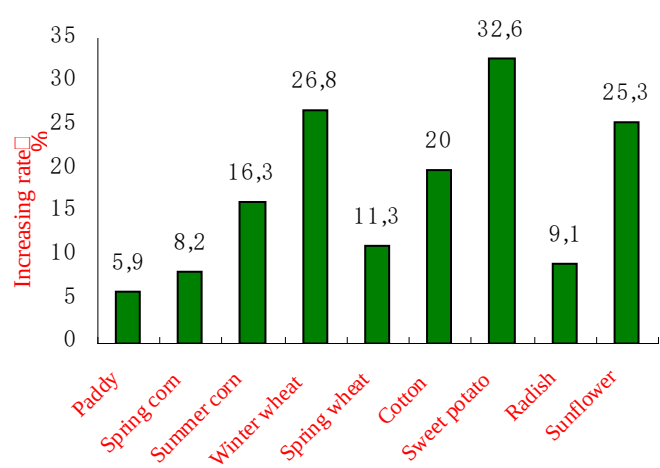


Figure 3: the yield increase effect of P fertilizer on various crops

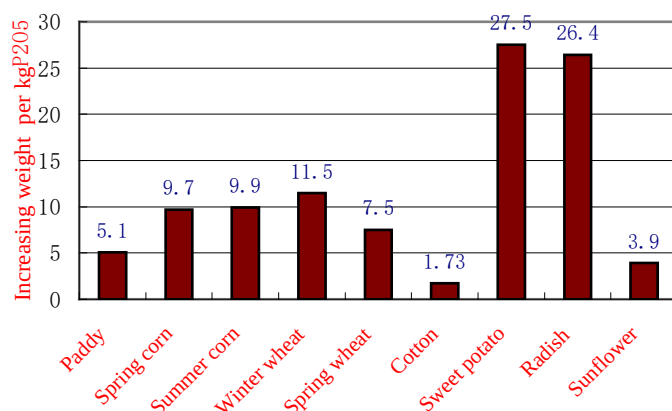


Figure 4: the yield increase per kg P₂O₅ on various crops

2.2 The rational P fertilizer application in terms of long-term fertilization

The agro-chemical properties of phosphorus fertilizers is the strong chemical fixation of P by soil constitutes, low P mobility in the soil and low recovery of P by crops. The chemical P fixation of the P fertilizers applied into soils is significant in northern China dominated by calcareous soils. It is necessary to study the effective conditions and the application techniques of P fertilizers in order to sustain the soil nutrient balance and enhance the agricultural production.

2.2.1 Long-term fertilizer application and the soil P accumulation

Long-term fertilization experiments in a fluvo-aquic soil; Soil and Fertilizer Institute of Henan Academy of Agricultural Sciences conducted a cinnamon soil and a Shajiang black soil from 1980. Results obtained during 1980-1997 showed that the decline of total soil P concentration in the plowed layers was well correlated with the soil P input and the crop P removal. If the soil P input exceeded the crop P removal, P surplus would be occurred in soil P balance and P would be accumulated in the soil. The experiment on fluvo-aquic soil in Zhengzhou used a split plot design with two main treatments (with or without organic manure application) and four sub-treatments (with no fertilizer, N, NP or NPK fertilizer applied). All treatments had four replicates. Each plot was 46.7m². The annual rate of N application during 1980-1993 was 240kg/ha, which was equally applied to winter wheat and corn. The annual rates for P₂O₅ and K₂O were 120 and 120kg/ha respectively. After 1993, the annual rate of N application was

300kg/ha, which was also equally applied to winter wheat and corn. The annual rates for P₂O₅ and K₂O were changed to 150 and 120kg/ha respectively. The organic manure, K and P fertilizers were applied as basal fertilizers before sowing of the winter wheat. Compost and cake used as the organic manure was applied at 3000 kg/ha and 1500-2250 kg/ha respectively. The compost contained N of 1.49g/kg, P₂O₅ of 3.14g/kg and K₂O of 3.61g/kg, and the cake contained N of 4.52g/kg; P₂O₅ of 25.9g/kg and K₂O of 17.8g/kg. The 17 years' results revealed that soil P was kept in deficit balance under the treatments of control, N, organic manure, and the N plus organic manure (Fig 5). The soil total P concentration in the plow layer was sharply decreased with only N application, which was the biggest reduction treatment with soil total P reduction of 0.16g/kg over 17 years. The resulted soil total P content under N application was 0.03g/kg lower than that of control treatment. Soil total P was positively balanced at the experimental rates in all P applied treatments. The most marked increase of soil total P was observed in the treatment of integrated application of N, P and organic manure. The soil total P content under NP plus organic manure treatment was 0.33g/kg higher than the content under control treatment, and increased by 0.20g/kg from the original content over 17 years (Fig. 6). The similar trend of soil available P content was observed (Fig. 7).

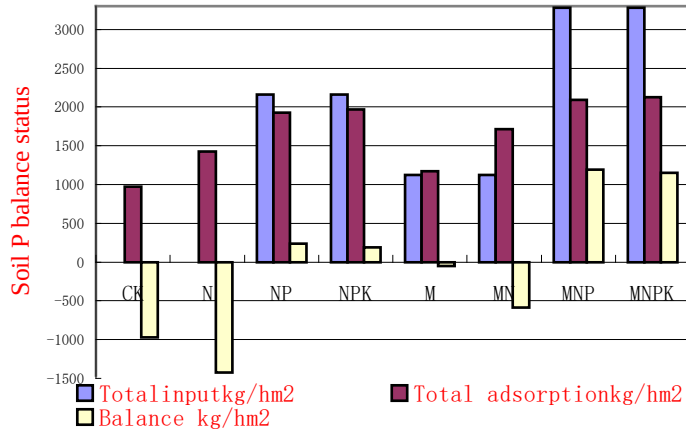


Figure 5: Soil P balance under different long term fertilization treatments

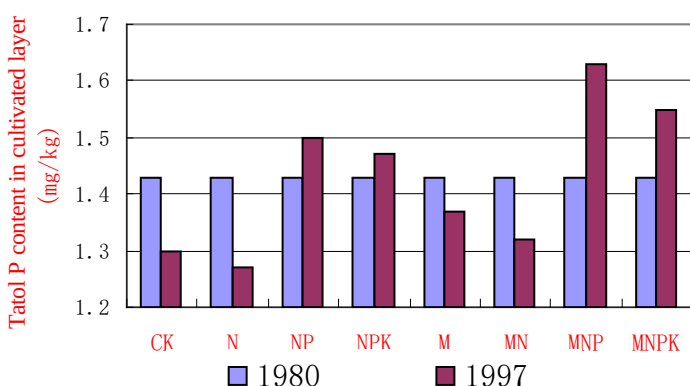


Figure 6: Soil total P in plow layer under different long term fertilization treatments

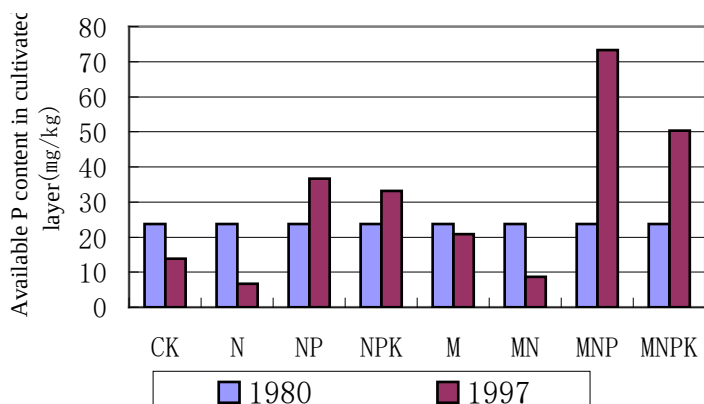


Figure 7: Soil available P level in plowed layer under different long-term fertilization treatments

Soil P accumulation was significant in surface soil both for soil total P and available P in all treatments. The soil P in the 20-40cm layers was also increased to certain extent under the treatments of NP, NPK, and NPK plus organic manure. As a result, it could be concluded that integrated application of N and P fertilizers, as well as K fertilizers and organic manures be important measures to maintain the balance of soil P and other nutrients and to assure the sustainable utilization of soil resource.

Table 8: The profile distribution of soil total P at Fluvo-alluvial soil site (g/kg)

Soil layer (cm)	CK	N	NP	NPK	M	MN	MNP	MNPK
0-20	1.30	1.27	1.50	1.47	1.37	1.32	1.63	1.55
20-40	1.07	1.11	1.17	1.12	1.08	1.07	1.26	1.26
40-60	0.95	1.04	1.00	1.00	1.03	0.96	1.08	1.07
60-80	0.86	0.90	0.90	0.96	0.91	0.87	0.93	0.90
80-100	0.85	0.62	0.90	0.90	0.89	0.87	0.92	0.90
Average	1.006	0.988	1.094	1.090	1.056	1.018	1.164	1.136

Table 9: The profile distribution of soil available P at Fluvo-alluvial soil site (mg/kg)

Soil layer (cm)	CK	N	NP	NPK	M	MN	MNP	MNPK
0-20	13.8	6.7	36.7	33.2	20.9	8.7	73.3	50.4
20-40	7.1	5.5	13.5	10.1	9.8	5.8	27.5	16.3
40-60	7.1	4.8	8.5	6.6	7.6	5.6	4.7	4.9
60-80	6.7	4.3	4.5	4.5	4.6	5.3	4.5	4.8
80-100	4.8	4.3	4.4	4.3	4.4	4.5	4.0	4.4
Average	7.90	5.12	13.52	11.74	9.46	5.98	22.80	16.16

2.2.2 The various soil P forms and their transformation and crop recovery of P fertilizers under long-term fertilization

There is a lot of information [10-18] about the soil P forms and their transformation and crop recovery of P fertilizers under long-term fertilization. Lin Zhi-an [10-16] reported that the Ca²-P was the most effective P source in the calcareous soils and Ca⁸-P, Al-P, Fe-P were the slow-release P sources with the availability order of Ca⁸-P>Al-P>Fe-P. Crops could not take up Ca¹⁰-P and occluded-P in soils. After P fertilizers were applied to calcareous soils, most of P applied would be transformed to Ca⁸-P and a small proportion of P could be changed to Al-P and Fe-P. Little Ca⁸-P would be transformed to Ca¹⁰-P in the soil Ca-P system. Lin Jixiong et al [17] reported the accumulated recovery of P fertilizer during 12 years in a long-term experiment under an annual winter wheat and corn rotation in Xinji of Hebei province. Under the winter wheat-corn cropping system, the effectiveness of initial application of 360-720 kg P₂O₅/ha could maintain to as long as 24 crops in 12 years. The yield increase resulted from one kg P₂O₅ could be accumulated to 16.8-28.8kg, which was 11.1-14.0 times higher than the corresponding value of first crop. The accumulated recovery of applied P was 26.7%-46.8%. The greater effectiveness was obtained with split application of P fertilizers. The yield increase per kg P₂O₅ increased to 31.1-42.3kg, and the accumulated recovery of applied P reached to 66.4-43.5% under the split application in 12 years. The P utilization rate decreased with the P application rates. The yield increasing effect of P fertilizer on winter wheat was greater than

that on corn. Yu Shufang et al [18] reported the results from 7 years' experiments on two calcareous soils (fluvo-aquic soil and cinnamon soil) and indicated that the contents of soil Ca₂-P and Ca₈-P increased by 2 and 0.6-1.1 mg/kg on average each year with only organic manure application. Compared with the P fertilizer applied only, soil Ca₂-P and Ca₈-P content increased by 3-4 and 0.6-4.4 mg/kg with the integrated application of organic manure and P fertilizer. Organic manure contributed much less to soil Ca₈-P increase than to Ca₂-P, while 90% of Ca-P was Ca₈-P with only application of P fertilizer. Ca₁₀-P content in two soils was reduced with organic manure application. It is suggested that organic manure decreased soil P fixation and enhanced the activation of soil original ineffective P source.

2.2.3 Determining P application rate according to soil P supply ability

It is necessary to determine the rational P rate based on the soil P supply ability. The soil deficiency indices according to the soil testing of available P value and crop response equations for P fertilizer application based on field experiments have been developed by most provincial soil and fertilizer institutes in northern China. With the help of these achievements, maximum economic P application rate could be derived for soils with different fertility and different soil P availability.

The transformation of different soil P forms in calcareous soils in northern China was also influenced by soil conditions such as soil water and temperature regimes. The studies of Shandong soil and fertilizer institute revealed that soil available P content showed higher values in summer season and lower in winter season under the winter wheat–corn rotation system. Soil available P content tended to be the lowest during the period of winter wheat seedling stage from winter to early spring and the highest from sowing to bolting of corn. With the annual yield goal of 10500kg/ha, P fertilizers should be applied to winter wheat and residual effect of P fertilizer be used by corn. With the annual yield goal of 12000kg/ha, P fertilizers should be distributed to two crops, with “heavy dose for winter wheat and slight dose for the following corn crop.

Summary

According to the recent studies on soil P status and P fertilization in northern China, following could be concluded:

- (1) With the development of agriculture and P fertilizer input, soil P balance tended to be positive. Soil P level in surface layer has been increased.
- (2) The results of pot experiments of the systematic approach for soil nutrient evaluation in northern China showed that P, following N, was still the major soil limiting nutrient for the crop growth. The average biomass production without P applied was only 49% of that with all the deficient nutrients applied. The soil P deficiency in the Northwest seems to be more severe.
- (3) Soil fixation of P applied accounted for 24%-57% of P application with an average of 36%. Soil P adsorption and fixation differs largely among soil types and correlated closely with the soil texture.
- (4) The crop yield response to P application differed significantly on various soils with different soil fertility conditions. On average, P fertilizer application could increase the yields of grain crops by 12.5% and one kilogram of P₂O₅ could raise the crop yield by 8.7 kg. Generally speaking, Better crop responses to P fertilizers could be gain on winter wheat. The higher yield increase on cotton and sweet potato could be observed.
- (5) The long-term experiments showed that the soil P fertility under long-term fertilization was largely determined by fertilizer application. The combined application of N, P and K fertilizers and organic manure should be important measures to maintain the soil nutrient balance and soil fertility build-up. It is necessary to determine the P fertilizer application rate based on soil P supply ability and crop requirement.

Acknowledgements

This research was supported by PPI-PPIC.

References

- Li Q K, Zhu Z L, Yu T R, The problems in agricultural sustainable development of China. Jiangxi: Science and Technology Press, 1998:52-58. (In Chinese)
- Wu Y, Wang Y Sun B, The farmland nutrient cycling and balance investigation in Heilongjiang province In Proceedings of Nutrient cycling and management in agro-ecosystems. Nanjin: Hehai University of press, 2000:77-81. (In Chinese)
- Jiao Y, Li G B, Duan B Y, Nutrients balance condition of farmland and fertilizer demand predict in Henan province in farmland In proceedings of Nutrient cycling and management in agro-ecosystems. Nanjin: Hehai university press, 2000:112-116. (In Chinese)
- Yang X Y, Zhang S L, Wang X F, Study on nutrient cycling and balance in farmland ecosystem in Shanxi province in proceedings of Nutrient cycling and management in agro-ecosystems. Nanjin: Hehai university press, 2000:117-123. (In Chinese)
- PPI/PPIC Beijing Office press, 1992:54-70. (In Chinese)
- Zhou J M, Fan Q Z, Xie J C, R. Hårdter-Nutrient cycling and management in agro-ecosystems. Nanjin: Hehai university press, 2000:42-52. (In Chinese)
- Huang S W, Jin J Y, Yang L P, Cheng M F, Vertical distributing characteristic of phosphorus and potassium in profile of cropland -1000-1000 Soil and Fertilizer, 2001(4): 8
- Zhang G L, Li G B, Sun K G, Wang Y, Wu S E, Jiao Y, Study on macro production and balanced fertilization by means of Systematic Approach for Soil Nutrient Evaluation in Henan province in symposium proceedings on Systematic Approach for Soil Nutrient Evaluation Beijing: China agricultural scientech press, 1995, 90-99. (In Chinese)
- Zhu J H, Zhou Y M, Jing H C, Lan Y L, Correlation study between soil texture and nutrients in Tianjin region In proceedings of Symposium proceedings on Systematic Approach for Soil Nutrient Evaluation Beijing: China agricultural scientech press, 1995, 121-124. (In Chinese)
- Zhang X P, Zhan Q H, Yi C L, Effect of continuous Applying fertilizer on crop growth and soil fertility in vertisol, ACTA Pedologica Sinica, 2000, 37:131-135. (In Chinese)
- Gu Y C, Qin S W, The accumulation, form change and validity of phosphorus in Chao soil under the condation of application of phosphate for long term, Chinese J. Soil Sci. 1997(1): 13-17. (In Chinese)
- Lu R K, Shi Z Y, Qian C L, Decline of phosphorus availability with time in soil, ACTA Pedologica Sinica, 2000(37): 323-329. (In Chinese)
- Lu R K, Shi Z Y, Qian C L, Study on soil phosphorus in form of accumulation Chinese J. Soil Sci. 1997(2), 57-75. (In Chinese)
- Li X M, Zhang J M, Zhao Z Q, Zai Y Z aquic soil Chinese J. Soil and Fert. 1996 (2): 4-7. (In Chinese)
- Liang G Q, Lin B, Lin J X, Rong X N, Effect of long-term fertilization on the forms of inorganic phosphorus in calcareous fluvo-aquic soil ACTA Plant Nutrient and Fertilizer Science 2001,7(3). 241-248. (In Chinese)
- Sun J G, Wang W, Liu H, Li Y F, Wang J L, The inorganic-P fraction availability of grey desert soil in Xinjiang, Research progress in plant protection and plant nutrition compiled by China association of agricultural science societies Beijing China agriculture press 1994: 515
- Lin Z A, Xie C T, Zhang Z S, Zhang X Y, The forms and transformation of phosphorus and fertilization in the upland calcareous soil -1000-1000 Soil and Fert. 1996(6): 26
- Lin J X, Lin B, Ai W, The residual effect of phosphate fertilizer and its use efficiency in the location trial Chinese J. Soil and Fert. 1995(6): 1-5. (In Chinese)
- Yu S F, Yang L, Study on Ca-P distribution and transformation feature in calcareous soil , ACTA Pedologica Sinica, 2001 (38): 373-378. (In Chinese)
- Wang J L h loim the J. J. Wang et al. Soil of Qinghai and Tibet F, Researc by China association of agricultural science societies Beijing China agriculture press 1994: 805-815. (In Chinese)
- Wu Z T, Study on critical levels of available P of wheat-grown irrigation -silting soil and application, Chinese J. Ningxia agricultural science -1000-1000 (In Chinese)
- Shao Y T, Zhen Q X, Study on critical levels of available P and phosphate rates in irrigated sierozon along Hexi Corridor of Gansu province. In SF-CAAS(ed) Proceedings of the international symposium on balanced fertilization. Beijing, Chinese Agri. Press, 1988: 76-82. (In Chinese)
- Zhang G L, Zhang Z W, Bao D J, Study on P supply ability of wheat-grown soil and optimal rates of P application. In SF-CAAS(ed) Proceedings of the international symposium on balanced fertilization. Beijing, Chinese Agri. Press, 1988: 83-88. (In Chinese)
- Zhang S M, Zhou J M, Zhang Z J, Rational distribution of phosphorus fertilizer on the winter wheat-summer corn cropping system, Chinese J. Soil and Fert. 1995(1): 26-29. (In Chinese)

Section 2

Fertilization and food quality

EFFECT OF SOIL WATER REGIMES AND INOCULATION WITH MYCORRHIZAE ON GROWTH AND NUTRIENTS CONTENT OF MAIZE PLANTS

I. M. Elwan

Ain Shams Uni., Faculty of Agriculture, Soil Department, Cairo, Egypt

Abstract

This experiment was carried out under glasshouse conditions at Faculty of Agriculture, Ain Shams Univ, Cairo, Egypt to study the effect of soil water regimes and mycorrhizal inoculation on growth and nutrient content of maize plants.

Data obtained show that dry matter production of mycorrhizal maize plants were markedly higher than those of non- mycorrhizal plants. The improved growth was observed for all soil water regimes. The greatest relative response to mycorrhizal inoculation was obtained at intermediate available water supply. Data also show that the percentage of infected root increased with decreasing water availability.

For all water treatments, the concentration of nutrients examined were usually higher in mycorrhizal than in non- mycorrhizal maize plants. The substantial increase in the uptake and concentration of nutrients in mycorrhizal maize plants, strongly suggests that mycorrhizal improved not only P nutrient, but also that of other elements.

Key words: Soil water regimes, VA- mycorrhizal, maize plants and nutrients contents.

Introduction

In many arid and semiarid regions, the major factor limiting plant production and nutrients uptake may be water availability (**Fisher and Turner, 1978**).

Mycorrhizal fungi are believed to improve the water relations of host plants, by increasing hydraulic conductivity (**Hardie and Leyton, 1981**), increasing transpiration rate and lowering stomatal resistance (**Lery and Krikun, 1980**), or by altering the balance of plant hormones (**Allen, et. Al. 1982**). **Nelsen and Safir (1982)** proposed that such physiological changes might be explained by the improved phosphorus nutrition of mycorrhizal plants exposed to drought stress.

Under well-watered conditions, VA- mycorrhizal fungi appear to have a little influence on the hydraulic conductivity of roots and transpiration of shoots in the absence of an effect of these fungi on P nutrition of the host plant (**Koide, 1985**). Although the potential for hyphae to increase water-uptake by mycorrhizal roots has been suggested by (**Allen, 1982**), water transport through hyphal entry points is considered insignificant, at least under well-watered conditions (**Koide, 1985**).

Several studies indicate that mycorrhizal increased P nutrition of plants, enhanced water conductivity was attributed at least in part to increase surface area for water uptake provided by mycorrhizal hyphae in soil (**Allen, et. Al. 1981**). Hyphae may also bridge the gap between soil and root that occurs when soil and root separate from each other when dry. Although VA-mycorrhizal fungi benefit plant growth mainly by providing supplemented nutrients required for optimum plant growth, these fungi have also been shown to improve the drought tolerance of colonized plants. Several mechanisms have been proposed to explain the improved water relation of mycorrhizal plants (**Gianninazzi-Pearson and Gianninazzi, 1983**), but there is strong evidence that improved drought tolerance of VA-mycorrhizal plants may be related to the phosphorus nutrition of the host plant (**Nelson and Safir, 1982**).

Most recently, **Bolgiano, et. Al. (1983)** observed lower root colonization of non drought stressed plants grown in fertile soil while plants exposed to drought stress were highly colonized despite the high soil fertility. **Saif (1987)** found that shoot and root dry weights and total uptake of P, N, K, Ca, Mg of all the test plants were significantly increased by mycorrhizal inoculation. Total uptake of all elements by non-mycorrhizal legumens and uptake of P, N and K by grasses was inversely correlated with mycorrhizal dependency.

The aim of this work was to study the effect of soil water regimes and inoculation with mycorrhizae on growth and nutrients content of maize plants.

Materials and Methods

This experiment was carried out with maize (*Zea mays* L.) in the glasshouse at Faculty of Agriculture, Ain Shams Univ., Cairo, Egypt.

Sandy soil was taken from El-Boseily, Egypt {some characteristics of this soil are given in Table (1)}. The soil was sterilized by autoclaving twice at 121°C for 1h with 24h interval between. Seven seeds were planted per pot (13 Kg sandy soil/pot) and after emergence plants were thinned to five plants/pot. Phosphorus was added as superphosphate at a rate of 30 mg/Kg soil. Pots of each soil water regime were divided into two groups with and without inoculation with VA-mycorrhiza. The treatments included inoculation with rhizosphere microorganisms together with VA-

Table 1: Chemical characteristics of the experimental soils.

pH	EC ds/m	Na	K	Ca	Mg	Cl	CO ₃	HCO ₃	SO ₄
(meqL ⁻¹)									
8.3	0.9	5.96	0.24	7.48	4.28	6.3	-	0.84	9.86

Available elements (ppm)					
% CaCO ₃	P	Fe	Mn	Cu	Zn
4.92	18.2	0.5	2.56	0.24	0.16

mycorrhiza fungi and inoculation with rhizosphere microorganisms without VA-mycorrhiza fungi. Each treatment had four replicates. The inoculum used in this experiment had been propagated on maize grown in a glasshouse for 12 weeks. Non- mycorrhizal maize plants were supplied with a sterilized {121°C, 20 min in an autoclave} inoculum and filtered extract of the inoculum used for multiplication. In both cases, the roots with adhering soil (50g) were used as inoculum (**Menge and Timmer, 1982**). In all treatments, the inoculum was mixed uniformly with the upper layer of soil of the roots. Different soil water regimes were started thirty days after establishment of mycorrhizal infection. Plants were rewatered after soil water depletion to approximately 10,50 and 90% of available water. Soil water depletion was measured by weighting the pots every day.

Methods of Analysis

Soils

The chemical properties of selected soil were analyzed using the standard methods, Jackson (1973). Calcium carbonate content was estimated using Scheibler Calcimeter. Soluble ions were determined in soil paste extractable according to Jackson (1973). Available phosphorus was determined using procedure reported by Jackson (1973). Field capacity was determined using method of Blake and Hartge, (1986). DTPA extractable for micronutrients, according the method of Lindsay and Norvell (1978).

Plant harvest and analyses

Plants were harvested after sixty days from planting. The roots were washed from soil with tap water and cut into segments one cm long for each treatment a sample of approximately 5g fresh roots was used to measure the percent of root infected evaluated by the grid line intersect

method (**Giovanetti and Mosse, 1980**). Dry weights of shoot were determined after drying at 70 °C for 48h. For determination of macro and microelements, ground plant samples were dry ashed at 500 °C and solved with 5 ml HCl (1:3). Mg, Mn, Fe, and Zn were determined by atomic absorption spectrometer. Phosphorus was determined by molybdate-vanadate yellow color using spectrometer. Calcium and K were determined using flame photometer.

Statistical analysis

Data were statistically analyzed using PC-MSTAT programs for ANOVA and LSD analysis according to **Power (1985)**.

Results and Discussions

Plant Growth

Both soil water regime and mycorrhizal inoculation had significant effects on plant growth. The dry matter productions of mycorrhizal and non-mycorrhizal plants were adversely affected by increased available water depletion at which plants were irrigated with water to field capacity (Table 2 and Fig.1).

The dry matter productions of mycorrhizal plants were markedly higher than those of non-mycorrhizal plants. The improved growth was observed over all soil water regimes. Similar observations have been reported by Nelsen and Safir (1982).

Data in Table 2 also show that the percentage of infected root increased with decreasing water availability. This finding is in agreement with data of Daniels, et. al. (1984) and Elwan (1989) who observed that root colonization was depressed in adequately watered plants at low phosphorus level as compared with droughted plants at similar P levels.

Effect of water regime on mycorrhizal and non- mycorrhizal plants was identical. However, under the experimental condition, the greatest relative response to mycorrhizal inoculation was obtained at intermediate available water supply (55% of field capacity). These results suggest that water stress could partially limit the beneficial effect of mycorrhizae, because the growth response to intermediate water supply was markedly greater than that under water stress (Sieverding, 1981).

Table 2: Effect of soil water regimes on dry matter production and percentage of root infected of maize plants.

Soil water regimes	Dry weight (g/pot)		Mean	% infected root with VA-mycorrhizae
	- M	+ M		
10%	24.6	29.8	27.2	53
50%	33.2	44.6	38.9	46
90%	57.6	65.7	61.7	40
Mean	38.5	46.7		

LSD	0.05%
Water	5.56
Mycorrhizae	4.54
Interaction	NS

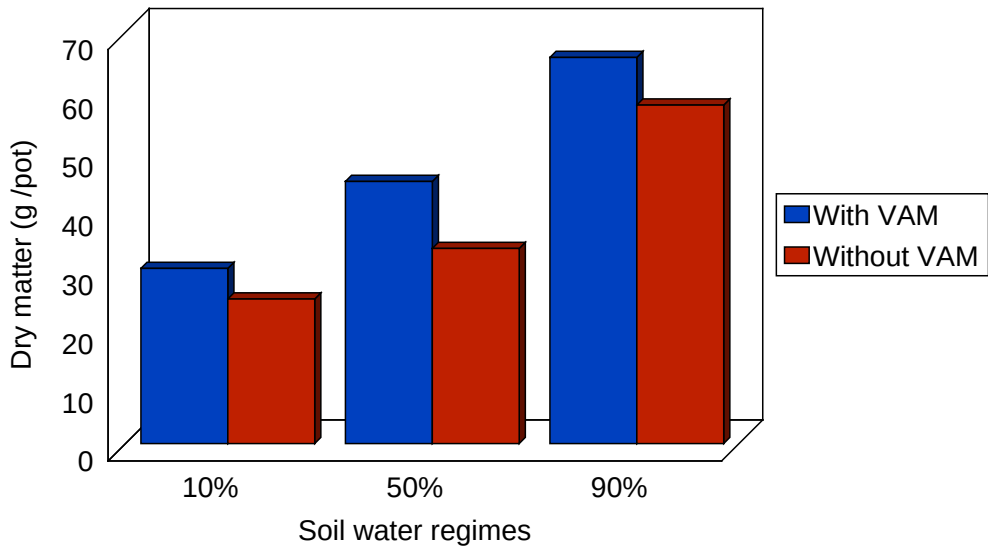


Figure 1: Effect of soil water regimes and mycorrhizal inoculation on dry matter production

Nutrients Contents

Data in Table (3) show that increased water supply markedly increased P, Ca, Zn and Fe concentration but suppressed that of Mn. There were only minor changes in the concentration of K with different soil water regimes. The low concentration of Mn might be attributed to growth dilution effect with improved water supply.

Overall, for all water treatments, the concentration of nutrients examined were usually higher in mycorrhizal than in non- mycorrhizal plants. Elwan (2001) showed that when soil growing plants are infected with VA- mycorrhizal, they frequently grow larger and the total uptake of all nutrients is therefore increased.

For all nutrients examined in the present experiment, an obvious increase in the uptake of nutrients by mycorrhizal plants was observed in Table (4). In general, the increased of uptake of nutrients was a result of improved plant growth which in turn, might be mainly due to improved P nutrition.

The substantial increase in the uptake and concentration of nutrients in mycorrhizal plants, strongly suggests that mycorrhizae improved not only P nutrition, but also that of other elements with low availabilities but high total native levels in the soil. Elwan (2001) demonstrated an enhanced absorption of Cu, Fe, Mg and K in mycorrhizal plants as compared to non-mycorrhizal ones.

The dominant mycorrhizal contribution to plant growth was, generally, much higher for all nutrients under study (Table 5 & Fig.2-5). This is generally attributed to she formation of an extension network of mycorrhizal hyphae extending from the root surface into the soil, absorbing large amount of soil nutrients (Hayman, 1983).

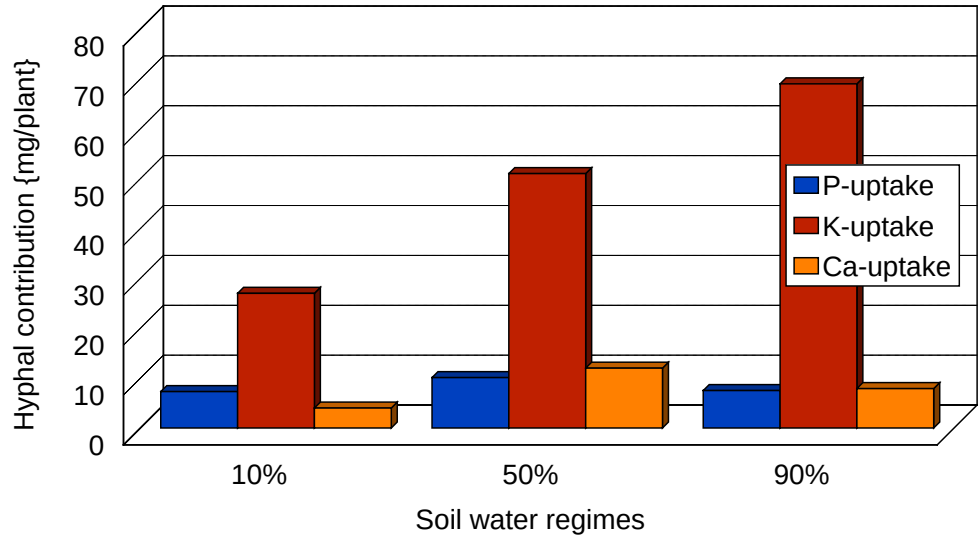


Figure 2:.Hyphal contribution to the macronutrients uptake (mg/plant)

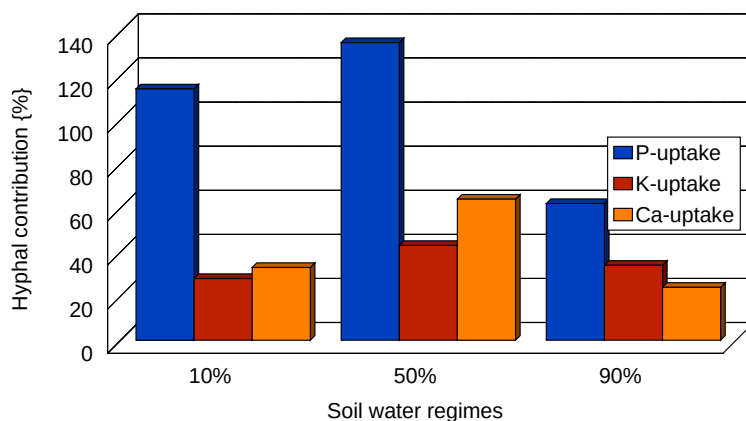


Figure 3: Hyphal contribution to the macronutrients uptake (%).

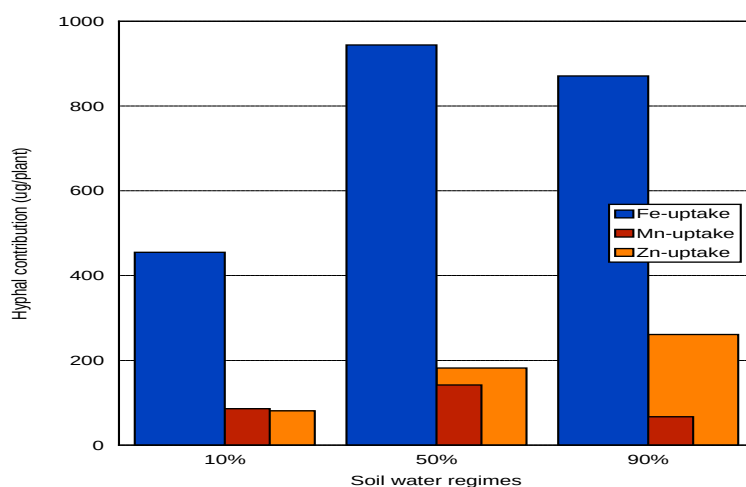


Figure 4: Hyphal contribution to micronutrients uptake (ug/plant)

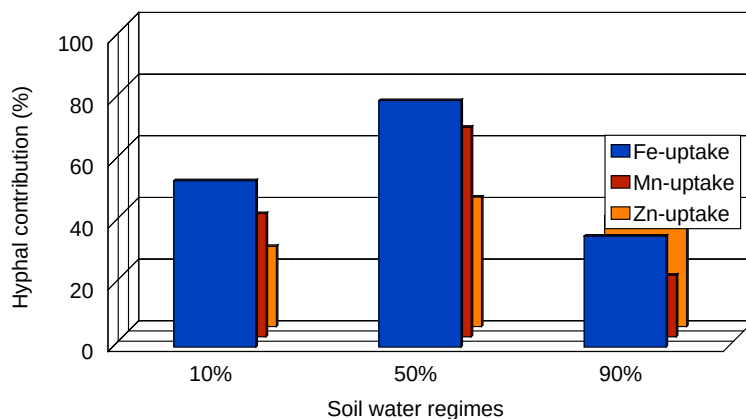


Figure 5: Hyphal contribution to macronutrients (%)

Table 5: Hyphal contribution to the nutrients uptake.

{A}

Soil water regimes	P		K		Ca	
	mg/plant	%	mg/plant	%	mg/plant	%
10%	7.30	114	27	28	4.00	33
50%	10.1	135	51	43	11.6	64
90%	7.50	62	69	34	7.90	24

{B}

Soil water regimes	Fe		Mn		Zn	
	ug/plant	%	ug/plant	%	ug/plant	%
10%	455	54	86	40	81	26
50%	944	80	142	68	182	42
90%	871	36	67	20	261	36

References

- Allen, M.F. (1982).** Influence of VA-mycorrhizae on water movement through *Bouteloua gracilis*. *New Phytol.* 91:191-196.
- Allen, M.F.; J.C. Seyton; M.S. Moore and M. Christensen (1981).** The influence of phosphate source on VA-mycorrhizae of *Bouteloua gracilis*. *New Phytol.* 87: 687-694.
- Allen, M.F.; T.S. Moore and M. Christensen. (1982).** Phytohormone changes in *Bouteloua gracilis* infected by VA-mycorrhizae: 1- Cytokinin increase in the host plant. *Can. J. Bot.* 58:371-374.
- Blacke, G.R. and Hartge, K.H. (1986)** " Methods of soil analysis " part 1. physical and mineralogical properties, A. (ed) *Agronomy Monograph*. No.9.
- Bolgiano, N.C.; G.R. Safir and D.D. Warncke. (1983).** Mycorrhizal infection and growth of onion in the field in relation to phosphorus and water availability. *J. Am. Soc. Hort. Sci.* 108:819-825.
- Daniels, H.B.A.; J.A. Hertick and J. Bloom. (1984).** Interaction of mycorrhizal infection, phosphorus level and moisture stress in growth of field corn. *Can. J. Bot.* 62:2267-2271.
- Elwan, I.M (1989).** Plant response to some edaphic soil factors. Thesis, Ph.D. Faculty of Agric., Ain Shams Uni. Cairo.
- Elwan, I. M. (2001).** Nutrients uptake by mycorrhizal hyphae by using hyphal tubes. *Zagazig J. Agric. Res.* 28: 163-172.
- Fisher, R.A and N.C. Turner (1978)** Plant productivity in the arid and semi-arid zones. *Annual Review of plant physiology* 29: 277-317.
- Gianninazzi- Pearson, V. and S. Gianninazzi (1983).** The physiology of VA-mycorrhizae of *Bouteloua gracilis*. *New Phytol.* 87:687-694.
- Giovanetti, M. and Mosse, M. (1980).** An evaluation of techniques for measuring vesicular-arbuscular mycorrhizal infection in roots. *New Phytol.* 84: 489-500.
- Hardie, K. and L. Leyton (1981).** The influence of VA-mycorrhizae on growth and water relations of red clover. I. In phosphate deficient soil. *New phytol.* 89:599-608.
- Hayman D.s. (1984).** The physiology of Vesicular – arbuscular endomycorrhizal Symbiosis. *Can J. Bot.* 61 : 944 – 963.
- Jackson, M.I. (1973)** " Soil chemical analysis " Prentice Hall of Indian private Limited, New Delhi.
- Koide, R. (1985).** The effect of VA-mycorrhizal infection and phosphorus status on sunflower hydraulic and stomatal properties. *J. of Experimental Bot.* 36:1087-1098.
- Lery, U. and J. Krikun (1980).** Effect of VA-mycorrhiza on citrus Jambhiri: water relations. *New phytol.* 85:25-31.
- Lindsay, W. L. and Norvell, W. A. (1978).** Development of a DTPA soil test for Zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.* 42: 421-428.
- Menge, J.A. and Timmer, L. W. (1982).** Procedures for inoculation of plant with mycorrhizae in the laboratory, greenhouse and field. In: Shenk, N.C. (Ed.), *Methods and principle of mycorrhizal research*. Florida Univ., USA.
- Nelsen, C.E. and G.R. Safir (1982).** The water relations of well-watered, mycorrhizal and non-mycorrhizal onion plants. *J. Am Soc. Hort. Sci.* 107:271-274.
- Power, P. (1985).** User's guide to MSTAT (ver.3.0), Michigan State Univ., USA
- Saif, S. R. (1987).** **Growth responses of tropical forage plant species to VA-mycorrhizae. I. Growth, mineral uptake and mycorrhizal dependency.** *Plant and Soil.* 97:25-35
- Sieverding, E. (1981).** Influence of soil water regimes on VA-mycorrhizal. I. Effect on plant growth, water utilization and development of mycorrhizae. *J. Agron. Crop. Sci.* 150:400-411

Table 3: Nutrients concentration of shoots as affected by soil water regimes and mycorrhizal inoculation.

Soil water regimes	P%			K%			Ca%			Fe (ppm)			Mn (ppm)			Zn (ppm)		
	- M	+ M	Mean	- M	+ M	Mean	- M	+ M	Mean	- M	+ M	Mean	- M	+ M	Mean	- M	+ M	Mean
10%	0.13	0.15	0.14	1.95	2.07	2.01	0.24	0.27	0.26	173	219	196	44.3	50.3	47.3	63	66	65
50%	0.11	0.20	0.16	1.79	1.91	1.85	0.26	0.32	0.29	178	238	208	31.3	39.3	35.3	65	69	67
90%	0.10	0.23	0.17	1.75	2.06	1.91	0.29	0.31	0.30	210	253	231	28.5	30.0	29.3	63	75	69
Mean	0.12	0.19		1.83	2.01		0.27	0.30		187	236		34.7	39.9		63.7	70	

LSD (0.05%)

Water	0.11	0.06	0.02	14.9	6.49	1.63
Mycorrhiza	0.009	0.08	0.02	12.2	5.30	1.33
Interaction	0.015	0.11	0.03	NS	NS	2.31

Table 4: Nutrients uptake by shoots of maize plants as affected by soil water regimes and mycorrhizal inoculation.

Soil water regimes	P (mg/plant)			K (mg/plant)			Ca (mg/plant)			Fe (µg/plant)			Mn (µg/plant)			Zn (µg/plant)		
	- M	+ M	Mean	- M	+ M	Mean	- M	+ M	Mean	- M	+ M	Mean	- M	+ M	Mean	- M	+ M	Mean
10%	6.40	13.7	10.1	96	123	110	12.1	16.1	14.1	849	1304	1077	214	300	257	313	394	353
50%	7.48	17.6	12.6	119	170	145	16.9	28.5	22.7	1181	2125	1653	208	350	278	434	616	525
90%	12.10	19.6	15.8	202	271	237	33.4	41.3	37.3	2418	3289	2853	328	396	362	725	986	855
Mean	8.66	17.0		139	188		20.8	28.6		1482	2239		250	348		490	665	

LSD (0.05%)

Water	1.61	23.99	2.87	193.56	48.03	80.1
Mycorrhiza	1.31	19.60	2.34	158.04	39.22	65.4
Interaction	N.S	N.S	4.06	273.73	NS	N.S

EFFECT ON LONG TERM MINERAL FERTILIZATION ON CEREAL QUALITY

Z. Győri

Department of Food Science and Quality Assurance, University of Debrecen, Centre of Agricultural Sciences, Faculty of Agronomy, 138. Böszörményi Street, H-4032 Debrecen, Hungary
Tel: +36-52-417-572, Fax: +36-52-417-572, E-mail: gyori@helios.date.hu

Abstract

The effects of long-term fertiliser application on the soil-vegetation system can be varied. Apart from the yield increasing effect, its influence on the quality of the plant cannot be neglected either. Some of these, such as protein contents, are felt in the short term while others can be seen only decades later. Owing to concomitant elements or the fact that macro fertilisers influence soil properties and the ability to take up elements, even harmonious NPK fertilisation can bring about significant changes over such periods of time. Of course the scope of quality testing has also to be widened and here, the changes in the concentrations of certain elements are an especially important issue as one that has a bearing on food quality. Our investigations aimed at finding out the effects of at least 20 years fertiliser application on various types of soils. We were seeking to find answers to questions such as, "The changes of Strontium contents in plants, and the effectiveness of P-Zn interaction in the grain yield.

Materials and methods

The field experiment

A field plot experiment was carried out at the Látókép Farm of University of Debrecen Center for Agricultural Sciences (RUZSÁNYI, (1992)). It is located 15 km from Debrecen in Hungary. The soil is a calcareous chernozem with 2.8-3.0 % humus content. The depth of the humus layer is 70-90 cm. The nitrogen and P supply of this calcareous chernozem soil is middle, the K content is high (total N = 0.14-0.18 %; AL-P₂O₅ = 130-200 mg/kg, AL-K₂O = 240-280 mg/kg). The pH_(KCl) is 6.2. Besides macro elements, there is no shortage of trace elements. Each treatment consisted of 46 m² plots, arranged in a randomized block design with four replication, where the basic treatment was the mineral fertilization; the additional treatments were crop rotation, irrigation and cultivation. Five levels of NPK fertilization doses, three varieties of irrigation water amount and two types of soil cultivation were used. The experiment has been started 21 years ago in 1982.

The applied dose of mineral fertilizers are 50 kg/ha N + 35 kg/ha P₂O₅ + 40 kg/ha K₂O and their double, triple, four and fivefold. The nitrogen, phosphate and potassium was added to the soil as NH₄NO₃ with lime, superphosphate and KCl respectively.

The used fertilisers have additional elements, for example the superphosphate S-content exceeded 10 % which means that with 100 kg superphosphate the S-input to the soil is 10.9 kg/ha, the Ca-content of this fertilizer is high and the Sr-content is high also (Table 1.).

The different soil types and cropping sites of our country are involved in the NLTFT (National Long-Term Field Trials) experiments. This experiment was established in 1967. In this experiment we applied the same mineral fertilizer rates and dose and we used the same varieties in every year. More details can be read in the book edited by DEBRECZENI and DEBRECZENINÉ (1994).

The analysis of the grain samples from the NLTFT experiment was performed in the Central Chemical Laboratory of DE-AC. We would like to present only the results for the control and one level of fertilisation (N 250 kg/ha + P₂O₅ 200 kg/ha + K₂O 200 kg/ha).

Measurement of elements from wheat grains

The amount of sample taken was calculated that it has to be enough for different types of analyses. The average mass of seed samples of winter wheat is 1.5-2.0 kg. After the purification and occasional drying the samples were milled with a Retsch SK-1 or SK-3 hammer mill using 1 mm sieve. Plant samples were prepared by wet digestion. 1 g dried plant samples were digested. The digestion consisted of two stages: 1. *Predigesting*: 1 g sample + 10 cm³ cc. HNO₃ at 60°C for 30 minutes; 2. *Digestion*: + 3 cm³ cc. H₂O₂ at 120°C for 1.5 hours. The volume of digested liquid was increased to 50 cm³ using deionised water and then filtered with MN (Macherey-Nagel) 640W filter paper. The element contents of plant samples were determined by the sample preparation (GYÖRI et al. (1995), KOVÁCS (1998), KOVÁCS et al. (1995, 1996a, 1996b, 1996c)) and analytical methods (GYÖRI et al. (1995), KOVÁCS (1997, 1998), KOVÁCS et al. (1994, 1995, 1996a, 1996b, 1996c, 1997, 1998)) elaborated in the University of Debrecen Centre of Agricultural Sciences Central Chemical Laboratory. We used different plant samples from the International Plant Exchange Network as quality control samples for the validation of measurement. The nitrogen content of grains was determined by a Kjel-Foss 16210 instrument with an automated Kjeldahl method.

The gluten content of wheat flour was determined by national and international method (MSZ-ISO 5531-1993 (1993)).

The statistical analysis were performed using Microsoft Excel 5.0 and SPSS for Windows 8.00.

Table 1: Element composition of fertilizers in the experiment

	ammonium nitrate	super phosphate	potassium chloride
	mg/kg	mg/kg	mg/kg
N	340000		
Ca	60000	174000	3470
P	1080	88000	870
S	1300	109000	2250
K	36.9	1470	405000
Zn	2.42	19.1	3.39
Sr	113	9500	152
Al	31.1	2050	670
As	1.11	147	1.31
B	6.6	107	3.44
Se	2.02	1.25	2.69
Pb	0.03	7.3	2.98
Ni	0.59	1.05	1.08
Na	187	1790	4360
Mo	2.5	2.5	2.5
Mn	0.299	152	19
Mg	23.8	570	302
Li	0.1	0.36	0.85
Fe	25.7	2080	1610
Cu	0.23	22.8	2.01
Cr	2.15	3.31	1.56
Co	0.175	0.62	0.403
Cd	0.005	0.54	0.05

Levels of fertilizer dose in the experiment

	N [kg/ha]	P ₂ O ₅ [kg/ha]	K ₂ O [kg/ha]
I.	0	0	0
II.	50	35	40
III.	100	70	80
IV.	150	105	120
V.	200	140	160
IV	250	175	200

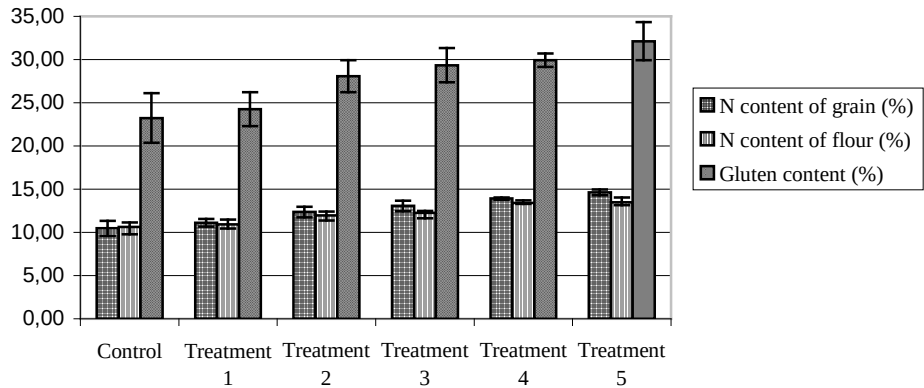
Results

Approaches to defining the links between nutrient supply and quality reveal a varied pattern in our days. They include primary quality indicators such as the ones related to use and utilisation (nutritive, feed value) as well as food safety related tests (potentially toxic elements). The latter is also important because term fertilisation may bring about changes in certain soil properties

(pH, y_1), which in turn bring about measurable changes in element uptake as well. Applying increasing fertiliser ratios in excess the needs of the crops will result in a considerable abundance of surplus nutrients.

An important indicator for the quality of cereals is their protein contents, which provides clues as regards amino acid contents and in the case of winter wheat, gluten contents. The findings from the research farm in Látókép, which was established almost twenty years ago, are shown in **Figure 1**. They reveal that the N- contents of winter wheat, both in the grains and the flour ground from them, considerably increased as a result of applying increasing ratios NPK fertilisation. The amount of wet gluten – an important quality indicator of wheat – could also be considerably increased by applying fertilisers.

Figure 1: Effect of mineral fertilization on the nitrogen and wet gluten content of winter wheat (Látókép, 2002)



As Table 1 indicates, fertilisers that are high in Ca (ammonium-nitrate, super phosphate) also contain high amounts of Sr. That is why the uptake of this element and the Sr contents of the part of the crop that is meant to be used as food has to be regularly tested since high Sr contents carry risks. Figure 2. shows the findings of sample analyses from Országos Egységes Műtrágyázási Tartamkísérlet (Single National Term Fertilisation Experiment), which was set more than thirty years ago. The data show that the Sr contents in wheat increased at all production locations and the most significant increases were found in Keszthely, Karcag and Putnok. The findings from the experiments in Debrecen are contained in Figure 3., where Sr contents are illustrated as a function of Ca contents and the linear correlation is very good. It shows that 600 mg/kg and 400 mg/kg Ca contents are accompanied by 4 mg/kg and 3 mg/kg Sr contents, respectively.

Figure 2: The effect of mineral fertilization on the Sr-content of winter wheat cultivated in different regions in Hungary, 1995

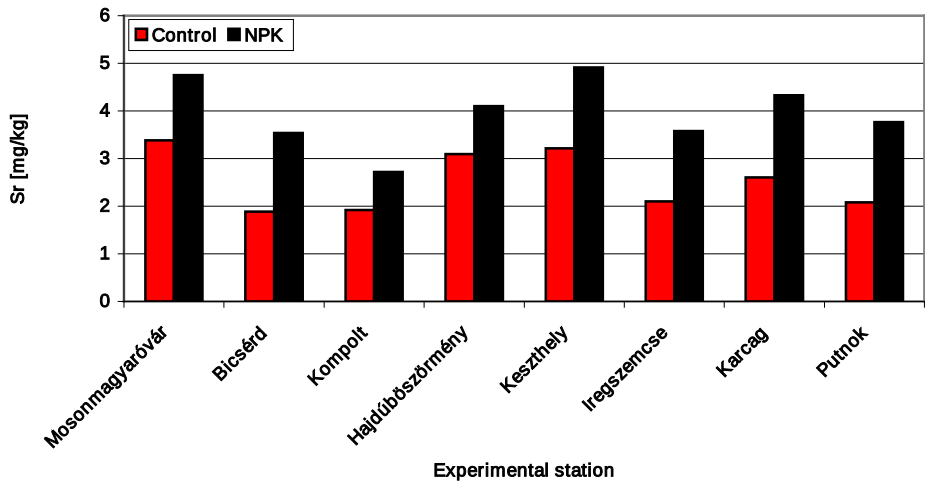
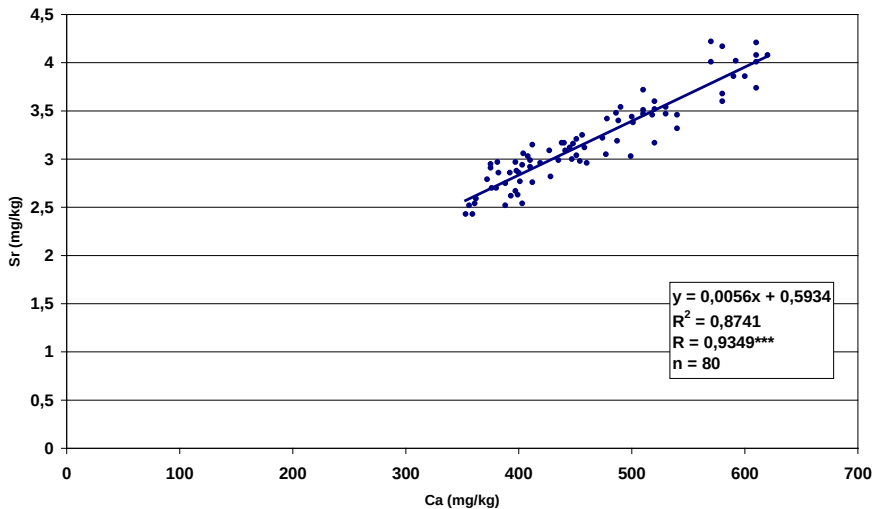
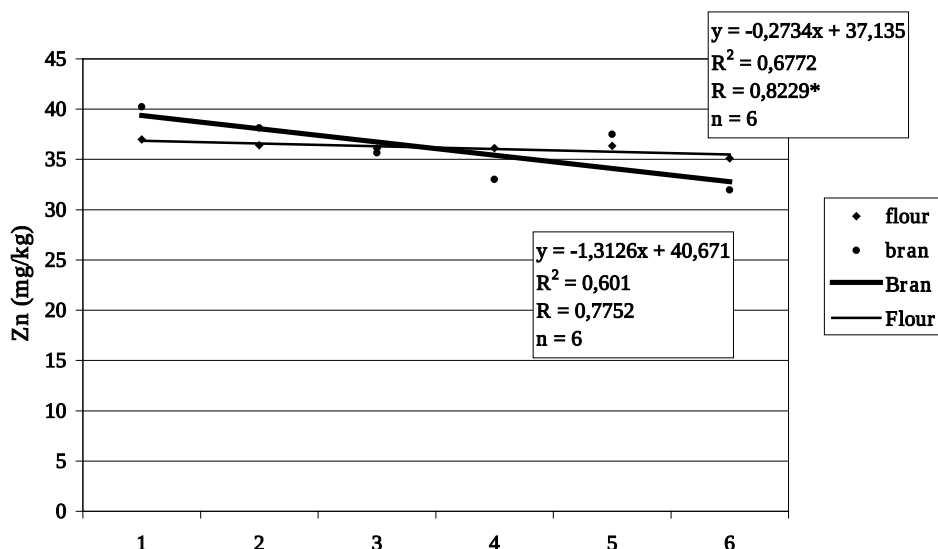


Figure 3: Correlation between Calcium and Strontium content of winter wheat grain, 1993



It is a generally-known fact that the application of high ratios of P fertilisation will decrease the Zn contents in corn. We found similar correlation in legumes for seed, too. Our experiments with winter wheat and the analytic opportunities available enabled us to also analyse the flour and bran made from wheat. Our findings show that long-term NPK fertilisation resulted in marked decreases in Zn levels in both the bran and the flour (**Figure 4.**). As regards the interpretation of the findings, however, it is reassuring that at N 100+ P₂O₅ 70+ K₂O 80 farm management level the effects are moderate.

Figure 4: The effect of mineral fertilization on the Zn-content of wheat flour and wheat bran [mg/kg], 1995



References

- Debreczeni B, Debreczeni B-né (szerk.) *Fertilization resources 1960-1990*. (In Hungarian) Akadémiai Kiadó, 1994, Budapest
- Győri, Z., Kovács, B., Prokisch, J., Loch, J. Studies on soil and plant sample preparation and ICP parameters. International Symposium on Soil and Plant Analysis, Wageningen, The Netherlands, 1995. Book of Abstracts 22.
- Kovács, B., Prokisch, J., Loch, J., Győri, Z., Plant analysis by ICP-OES (Növényvizsgálatok ICP spektrométerrel). XXXVII. Magyar Színképelemző Vándorgyűlés, Kaposvár, 1994. MKE Kiadvány 317.
- Kovács, B., Prokisch, J., Győri, Z., Posta, J. Using ICP with hydraulic high - pressure nebulizer in determination of heavy metal contaminants in soils and plants at various roadside areas in Hungary. Metal Compounds in Environment and Life. 9-12 May, 1995. Jülich, Germany.
- Kovács, B., Prokisch, J., Győri, Z.. Talajok vizsgálata nedves roncsolással. (Analysis of soil samples digested with wet digestion method.) 39. Magyar Spektrokémiai Vándorgyűlés. (39th Hungarian Spectrochemical Symposium.) Book of the Symposium. 1996a p. 31-36.
- Kovács, B., Győri, Z., Prokisch, J., Loch, J., Dániel, P. A study of plant sample preparation and Inductively Coupled Plasma Emission Spectrometry parameters. Communications in Soil Science and Plant Analysis. 1996b, 27:(5-8), 1177-1198.
- Kovács, B., Győri, Z., Prokisch, J., Dániel, P. A study of plant sample preparation and inductively coupled plasma atomic emission spectrometry parameters, Communications in Soil Science and Plant Analysis, 1996c, 27. 3-4: 207-215.
- Kovács, B.. Investigation of ICP parameters. Soil, Plant and Environment Relationships. Proceedings of the First and Second International Seminars on Soil and Plant Science, Debrecen, 1997, 1-2:240-251.
- Kovács, B. Evaluation of optimization of sample preparation and plasmaemission parameters for analysis of element content in plant samples. Ph.D. thesis. Debrecen. 1998
- Kovács, B., Dániel, P., Győri, Z., Prokisch, J.. Studies on Parameters of Inductively Coupled Plasma Spectrometer. Communications in Soil Science and Plant Analysis. 1998. 29.11-14: 2035-2054.
- MSZ-ISO 5531-1993. Determination the wet gluten content of winter wheat flour. Hungarian Standard
- Ruzsányi L. Investigation the interrelationships of different agrotechnical factors and soil watering (In Hungarian). DSC Thesis. 1992 Budapest

RELATIONSHIP BETWEEN THE NUTRIENT SUPPLY AS WELL AS THE YIELD QUANTITY AND QUALITY OF MAIZE

Z. Izsáki

Tessedik Sámuel College Faculty of Agricultural Water and Environmental Management, Szarvas, H-5541 P. O. B. 3. Hungary,

Abstract

A long-term mineral fertilization experiment was set up in 1989, on chernozem meadow soil in Szarvas, where for levels of N-, P-, K- fertilizers were applied in complete combination with 64 treatments, in split-split plot design with 3 replications. Nitrogen fertilizer was applied as ammonium nitrate at rates of $N_0=0$; $N_1=80$; $N_2=160$; $N_3=240$ kgNha⁻¹ year⁻¹. The applied P₂O₅ treatments: $P_0=0$; $P_1=100$ kgha⁻¹ year⁻¹; $P_2=500$ kgha⁻¹ in 1989, 1993 and 2001. The applied K₂O treatments: $K_0=0$; $K_1=300$ kgha⁻¹ year⁻¹ 1989-1992 and 100 kgha⁻¹ year⁻¹ from 1993; $K_2=600$ kgha⁻¹ in 1989, 1000 kgha⁻¹ in 1993 and 600 kgha⁻¹ in 2001; $K_3=1200$ kgha⁻¹ in 1989 1500 kgha⁻¹ in 1993 and 1200 kgha⁻¹ in 2001. The main soil properties were as follows: humus content 3,0-3,2%, depth of humus layer 85-100 cm, pH (KCI) 5,0-5,2, clay content 32%.

On chernozem meadow soil where the humus content was 3,0-3,2% the highest grain yield was obtained if the NO₃-N capacity of the soil in 0-60 cm, prior to planting was 80-85 kgha⁻¹. At 120-180 mgkg⁻¹ AL-P₂O₅ level of soil the grain yield increased in line with the better P-supply. If the soil K-status is above 230 mgkg⁻¹ AL-K₂O the K-fertilization is not needed. The K over-supply, if the AL-K₂O is above 350 mgkg⁻¹ resulted in lower grain yield. At 120-340 mgkg⁻¹ AL-P₂O₅ and 230-465 mgkg⁻¹ AL-K₂O levels of the soil the crude protein content and the amino acid composition were not influenced by the P- and K-supply. The better N-supply resulted in significantly higher crude protein content to 80-85 kgha⁻¹ NO₃-N content of the soil in 0-60 cm, prior to planting. The crop year effect on crude protein content is more significant than the nutrient supply. The ratio of essential and non essential amino acid were not influenced by N-supply only their quantity. The sufficient nutrient concentration of the maize leaf at beginning of the flowering were as follows: N 3,0-5,0%, P 0,30-0,40%, K 1,5-2,5%, Ca 0,15-0,50%, Mg 0,10-0,35%, micro elements mgkg⁻¹: Fe 100-350, Mn 60-180, Zn 10-30, Cu 3-10.

Key words: Nutrient supply, yield quantity and quality, plant analysis, maize

Introduction

The basic requirement of the environmentally friendly and quality oriented fertilization as well as the precision nutrient management is to determine the nutrient supply categories for the different land-site groups. These nutrient supply values were elaborated for the aggregated land-site groups in Hungary reported by Németh (1998). The fertilization advisory system can be improved by the determination of the soil nutrient supply limit values for crop groups or crop species and land-sites (Csathó1997, Csathó et al. 1998, Izsáki 1999). Beside the calibration of the soil testing results another possibility for making more precisely the fertilization practice is to apply the plant analysis. Analysis of plant parts can provide useful indications of absolute or relative nutrient deficiencies or surpluses and it is proper to control the soil testing results and

the fertilization practice, to reveal the nutrient interactions and the limits of plant growth as well as to predict the yield quantity and quality (Kádár 1992, Izsáki 2000). The nutrient supply limit values of plant analysis for maize are compiled and report by Kádár (1992, 2000).

The objective of this paper is to provide data for yield quantity and quality of maize at different N-, P-, K-supply levels as well as nutrient supply values for plant analyses of maize.

Methods and Material

A long-term mineral fertilization experiment was set up in 1989, on chernozem meadow soil in Szarvas, where for levels of N-, P-, K- fertilizers were applied in complete combination with 64 treatments, in split-split plot design with 3 replications. Nitrogen fertilizer was applied as ammonium nitrate at rates of $N_0=0$; $N_1=80$; $N_2=160$, $N_3=240$ kgNha⁻¹ year⁻¹. The applied P₂O₅ treatments: $P_0=0$; $P_1=100$ kgha⁻¹ year⁻¹; $P_2=500$ kgha⁻¹ in 1989, 1993 and 2001. The applied K₂O treatments: $K_0=0$; $K_1=300$ kgha⁻¹ year⁻¹ 1989-1992 and 100 kgha⁻¹ year⁻¹ from 1993; $K_2=600$ kgha⁻¹ in 1989, 1000 kgha⁻¹ in 1993 and 600 kgha⁻¹ in 2001; $K_3=1200$ kgha⁻¹ in 1989 1500 kgha⁻¹ in 1993 and 1200 kgha⁻¹ in 2001. The target of the ameliorative application of P- and K-fertilizers was to create different P- and K-supply levels in the soil. The P- and K-fertilizers were broadcasted in autumn prior to ploughing in the form of superphosphate and potassium chloride. The main soil properties were as follows: humus content 3,0-3,2%, depth of humus layer 85-100 cm, pH (KCI) 5,0-5,2, clay content 32%.

The soil NO₃-N assesment was made by sampling the soil at 0-60 cm depth in autumn and in spring prior to drilling. The NO₃-N content was determined from the 1 N KCI extraction. For determination of available phosphorus and potassium content of the soil the ammonium lactate (AL) method was used. Nitrogen was determined by the macro-Kjeldal procedure and a factor of 6,25 was used to convert nitrogen to crude protein. Amino acid composition was analyzed by ion-exchange column chromatography. The grain yield of maize is given in dry matter. Samples of maize leaf (opposite to the cob) for diagnostic purpose plant analysis were taken at the beginning of flowering from the 64 treatments each year. During the growing season, from March to August, the precipitation was 402 mm in 2001 and 309 mm in 2002. Correlation between the grain yield and the leaf nutrient content was estimated by using boundary line method. The optimum intervals of nutrient concentrations of leaf were determined at 10 tha⁻¹ grain yield.

Results and Discussion

The effect of N-, P-, K-supply on the grain yield of maize in 2001, 2002 is shown in Table 1. and 2.

In 2001 significant N $\times$ P $\times$ K interactions were not obtained in the grain yield. So, the main N-, P-, K- effects are evaluated and discussed. This experimental year the water supply of the maize was good especially during the stage of rapid growth and seed formation. As a result of it without N fertilization when the NO₃-N content of the soil was only 38 kg ha⁻¹ in 0-60 cm, prior to planting the grain yield was high, 9,52 t ha⁻¹. The better N supply resulted in significant increase in the grain yield compared with the control. But, if the NO₃-N capacity of the soil was above 80 kg ha⁻¹ there was no further yield surplus.

Without P-fertilization during the 12-year experimental period the AL-P₂O₅ content of the cultivated layer did not diminish significantly because its value changed between 120-158 mg kg⁻¹. In 2001 without P fertilization at 120 mg kg⁻¹ AL-P₂O₅ level the average grain yield was 10,18 t ha⁻¹ while 156-204 mg kg⁻¹ AL-P₂O₅ level the yield increased by 5-7%.

Without K-fertilization during the 12-year experimental period the AL-K₂O content of the cultivated layer decreased by 90 mg kg⁻¹. But the soil K-status remained in the good supply category (232 mg kg⁻¹ AL-K₂O) and the grain yield was 11,01 t ha⁻¹ in average. If the soil K-status was higher – 352-373 mg kg⁻¹ AL-P₂O₅ – the yield diminished significantly.

In 2002 the growing season was relatively drier and the grain yield was considerably lower than in 2001. Evaluating the main N-, P-, K effects the following results were obtained.

Without N-fertilization, with a base level of 60 kg ha⁻¹ NO₃-N of the soil prior to planting, the grain yield was 6,08 t ha⁻¹. The maximum yield was obtained at 85 kg ha⁻¹ NO₃-N content of the soil. At higher NO₃-N status – 180, 205 kg ha⁻¹ – the yield showed significantly lower level compared with maximum yield.

At 120 mg kg⁻¹ AL-P₂O₅ content of the soil without P-fertilization the grain yield was 6,05 t ha⁻¹. The better P-supply of the soil resulted in significantly higher yield. But if the soil P-status was in 176-339 mg kg⁻¹ AL-P₂O₅ interval the yield did not change considerably. In 2002 a N $\times$ P interaction was observed. The yield increase effect of the N-supply was stronger at good P-supply level.

In 2002 when the soil AL-K₂O content was 229-465 mg kg⁻¹ the grain yield was not influenced by the K-supply. But a decreasing tendency was obtained in the grain yield at over-supply level of K.

Table 1: Effect of N-, P-, K- supply on grain yield of maize, tha-1 (Szarvas, 2001)

N-, P- supply	K-supply, AL-K ₂ O mgkg ⁻¹				Average
	232	354	352	373	
	K ₀	K ₁	K ₂	K ₃	
P ₀ = 120 mgkg ⁻¹ AL-P ₂ O ₅					
N ₀ P ₀	8,32	8,83	9,15	8,87	8,79
N ₁ P ₀	10,65	10,61	10,27	9,90	10,35
N ₂ P ₀	10,83	10,63	11,30	10,60	10,84
N ₃ P ₀	11,53	9,46	11,14	10,85	10,74
Average	10,33	9,88	10,46	10,05	10,18
P ₁ = 183 mgkg ⁻¹ AL-P ₂ O ₅					
N ₀ P ₁	10,41	9,11	10,15	10,02	9,92
N ₁ P ₁	11,48	11,17	10,96	11,20	11,20
N ₂ P ₁	10,87	11,26	11,16	10,86	11,03
N ₃ P ₁	11,14	10,73	11,28	11,00	11,03
Average	10,97	10,56	10,88	10,77	10,79
P ₂ = 156 mgkg ⁻¹ AL-P ₂ O ₅					
N ₀ P ₂	10,69	9,40	9,92	8,87	9,72
N ₁ P ₂	11,54	11,37	11,54	11,54	11,49
N ₂ P ₂	11,18	11,26	11,22	11,41	11,26
N ₃ P ₂	11,62	10,98	11,46	11,20	11,31
Average	11,25	10,75	11,03	10,75	10,94
P ₃ = 204 mgkg ⁻¹ AL-P ₂ O ₅					
N ₀ P ₃	10,90	9,35	9,40	9,03	9,67
N ₁ P ₃	11,85	10,51	10,71	10,83	10,97
N ₂ P ₃	11,89	11,04	11,47	10,91	11,32
N ₃ P ₃	11,38	10,89	10,98	10,47	10,93
Average	11,50	10,44	10,64	10,31	10,72
NO ₃ -N kgha ⁻¹ In average of P-supply					
N ₀ = 38	10,08	9,17	9,65	9,19	9,52
N ₁ = 80	11,38	10,91	10,87	10,86	11,00
N ₂ =131	11,19	11,04	11,28	10,94	11,11
N ₃ =148	11,41	10,51	11,21	10,88	11,00
Average	11,01	10,40	10,75	10,47	
LSD _{5%} :	K ₀ -K ₁ : 0,36 P ₀ -P ₁ : 0,35 N ₀ -N ₁ : 0,27				

Table 2: Effect of N-, P-, K- supply on grain yield of maize, tha-1 (Szarvas, 2002)

N-, P- supply	K-supply, AL-K ₂ O mgkg ⁻¹				Average
	229	334	394	465	
	K ₀	K ₁	K ₂	K ₃	
P ₀ = 120 mgkg ⁻¹ AL-P ₂ O ₅					
N ₀ P ₀	5,94	5,53	6,00	6,08	5,84
N ₁ P ₀	6,46	5,88	6,52	6,68	6,38
N ₂ P ₀	6,08	6,59	5,52	6,66	6,21
N ₃ P ₀	5,56	5,97	6,08	5,50	5,78
Average	6,01	5,94	6,03	6,22	6,05
P ₁ = 176 mgkg ⁻¹ AL-P ₂ O ₅					
N ₀ P ₁	6,26	6,98	5,89	6,00	6,28
N ₁ P ₁	6,86	7,62	6,91	6,86	7,06
N ₂ P ₁	6,35	6,13	6,12	6,00	6,15
N ₃ P ₁	5,91	6,00	6,40	5,91	6,05
Average	6,34	6,68	6,33	6,19	6,39
P ₂ = 195 mgkg ⁻¹ AL-P ₂ O ₅					
N ₀ P ₂	6,06	6,42	6,72	6,13	6,33
N ₁ P ₂	7,19	7,21	7,47	7,11	7,25
N ₂ P ₂	6,84	7,35	7,43	6,22	6,96
N ₃ P ₂	6,27	6,87	6,36	6,02	6,38
Average	6,59	6,96	6,99	6,37	6,73
P ₃ = 339 mgkg ⁻¹ AL-P ₂ O ₅					
N ₀ P ₃	5,74	6,18	6,31	5,23	5,87
N ₁ P ₃	7,44	7,33	7,22	6,77	7,19
N ₂ P ₃	6,74	7,06	6,48	6,27	6,64
N ₃ P ₃	6,55	6,23	6,15	6,21	6,29
Average	6,62	6,70	6,54	6,12	6,49
NO ₃ -N kgha ⁻¹ In average of P-supply					
N ₀ = 60	6,00	6,23	6,23	5,86	6,08
N ₁ = 85	6,99	7,01	7,03	6,85	6,97
N ₂ =180	6,50	6,78	6,39	6,28	6,49
N ₃ =205	6,07	6,27	6,25	5,91	6,12
Average	6,39	6,57	6,47	6,22	
LSD _{5%} :	P ₀ -P ₁ : 0,31 N ₀ -N ₁ : 0,20 P ₀ N ₀ -P ₁ N ₀ : 0,47 N ₀ P ₀ -N ₁ P ₀ : 0,41				

The crude protein content and the amino acid composition of maize grain was not influenced by the P- and K-supply there for in Table 3. only the N effects are presented.

The crude protein content of maize is basically determined by the genotype but there are some factors, such as fertilization, irrigation, plant density, and crop year, which can modify it (Veress 1973, Proksza – Harmati 1988, Pásztor et al. 1997). Among these factors the N-fertilization and the crop year have the strongest effect on the crude protein content. In our experiment the crude protein content of the maize grain in the wet season (2001) was 9,6% in average and in the drier season (2002) was 12,3%. But the crude protein yield was higher in the wet season. In line with the higher $\text{NO}_3\text{-N}$ capacity of the soil the crude protein content increased compared with the control. But if the $\text{NO}_3\text{-N}$ content in the 0-60 cm soil layer prior to planting was above $80\text{-}85 \text{ kg ha}^{-1}$ there was no significant increase in the crude protein.

The amino acid composition of maize is strongly determined by the genotype but the agrotechnical and ecological factors can modify it (Veress 1973, Pásztor et al. 1997). On the basis of our experiment data the quantity of the amino acid increased in line with the higher crude protein content. From the 17 amino acid analysed in 2001 six and in 2002 eleven showed significantly higher values at the better N-supply Lysine and methionine were very stable and their quantity as well as the ratio of essential and non essential amino acid were not influenced by N-supply.

The nutrient content and ratio of the maize leaf for the diagnostic purpose plant analysis are shown in Table 4. The sufficient nutrient concentration to obtain high yield and good quality were as follows: N 3,0-5,0%, P 0,30-0,40%, K 1,5-2,5%, Ca 0,15-0,50%, Mg 0,10-0,35%, micro elements mg kg^{-1} : Fe 100-350, Mn 60-180, Zn 10-30, Cu 3-10.

Table 3: Effect of N-supply on crude protein content and amino acid composition of maize grain (Szarvas, 2001-2002)

Components	NO ₃ -N kgha ⁻¹ in 0-60 cm soil layer				LSD _{5%}	NO ₃ -N kgha ⁻¹ in 0-60 cm soil layer				LSD _{5%}	Average
	N ₀	N ₁	N ₂	N ₃		N ₀	N ₁	N ₂	N ₃		
	38	80	131	148		60	85	180	205		
	2001					2002					
Crude protein %	8,44	9,65	10,02	10,18	0,67	11,17	12,43	12,74	12,87	0,54	10,93
Amino acid %											
Essential											
Arginine	0,47	0,47	0,47	0,47	-	0,42	0,50	0,48	0,49	-	0,47
Histidine	0,35	0,31	0,35	0,38	-	0,35	0,40	0,40	0,41	0,03	0,37
Isoleucine	0,23	0,32	0,33	0,31	0,05	0,36	0,41	0,41	0,43	0,03	0,35
Leucine	0,92	1,12	1,24	1,23	0,12	1,42	1,67	1,69	1,75	0,07	1,38
Lysine	0,34	0,35	0,33	0,34	-	0,43	0,44	0,42	0,47	-	0,39
Methionine	0,09	0,09	0,11	0,09	-	0,25	0,26	0,27	0,28	-	0,18
Phenilalanine	0,43	0,51	0,56	0,57	0,05	0,53	0,67	0,62	0,65	0,06	0,57
Treonine	0,34	0,35	0,38	0,38	-	0,41	0,47	0,48	0,50	0,04	0,41
Valine	0,37	0,40	0,42	0,38	-	0,40	0,48	0,46	0,50	0,06	0,43
Total	3,54	3,92	4,19	4,15		4,57	5,30	5,23	5,48		4,55
Non-essential											
Alanine	0,58	0,69	0,74	0,71	0,07	0,88	1,00	1,01	1,04	0,05	0,83
Asparagine	0,69	0,66	0,75	0,73	-	0,79	0,86	0,91	0,90	0,08	0,79
Cysteine	0,10	0,11	0,11	0,10	-	0,24	0,26	0,26	0,27	-	0,18
Glicine	0,40	0,42	0,47	0,42	0,04	0,50	0,57	0,56	0,59	0,03	0,49
Glutamine	1,55	1,62	1,75	1,75	0,14	2,23	2,54	2,69	2,68	0,28	2,10
Proline	0,62	0,67	0,76	0,63	-	1,06	1,04	1,08	1,05	-	0,86
Serine	0,43	0,46	0,49	0,45	-	0,55	0,65	0,66	0,67	0,05	0,55
Tyrosine	0,24	0,23	0,26	0,25	-	0,10	0,10	0,11	0,10	-	0,17
Total	4,61	4,86	5,33	5,04		6,35	7,02	7,28	7,30		5,97
EA+NEA	8,15	8,78	9,52	9,19		10,92	12,32	12,51	12,78		10,52
Rel. %	100,00	108,00	117,00	113,00		100,00	113,00	115,00	117,00		-
EA/NEA	43/57	45/55	44/56	45/55		42/58	43/57	42/58	43/57		43/57

Table 4: Nutrient supply values of maize on the basis of the nutrient content and ratio of the leaf at beginning of flowering (Szarvas, 2001-2002)

Nutrient		Nutrient supply			
		Poor	Sufficient	High	
N	%	< 3,0	3,0-5,0	5	<
P	%	< 0,30	0,30-0,40	0,40	<
K	%	< 1,5	1,5-2,5	2,5	<
Ca	%	< 0,15	0,15-0,50	0,50	<
Mg	%	< 0,10	0,10-0,35	0,35	<
Fe	mgkg ⁻¹	< 100	100-350	350	<
Mn	mgkg ⁻¹	< 60	60-180	180	<
Zn	mgkg ⁻¹	< 10	10-30	30	<
Cu	mgkg ⁻¹	< 3	3-10	10	<
N/P		< 10	10-13	1,3	<
K/P		< 5	5-7	7	<
N/K		< 1,8	1,8-2,2	2,2	<
K/Ca		< 5	5-10	10	<
K/Mg		< 7	7-15	15	<
Mn/Zn		< 5	5-7	7	<
P/Fe		< 10	10-30	30	<
P/Mn		< 20	20-50	50	<
P/Zu		< 130	130-300	300	<
P/Cu		< 100	100-400	400	<
N/Cu		< 4 000	4000-10000	10000	<

Conclusion

On chernozem meadow soil where the humus content was 3,0-3,2% the highest grain yield was obtained if the NO₃-N capacity of the soil in 0-60 cm, prior to planting was 80-85 kgha⁻¹.

At 120-180 mgkg⁻¹ AL-P₂O₅ level of soil the grain yield increased in line with the better P-supply.

If the soil K-status is above 230 mgkg⁻¹ AL-K₂O the K-fertilization is not needed. The K over-supply, if the AL-K₂O is above 350 mgkg⁻¹ resulted in lower grain yield.

At 120-340 mgkg⁻¹ AL-P₂O₅ and 230-465 mgkg⁻¹ AL-K₂O levels of the soil the crude protein content and the amino acid composition were not influenced by the P- and K-supply.

The better N-supply resulted in significantly higher crude protein content to 80-85 kgha⁻¹ NO₃-N content of the soil in 0-60 cm, prior to planting.

The crop year effect on crude protein content is more significant than the nutrient supply.

The ratio of essential and non essential amino acid were not influenced by N-supply only their quantity.

The sufficient nutrient concentration of the maize leaf at beginning of the flowering were as follows: N 3,0-5,0%, P 0,30-0,40%, K 1,5-2,5%, Ca 0,15-0,50%, Mg 0,10-0,35%, micro elements mgkg⁻¹: Fe 100-350, Mn 60-180, Zn 10-30, Cu 3-10.

Acknowledgements

This research project was supported by the Hungarian Scientific Research Found (OTKA-T-034436).

References

- Csathó, P. (1997): Összefüggés a talaj K-ellátottsága és a kukorica, őszi búza és lucerna K-hatások között a hazai szabadföldi kísérletekben, 1960-1990. *Agrokémia és Talajtan*, 46: 327-346.
- Csathó, P. – T. Árendás – T. Németh (1998): New environmentally friendly fertilizer recommendation system for Hungary. *Bibliotheca Fragmenta Agronomica*, 3: 225-230.
- Izsáki, Z. (1999): A nitrogén és foszfor ellátottság hatása néhány szántóföldi kultúra fehérjetartalmára és aminosav összetételére. In: *Növénytermesztés és környezetvédelem* (szerk.: Ruzsányi, L – P. Pepó), 92-96, MTA, Budapest.
- Izsáki, Z. (2000): A diagnosztikai célú növényanalízis alkalmazása a cukorrépa tápanyagellátásának rendszerében. *Cukoripar*, LIII: 141-147.
- Kádár, I. (1992): A növénytáplálás alapelvei és módszerei. MTA Talajtani és Agrokémiai Kutató Intézete, Budapest.
- Kádár, I. (2000): A műtrágyázás hatása a kukorica (*Zea mays* L.) elemfelvételére meszes csernozjom talajon II. *Növénytermelés*, 49: 127-140.
- Németh, T. (1998): Role of phosphorus in Hungarian agriculture. *Bibliotheca Fragmenta Agronomica*, 3: 298-309.
- Pásztor, K. – B. Forgács – Z. Győri – Sz. Szilágyi (1997): Kukorica hibridek fehérje- és aminosav-összetételének vizsgálata. *Növénytermelés*, 46: 23-35.
- Proksza Paplogó, Zs. – I. Harmati (1988): Kukorica hibridek keményítő-, fehérje- és olajtartalma. *Növénytermelés*, 37: 17-25.
- Veress, I. (1973): A kukoricaszem aminosavjainak változása nitrogén műtrágyázás hatására. *Növénytermelés*, 22: 125-136.

THE IMPACT OF BIOPREPARATIONS APPLIED WITH MINERAL FERTILIZERS ON SPRING BARLEY

J. Hýsek, M. Vach, J. Brožová and M. Javůrek

Research Institute of Crop Production, 161 06 Praha 6 - Ruzyně, Czech Republic

Abstract

Spring barley (cv. Akcent) was used as a model cereal. The effect of three biopreparations, Supresivit (based on *Trichoderma harzianum*), Polyversum (based on *Pythium oligandrum*) and Ibefungin (based on *Bacillus subtilis*), was investigated. We compared three ways of application: a) seed treatment, b) in the mixture with ammonium sulphate, c) spraying in the tillering stage. We evaluated the influence of treatments on plant health, yield characteristics and the compounds of soil mycoflora. The health state of plants was better and the yield and its characteristics were more positive in the variants where the biopreparations were applied. The germs of the fungi of genus *Fusarium* in the soil increased more rapidly in non-treated variants. The biopreparations influenced the composition of soil mycoflora, yield and health of spring barley.

Key words: Spring barley, biopreparations (Supresivit, Polyversum, Ibefungin), *Trichoderma harzianum*, *Pythium oligandrum*, *Bacillus subtilis*, health state of plant, soil pathogenic fungi, soil saprophytic fungi, *Fusarium* spp.

The fungi of the genus *Fusarium* should be suppressed by the bioagents from the biopreparations or other mycoparasitic soil fungi. These fungi had also saprophytic ability. Cereal root-rot pathogen *Helminthosporium sativum* has been shown to have a relative poorly developed competitive saprophytic ability than *Fusarium* (Butler, 1953). On the contrary some fungi persist long-time in the soil in different structures like e.g. sclerotia. The tiny sclerotia of *Verticillium dahliae* are produced in abundant host plants. So far as is known the conidia and mycelium do not survive in the soil, but the sclerotia are very persistent (Schreiber et Green, 1962). Conidia of *Cochliobolus sativus* and *C. victoriae* became dependent upon exogenous nutrients after 7 days' incubation on soil or leached sand. Decreased viability followed the loss of nutrient independent germination of *C. victoriae* was stimulated when it was leached with exudate from spores of either fungus, or by a dilute nutrient solution stimulating natural exudate (Bristow and Lockwood, 1975). Elmholt (1997) used microbial activity, fungal abundance and distribution of *Penicillium* and *Fusarium* as bioindicators to characterize organically cultivated soils. The importance of the crop was clearly demonstrated in the form of a significantly higher abundance in the cultivated soils. The abundance of the mainly soil-borne penicillia was significantly higher at the oldest organically cultivated farm than at the other localities. The abundance of

Fusarium was more variable at the genus level, especially *F. culmorum*. The aim of our paper is to give the knowledge about the biopreparations (Supresivit, Polyversum and Ibefungin) with the fertilizers for plant protection of spring barley in the topics - plant health and the composition of soil mycoflora.

Material and Methods

We established field experiments on little parcels (3 x 6m) with following variants:

- 1) Control, without fertilizing
- 2) The fertilization with ammonium sulphate (30 kg N per ha before sowing)
- 3) The fertilization with ammonium sulphate (30 kg N before sowing per ha), seed-treatment with Vitavax
- 4) dtto, seed-treatment with Polyversum
- 5) dtto, seed treatment with Ibefungin
- 6) dtto, seed treatment with Supresivit
- 7) The mixture of ammonium sulphate with Polyversum (3g)
- 8) The mixture of ammonium sulphate with Ibefungin (0,5 ml)
- 9) The mixture of ammonium sulphate with Supresivit (0,5 g)
- 10) Ammonium sulphate - spraying with Polyversum
- 11) Ammonium sulphate - spraying with Ibefungin
- 12) Ammonium sulphate - spraying with Supresivit

All parcel 2-12 were fertilized with ammonium sulphate (30 kg N per ha)

We evaluated plant yield and plant health state (the infestation with fungal diseases) and the composition of soil microfungi. The composition of soil mycoflora was determinated by the cultivation of soil extract (5g per 500 ml of distilled water) - 1 ml on malt extract agar.

Results

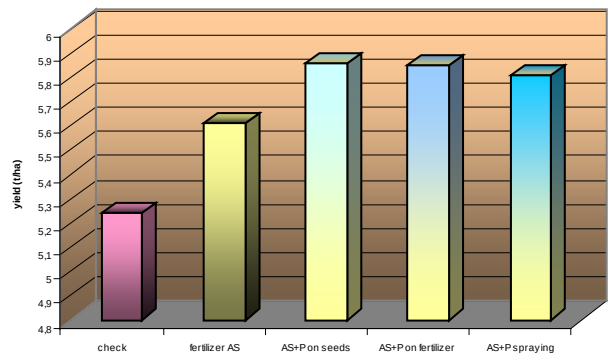


Figure 1: Spring barley yield harvest in 2002 - different application ways of the biopreparation Polyversum

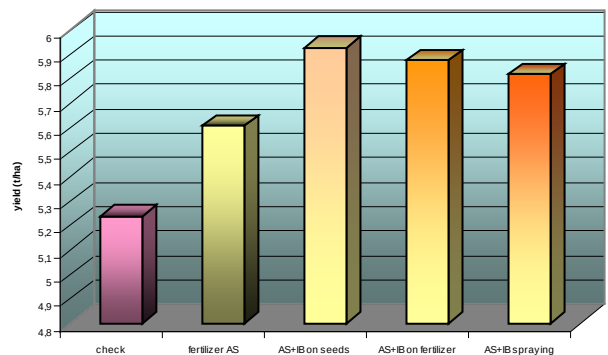


Figure 2: Spring barley yield harvest in 2002 - different application ways of the biopreparation Ibefungin

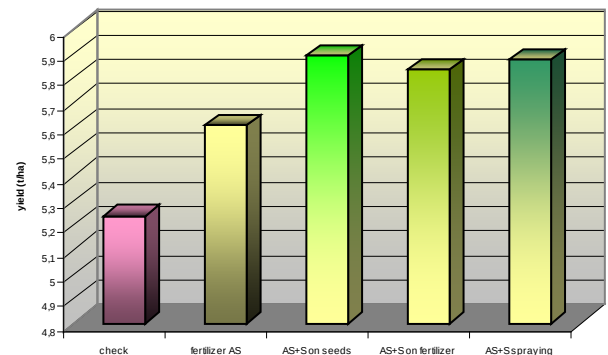


Figure 3: Spring barley yield harvest in 2002 - different application ways of the biopreparation Suprevisit

The bioagens of the biopreparations (Supresivit, Polyversum and Ibefungin) reacted with soil mycoflora. The following the spectrum of soil mycoflora was found out before sowing of spring barley:

Paecilomyces varioti

Paecilomyces spp.

Acremonium spp.

Humicola fuscoatra

Penicillium sp.

Verticillium sp.

Fusarium oxysporum (5 %)

sterile mycelium

After the seed treatment with chemical preparation of Vitavax or when we used the biopreparates we reached following spectrum of soil fungi:

Table 1: 1 month after sowing:

Vitavax	Supresivit	Ibefungin	Polyversum
<i>Fusarium graminearum</i> (12 %)	<i>Fusarium</i> sp. (25%)	<i>Fusarium graminearum</i> (6%)	<i>Fusarium graminearum</i> (3%)
<i>Fusarium culmorum</i> (16 %)	<i>Fusarium oxysporum</i> (8%)	<i>Fusarium oxysporum</i> (8%)	<i>Fusarium oxysporum</i> (34%)
<i>Fusarium poae</i> (4 %)	<i>Fusarium chlamydosporum</i> (6%)	<i>Fusarium</i> sp. (15%)	<i>Fusarium</i> sp. (5%)
<i>Fusarium tricinctum</i> (2 %)			
<i>Fusarium</i> sp. (4 %)			
<i>Paecilomyces</i> sp.			

Table 2: 2 month after sowing

Vitavax	Supresivit	Ibefungin	Polyversum
<i>Fusarium graminearum</i> (25%)	<i>Fusarium oxysporum</i> (9%)	<i>Fusarium</i> sp. (0%)	<i>Fusarium oxysporum</i> (18%)
<i>Fusarium tricinctum</i> (9%)	<i>Acremonium</i> sp.(9%)	<i>Acremonium</i> sp.(27%)	<i>Acremonium</i> sp. (18%)

The spraying had only weak effect in comparison with seed treatment or with mixture the biopreparations with fertilizer.

Discussion

From our results there is visible that the application of different biopreparations based on the microorganisms (Supresivit - *Trichoderma harzianum*, Polyversum - *Pythium oligandrum* and Ibefungin - *Bacillus subtilis*) leads to the suppression of the fungi of the genus *Fusarium*. These fungi had long-term persistence in organically fertilized soils (Elmholt, 1997) but the mechanism of its surviving was another than in the form of sclerotium (Schreiber and Green, 1962). In our experiments we used named biopreparations which were comparable with different saprophytic mycoflora (Butler, 1953, Schreiber and Green, 1962, Bristow and Lockwood, 1975, Elmholt, 1997) and described from the point of view of their reaction with soil microfungi. The fungi of the genus *Fusarium* in the soil were actively suppressed with the microorganisms from the biopreparations (*Trichoderma harzianum*, *Pythium oligandrum*, *Bacillus subtilis*) and the fertilizer used by us (ammonium sulphate) had concomitant role in the application.

References

- Bristow, P.R., Lockwood, J.L., 1975: Soil Fungistasis: Role of Spore Exudates in the Inhibition of Nutrient-Independent Propagules. J.Gen.Microbiol, 90, 140-146
- Butler, F.C., 1953: Saprophytic behavior of some cereal root rotting fungi. I. Saprophytic colonization of wheat straw. Ann.Appl. Biol. 40: 284-297
- Elmholt S., 1996: Microbial Activity, Fungal Abundance, and Distribution of Penicillium and Fusarium as Bioindicators of a Temporal Development of Organically Cultivated Soils. Biological Agriculture and Horticulture, 13: 123-140
- Schreiber, L.R., Green, R.J., 1962: Comparative Survival of Mycelium, Conidia and Microsclerotia of Verticillium albo-atrum in mineral soil. Phytopathology 52: 288 - 289

NITROGEN IMPACT ON WHEAT QUALITY

M. Jolánkai, Zs. Szentpétery, F. H. Nyárai and A. Máté

Szent István University, 2103 Gödöllő, Páter Károly utca 1, Hungary

Abstract

Milling and baking quality of wheat is mainly determined by the genetic basis, however it can be influenced by management techniques. Series of winter wheat varieties were examined under identical agronomic conditions in seven consecutive experimental years in 1996-2002. Weed control, the rate and application time of nitrogen top dressing, insecticide and fungicide use and the climate of the production year were evaluated as main factors. In the given study two major characteristics; protein- and gluten-content of grain samples were examined.

The effect of nitrogen fertilization proved to have the strongest impact on both quality figures. There were no significant quality differences induced by the means of weed control. Plant protection treatments had a rather diverse effect on protein and gluten manifestation in certain years. Protein and gluten values correlate in all experimental applications, however the level of that shows considerable variations. The effect of crop year was proved to be the strongest with fertilization second to that from among quality determining factors. Protein versus gluten correlation was found to be the closest also in the case of nitrogen top dressing applications.

Key words: winter wheat, protein, gluten, agronomic impacts

Introduction

Nitrogen is a most ubiquitous element in nature, as well as an essential constituent of proteins and other important macromolecules in all organisms. Nitrogen exists in nature in a number of important chemical forms, only a few of which are environmentally significant. Ammonia (NH_4), nitrate (NO_3), nitrite (NO_2), and organic nitrogen are the principal nitrogen forms concerning plant growth. The nitrogen cycle is manifested in a continuous cyclic exchange between combined nitrogen in the soil and molecular nitrogen in the atmosphere. It includes all the transformations concerned in the mineralization of nitrogenous organic substances and in the loss or gain of nitrogen by the soil. Soil nitrogen occurs naturally in organic and inorganic forms as a result of plant, animal, and microbial growth. Nitrogen is stored in soil primarily in organic combinations not utilizable by higher plants, but made available as ammonia through the activities of soil microorganisms. The ammonia may be used by both higher plants and microorganisms either directly or after oxidation to nitrate-nitrogen. Both ammonia and nitrate may be lost from soil by leaching or through microbial action. Soil gains nitrogen chiefly through the addition of fertilizers and through microbial fixation of atmospheric nitrogen. The nitrogen cycle comprises the process of ammonification, nitrification, denitrification, and nitrogen fixation.

Quality of agricultural crops is often related to proteins and proteionous substances manufactured by the plant. Grain crops are a major source of human bread supply as well as a source of animal feed. Winter wheat is one of the most important grain crops in the world with a high economic value. For this reason the improvement of wheat cultivation techniques is a main task in research and development. We are able to utilise a very wide range of wheat types because the various food and feed industries differ in their requirements. Use of wheat for flour milling has remained relatively stable in recent years. The aim of wheat production is twofold; to provide quantity and quality. Milling and baking quality of wheat is mainly determined by the genetic basis, however it can be influenced by management techniques. The aim of this study was to determine the role of some agronomic impacts on wheat quality. Since protein and gluten values as main quality indicators have a rather similar manifestation, there is a need to gain more information concerning the diverse behaviour of them.

Materials and Methods

Series of winter wheat varieties were examined under identical agronomic conditions in the experimental years of 1996-2002. . The cereal management small plot trials were run at the Nagygyombos experimental field of the SZIU Crop Production Institute. Soil type of the experimental field is calcic chernozem (calciustoll). Average humus content is 2.4 %. Experiments were conducted in split-plot design with four replications. The size of each plot was 10 m². Plots were planted and harvested by plot machines. Various agronomic treatments were applied to plots. Weed control, the rate and application time of nitrogen top dressing, insecticide and fungicide use and the climate of the production year were evaluated as main factors. Grain samples were taken from all plots harvested. The present study evaluates quality manifestation related to Alföld-90 variety, a wheat produced as an agronomic standard in all experimental years. Milling and baking quality tests were done at the Concordia Laboratories and at the Crop Production Laboratory according to Hungarian standards (MSZ ISO 5531:1993, MSZ ISO 6645:1993).

Trial 1. Weed control impacts

In case of herbicide treatments provocative sprayings were applied after heading (Feekes 9-10) . All pesticides were used at the recommended dose in order to study the effects of different herbicides to winter wheat. The trial had a double control; a weedy control with no protection and a hand weeded control with no herbicide applications.

Applied herbicides and their active agents: Starane (fluroxipir) 0,8 l/ha, Pardner (bromoxynil) 2 l/ha, Banvel 480 (dicamba) 0,7 l/ha.

Trial 2. N top dressing impacts

N fertilizer was applied containing 34% ammonium nitrate. The following doses were applied at different divisions:

1. Control no chemical fertilizer
2. 40 kg/ha N (t)
3. 40+40 kg/ha N (t+f)

Single top dressing treatments were carried out at tillering (t), timing of divided treatments were at tillering and flowering (t+f).

Trial 3. Plant protection impacts

Fungicide and insecticide treatments were applied regarding the principles of Integrated Pest Management. The treatments were as follows; untreated control, fungicide, insecticide, fungicide and insecticide combined treatments.

Fungicides and active agents: Bayleton 125EC (triadimefon) l/ha, Folicur TOP (tebukonazol+ triadimefon) l/ha.

Insecticide and active agent: Bancol 50WP (bensultap) 0,75 kg/ha.

Results and discussion

The effect of nitrogen fertilization proved to have the strongest impact on both quality figures. There were no significant quality differences induced by the means of weed control. Plant protection treatments had a rather diverse effect on protein and gluten manifestation in certain years. Tables 1-3 present protein and wet gluten values recorded in the three trials.

Table 1: Protein and wet gluten manifestation in winter wheat samples, Trial 1. Weed control impacts (Gödöllő-Nagyombos, 1996-2002)

Crop year	weedy control		hand-weeded control		fluroxipir		bromoxynil		Dicamba	
	prot. %	glut. %	prot. %	glut. %	prot. %	glut. %	prot. %	glut. %	prot. %	glut. %
1996	15.5	40.2	15.8	40.3	14.9	37.4	15.8	38.5	15.8	40.6
1997	12.7	24.7	13.2	26.0	14.5	30.5	13.2	26.9	12.1	22.6
1998	12.9	28.6	13.1	27.8	12.5	27.5	11.5	24.4	12.4	27.6
1999	13.8	30.5	13.5	30.8	13.2	28.8	14.3	32.2	14.2	38.4
2000	11.8	29.0	11.5	27.7	12.3	30.1	11.6	28.3	10.8	25.7
2001	11.4	26.6	11.4	26.6	11.5	26.8	12.0	27.5	11.1	25.6
2002	17.4	39.6	17.4	39.6	17.6	38.4	18.2	41.4	18.5	39.7
LSD _{0.95}										
- protein	1.12									
- gluten	4.53									
Mean	13.6	31.3	13.7	31.3	13.8	31.4	13.8	31.3	13.6	31.5

Table 2: Protein and wet gluten manifestation in winter wheat samples, Trial 2. N top dressing impacts (Gödöllő-Nagyombos, 1996-2002)

Crop year	control		40 kg N		40+40 kg N	
	prot. %	glut. %	prot. %	glut. %	prot. %	glut. %
1996	15.7	38.0	15.9	37.5	15.8	38.8
1997	13.0	25.4	13.6	26.7	14.1	29.5
1998	12.5	27.0	14.8	35.0	14.6	33.6
1999	15.5	32.8	16.5	35.0	18.8	39.8
2000	10.6	26.0	12.0	29.9	11.8	28.3
2001	11.7	28.4	10.9	25.7	17.4	39.2
2002	13.7	30.1	15.0	33.2	19.0	39.7
LSD _{0.95}						
- protein	0.92					
- gluten	2.56					
Mean	13.3	29.7	14.1	31.9	15.9	35.6

The experimental years could be sorted into two main groups: “good and bad quality” crop years. 1996, 1999 and 2002 were outstanding crop years concerning quality parametres. Both protein and wet gluten values manifestation were good compared to other years.

The agronomic treatments examined had various effects on quality parameters. Weed conditions had less influence on protein manifestation, however means of weed control eg. the use of some herbicide substances has shown differences (Table 1). The strongest effect was observed in all years concerning N topdressing applications (Table 2). Plant protection treatments against diseases and insect pests had a rather diverse effect on quality. Protein was less affected, but gluten figures proved to be rather various in certain crop years (Table 3).

Table 3: Protein and wet gluten manifestation in winter wheat samples, Trial 3. Plant protection impacts (Gödöllő-Nagyombos, 1996-2002)

Crop year	control		bensultap		triadimefon+ tebukonazol		Bensultap and triadimefon+ tebukonazol	
	prot. %	glut. %	prot. %	glut. %	prot. %	glut. %	prot. %	glut. %
1996	15.4	38.3	15.5	39.9	15.7	40.5	15.8	38.5
1997	14.5	30.3	13.4	27.5	13.6	26.8	12.4	24.9
1998	11.0	24.4	12.7	28.5	12.2	27.5	12.3	26.7
1999	14.5	31.9	14.3	30.9	14.0	31.2	14.8	33.5
2000	11.9	28.4	11.1	28.1	12.2	30.2	11.1	28.1
2001	10.7	24.7	11.5	25.7	10.5	24.7	11.3	26.2
2002	19.4	40.4	19.8	41.8	19.3	40.6	19.0	40.9
LSD _{0.95}								
- protein	1.18							
- gluten	3.34							
Mean	13.9	31.2	14.0	31.8	13.9	31.6	13.8	31.3

Protein and gluten values correlate in all experimental applications, however the level of that shows considerable variations. Since the effect of crop year was proved to be the strongest with fertilization second to that from among quality determining factors, protein versus gluten correlation was found also to be the closest in the case of nitrogen top dressing applications.

Table 4: Correlations between protein and gluten manifestation (Gödöllő-Nagygyombos, 1996-2002)

treatment	r	P*
weed control impacts		
weedy control	0.7142	+
hand-weeded control	0.6857	+
fluroxipir	0.8285	++
bromoxynil	0.7714	++
dicamba	0.7714	++
<i>N top dressing impacts</i>		
control	0.6000	-
40 kg nitrogen	0.8857	+++
40+40 kg nitrogen	0.9714	+++
plant protection impacts		
control	0.9428	+++
bensultap	0.7142	+
triadimefon+tebukonazol	0.8571	++
bensultap and triadim.+tebukon.	0.4857	-

* P 10% = +; P 5% = ++; P 1% = +++

Conclusions

The use of different agrochemical applications had various effects on wheat quality parametres. From among treatments fertilization had the strongest effect on wheat quality, especially on protein content. Herbicides, fungicides and insecticides had occasional effects only. The results obtained suggest, that agrochemical applications in general, N fertilization in particular may have an influence in quality. Protein content and wet gluten figures of the wheat samples had close correlation in most cases. However there were experimental years and treatments, where their manifestation was not bound together. Strong correlations were found mainly in “good quality” crop years.

References

- Bedő, Z., Láng, L. (1997): A minőségbúza termesztése és nemesítése. (Growing and breeding of quality wheat). Agro-21 Füzetek, 97/14, 8-28.
- Bingham, J., Blackman, J.A., Newman, R.A. (1985): Wheat. National Seed Development Organization Ltd. Cambridge.
- Győri, Z., Győriné, M.I., Szilágyi, Sz. (2002): Complex evaluation of winter wheat quality parameters. In: Proceedings of the Alps-Adria Scientific Workshop. Ed.: Gyuricza Cs. Akaprint. Opatija. 64-69.
- Németh, T. (1996): Environment-friendly fertilizer recommendation for sustainable agriculture. In: Environmental Pollution. Ed.: B. Nath et al. ECRP, Queen Mary and Westfield College, London, 99-105
- Vida, Gy., Bedő, Z., Jolánkai, M. (1996): Agronómiai kezeléskombinációk őszi búzafajták sütőipari minőségére gyakorolt hatásának elemzése főkomponens-analízissel. (Impacts of various agronomic methods on baking quality of wheat evaluated with factor analysis). *Növénytermelés*, 45. 6. 453-462.

This research was supported by the Hungarian Scientific Research Fund
(OTKA 16921 and 29302)

THE INFLUENCE OF FERTILIZATION ON THE QUALITY OF STRAWBERRY FRUITS IN FOUR-YEAR-OLD PLANTATION

U. Moor, K. Karp and P. Põldma

Institute of Horticulture, Estonian Agricultural University, Kreutzwaldi 64, Tartu 51014, Estonia
e-mail: ulvi26@hotmail.ee, kkarp@eau.ee, ppoldma@eau.ee

Abstract

A field experiment was carried out with strawberry (*Fragaria x ananassa* Duch.) 'Bounty' to study the influence of fertilization on the quality of strawberry fruits in four-year-old plantation. Plantation was established in spring 1999 with plastic mulch and without mulch (straw mulch in yielding years and defoliation by flaming after harvest). Prior establishing a complex fertilizer was applied according to the nutrient content of the soil. Additional fertilization was carried out in 2002, when soluble fertilizers Kemfos (10:22.7:14) 2% solution and later Kemira Ferticare 14:11:25 + micronutrients was given at the same amount. Fertilizers were injected into the soil close to the plants in cases where plastic mulch was used. In plantation with straw mulch the same solutions in same amounts and at the same time were used, but they were irrigated to the topsoil close to the plants. The data of the experiment showed that the yield of first grade fruits decreased significantly in 2002 (4-year-old plants). Fertilizing had a significant positive effect to the yield of first grade fruits both in plastic and straw mulch. Fertilizing also reduced amount of spoiled fruits. In plastic mulch fertilizing increased, but in straw mulch decreased the content of vitamin C in strawberry fruits. None of the experimental factors had significant effect on content of soluble solids.

Introduction

The consumption of fresh produce is increasing throughout the world mostly due to increased health-consciousness of people. Consumers are demanding fresh fruits and vegetables of high quality – i.e. excellent appearance, flavor, texture and storage life – that are free from pesticide residues and human pathogens (Gross and Wang, 1999). Therefore, at the end of the last century and at the present time several leading scientists have pointed out the need to change the research trend in horticulture from increasing productivity to increasing quality. Quality is not a single, well-defined attribute but comprises many properties or characteristics. The component attributes of quality vary with context. The choice what to measure, and what values are acceptable, are determined with consideration of the intended use of the product, available technology, economics and often tradition (Abbott, 1999).

Several experiments have been carried out in recent years in Estonia to study the effect of growing technologies and plant age on strawberry yield (Karp and Starast 2002, Karp et al. 2002). Results from these studies have shown that, during the first two production years, strawberry yields are high even without fertilizers, at the expense of reserve fertilizers. Therefore, high investment in drip-irrigation is not necessary. A decrease in first grade fruits

becomes a real problem in the third and fourth year of production, and then it is necessary to find a low-input system for fertilizing plantations with plastic mulch, without using drip-irrigation.

The aim of the present research was to find out, whether it is possible to avoid a decrease in fruit size by injecting fertilizers under the plastic mulch in a four-year-old plantation, and to study the influence of fertilization on several quality characteristics of strawberry fruits.

Materials and methods

The plantation was established in spring 1999 as a field experiment, which was part of the production field in Tartu County, South Estonia. Fixed complete block design was used and strawberry 'Bounty' plants were planted in single rows 33 cm apart with plastic mulch and without mulch (straw mulch in yielding years and defoliation by flaming after harvest). Prior establishing a complex fertilizer was applied according to the nutrient content of the soil. Additional fertilization was carried out in 2002, when soluble fertilizers Kemfos (10:22.7:14) 2% solution and later Kemira Fercicare 14:11:25 was given at the same amount. Fertilizers were injected into the soil close to the plants in cases where plastic mulch was used. In plantation with straw mulch the same solutions in same amounts and at the same time were used, but they were irrigated to the topsoil close to the plants.

The influence of plant age and mulching on the share of first grade fruits was studied during three years (2000-2002). The total yield from 25 plants, in three replications, was picked from each of the variants (plants grown with black plastic mulch, with straw mulch, and of different ages). Fruits were divided into three categories: first grade, second grade (fruits more than 2 cm and less than 2 cm in diameter, respectively) and spoiled fruits. Average yield of first grade fruits was calculated per plant. Influence of fertilizers on the share of spoiled fruits (% from total yield), content of vitamin C and soluble solids was studied in summer 2002.

Following variants were used to study the influence of fertilization on strawberry fruit quality in four-year-old plantation:

1. Plastic mulch without fertilizers.
2. Plastic mulch plus fertilizers. In this variant fertilizer Kemfos (10:22.7:14) was used: 2% solution was injected under the plastic mulch into the soil to every single plant just before flowering and at the beginning of flowering at a dose of 1 litre per plant. For the injection, special equipment attached to the tractor was used. Additionally, at the

anthesis and at the beginning of maturation of fruits, complex fertilizer Kemira Ferticare 14:11:25 was injected at the same dose.

3. Straw mulch without fertilizers.
4. Straw mulch plus fertilizers. In this variant, the fertilizers were the same as in variant 2, but the solution was applied from above on to the plant rows.

On June 17th, 20 randomly chosen first grade fruits, in three replications, were picked, cooled down, weighed one by one, and the content of soluble solids of each individual fruit was measured with a refractometer (URL–U4.2). On June 28th, 10 fruits in three replications were picked from each variant and the content of vitamin C was measured using Tillman's method.

To study the influence of mulch and fertilizers, data was analyzed by two-way analysis of variance; for the influence of plant age, one-way analysis of variance was used; and to study correlation between different characteristics, regression analysis was used. The main effect means are presented in figures. The mean values to be compared are followed by the same letter if they are not significantly different at $P \leq 0.05$.

Results

Yield of first grade fruits

Research results showed that with cultivar Bounty the yield of the first grade fruits decreases significantly in the third yield (Fig. 1). The decline was significant for both mulches: on average, only 59 g of first grade fruits per plant were obtained in the third yield, instead of 241g plant⁻¹ in the second yield. Even though the average effect of mulch was insignificant, we may see that the decrease in first grade fruits on plastic mulch was somewhat bigger than that on straw mulch: only 22g of first quality fruits per plant were picked in the third production year instead of 238g in the second production year in plantation with plastic mulch. Fertilization had a positive effect on fruit size for both mulches and also as an average for the experiment (Fig. 2). The highest amount of first grade fruits (171g plant⁻¹) was obtained using fertilizers together with straw mulch.

Share of spoiled fruits.

Grey mould (*Botrytis cinerea*) was the main cause for fruit spoilage in our experiment. The amount of rotted fruits varied between 13 and 41% (Fig. 3). The highest amount of spoiled fruits were picked from plants grown with plastic mulch without fertilization. At the same time

minimum spoilage of fruits appeared from strawberries grown with plastic mulch with fertilization. Thus, fertilization had a positive effect on the fruits grown with plastic mulch, decreasing spoilage for 28%. The average effect of fertilization was also significant. In straw mulch fertilization did not have a significant influence on the amount of spoiled fruits, but we may still see the positive tendency to decrease the amount of rotted fruits.

In addition to diseases, another problem - fruit cracking- occurred after heavy rainfall of 81 mm on the third decade of June, which exceeded the average amount of precipitation for the whole June for 30 mm-s. Such a big change in water supply within so short a time caused remarkable damage in strawberry fruits: 55...79% of the fruits from one harvest were spoiled by cracking. The results of our research showed, that fertilization decreased the amount of cracked fruits by 12% for fruits grown with straw mulch (data not shown). The average effect of fertilization on the amount of cracked fruits was insignificant.

Content of soluble solids and vitamin C

Content of soluble solids of strawberry fruits in the current experiment varied between 10.4...11.5%. None of the experimental factors had a significant effect on the content of soluble solids.

Content of vitamin C varied between 7.1 and 20.0 mg 100 g⁻¹ FW (Fig. 4). Fertilization had a significant influence on content of vitamin C both with plastic and with straw mulch, but the influence was in opposite directions. With plastic mulch, fertilization had a positive influence, increasing content of vitamin C in fruits by 3%. In contrast, for straw mulch, fertilization decreased the content of vitamin C in fruits by as much as 10%. Average effect of mulches on the content of vitamin was insignificant.

Discussion

It is claimed that highest strawberry yields are obtained when plants are grown in deep fertile soil, with high organic matter content and good drainage (Hancock 1999). As mentioned by Perkinz–Veazie (1996), elevated temperatures have a negative effect on fruit size and quality, because strawberries have a high respiration rate, high surface to volume ratio, and a thin cuticle. Grey mould development is favored by wet conditions and warm temperatures (Bulger et al., 1987; Sosa-Alvarez et al., 1995). Thus, we may say that weather conditions were not advantageous for grey mould development.

As the plantation with straw mulch was scarified and defoliated by burning, and the ashes of the straw also act as a fertilizer, plants with straw mulch had much better growing conditions as it was, and did not have so great need for additional fertilization. Plants grown with plastic mulch had worse growing conditions: black plastic accumulates more heat than straw, the aeration is poor and there is probably the lack of available nutrients in the soil. Therefore plants grown with plastic mulch reacted positively to injected fertilizer solution in many ways: the share of first grade fruits increased, the spoilage of fruits was minimum of the variants, content of vitamin C in strawberry fruits increased. The only characteristics, which were not influenced by fertilization, were soluble solids and fruit cracking.

As mentioned, plants with straw mulch had much better growing conditions as it was, and therefore the reaction to fertilizers was somewhat different from previously discussed. For example, fertilization decreased the content of vitamin C in fruits by as much as 10%. At the same time fertilization decreased the amount of cracked fruits by 12%. But finally, the highest amount of first grade fruits (171g plant⁻¹) were obtained using fertilizers together with straw mulch.

The most intensely flavored fruits generally have high levels of both titratable acidity and soluble solids, whereas the most bland fruits are low in both these components (Kader 1991). High sugar and lower acidity will be preferred by many consumers (Haffner 2002). Thus we may say that soluble solids content is another important quality parameter and it needs further experiments to find out, is it possible to influence content of soluble solids by using different growing technologies.

We may conclude that from the producer's point of view fertilization by injecting fertilizers under the plastic is an inexpensive alternative to drip-irrigation for maintaining high quality yield in four-year-old plantation. From the consumer's point of view fertilization is not always beneficial. Vitamin C, as an antioxidant, reportedly reduces the risk of arteriosclerosis, cardiovascular diseases and some forms of cancer (Harris 1996) and therefore increasing the content of mentioned vitamin will be the important issue for the future.

Acknowledgements

The authors would like to thank companies Vasula Aed and Kemira GrowHow for their financial support.

References

- Abbott, J. A. 1999. Quality measurement of fruits and vegetables. *Postharvest Biology and Technology* 15: 207–225.
- Bulger, M. A., Ellis, M. A. and Madden, L. V. 1987. Influence of temperature and wetness duration on infection of strawberry flowers by *Botrytis cinerea* and disease incidence of fruit originated from infected flowers. *Phytopathology* 77: 1225–1230.
- Gross, K. C. and Wang, C. Y. 1999. Fresh fruits and vegetables: quality and food safety. Beltsville Symposium XXIII. *Postharvest Biology and Technology* 15: 195–196.
- Haffner, K. 2002. Postharvest quality and processing of strawberries. *Acta Horticulturae* 567: 715–722.
- Hancock, J. F. 1999. *Strawberries. Crop production science in horticulture* 11. CABI Publishing. 237 p.
- Harris, J. R. 1996. Subcellular Biochemistry. Ascorbic Acid: Biochemistry and Biomedical Cell Biology, vol. 25. Plenum, New York.
- Karp, K. & Starast, M. 2002. Effects of springtime foliar fertilization on strawberry yield in Estonia. *Acta Horticulturae* 594: 501–505.
- Kader, A.A. 1991. Quality and its maintenance in relation to the postharvest physiology of strawberry. In: Luby J. J. & Dale, A. (eds.). *The Strawberry into the 21st Century*. Timber Press, Portland, Oregon. p. 145–152.
- Karp, K., Starast, M. & Kaldmäe, H. 2002. Influence of the age of plants and foliar fertilization on the yield of strawberry cultivar Jonsok under plastic mulch. *Acta Horticulturae* 567: 459–462.
- Perkins-Veazie, P. 1996. Strawberry physiology and maintenance of quality. In: Pritts, M. P., Chandler, C. K. & Crocker, T.E. (eds.). *Proceedings of the IV North American Strawberry Conference*. Orlando, Florida.
- Sosa-Alvarez, M., Madden, L. V. and Ellis, M. A. 1995. Effects of temperature and wetness duration on sporulation of *Botrytis cinerea* on strawberry leaf residues. *Plant disease* 79: 609–615.

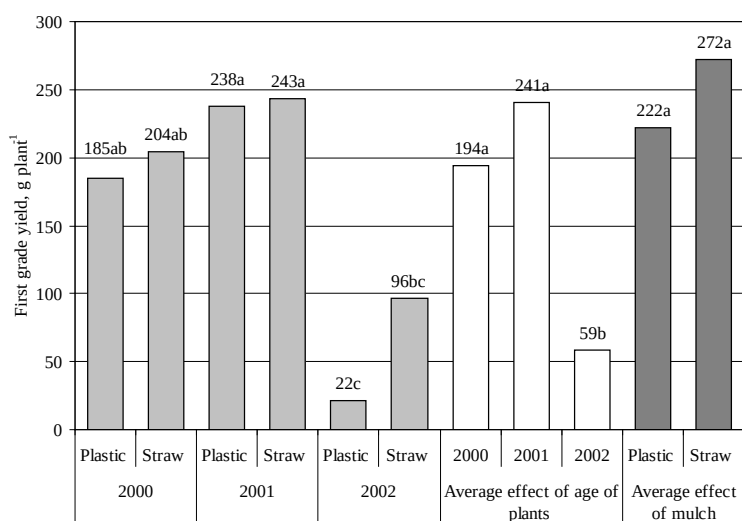


Figure 1: The yield of first grade fruits (g plant⁻¹) grown with different mulches during 2000-2002.

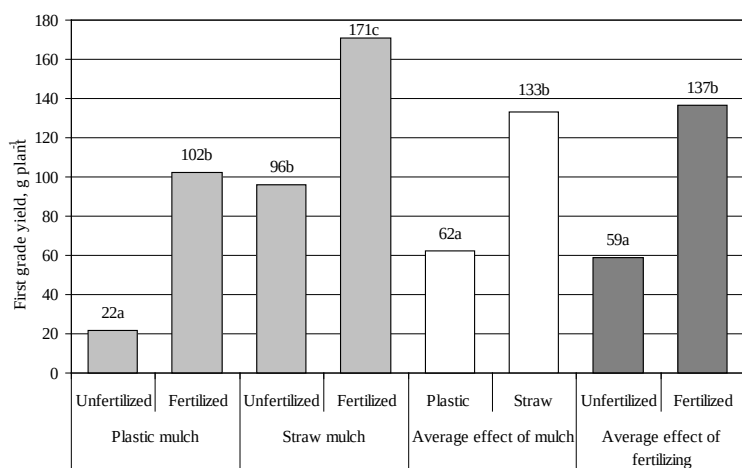


Figure 2: Influence of fertilization in different mulches on first grade yield (g plant⁻¹) of strawberry 'Bounty' in four-year-old plantation.

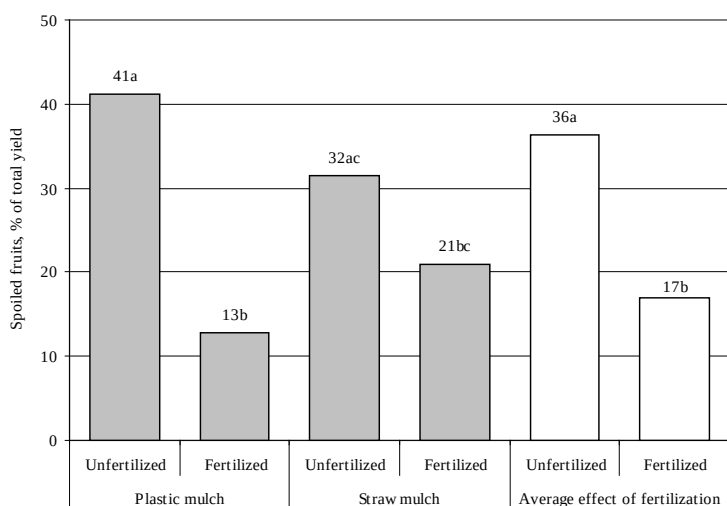


Figure 3: Influence of fertilization on the amount of spoiled fruits (% of total yield) of strawberry 'Bounty' in four-year-old plantation.

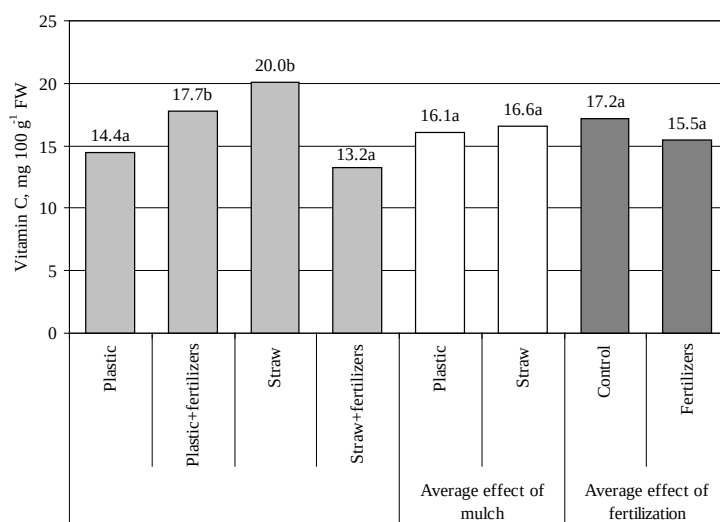


Figure 4: Influence of fertilization in different mulches on the amount of vitamin C (mg 100 g⁻¹ FW) of strawberry 'Bounty' fruits in four-year-old plantation.

VARIETY SPECIFIC FERTILIZATION IN WINTER WHEAT PRODUCTION

P. Pepó

University of Debrecen, Faculty of Agronomy, Hungary

E-mail: pepopeter@helios.date.hu

Abstract

In sustainable, environmental friendly winter wheat production nutrient-supply and fertilization has a central and decisive role among the managing elements because of their direct and indirect effects on the other crop management factors. In long-term experiments we have studied the role of agroecological, genetic-biological and agrotechnical factors on the nutrient-supply and fertilization of different winter wheat varieties on chernozem soil in Trans-Tisza (eastern part of Hungary). Our results have proved that there were different (positive and negative) interactions among the ecological-biological-agrotechnical elements of wheat production. These interaction effects could modify the natural nutrient utilization ability, the nutrient demand and the fertilizer response (mainly nitrogen) of winter wheat, and they could modify the efficiency of fertilization. On chernozem soil the average yields of wheat varieties in control treatment were 4042 kg ha⁻¹ in 1999, 4041 kg ha⁻¹ in 2000, 3193 kg ha⁻¹ in 2001, 4466 kg ha⁻¹ in 2002, respectively. We obtained the maximum yield in average of varieties 6598 kg ha⁻¹, 8296 kg ha⁻¹, 7226 kg ha⁻¹, 6555 kg ha⁻¹ respectively. The optimum N-doses (+PK) of wheat varieties varied from 60 kg ha⁻¹ (+PK) to 150 kg ha⁻¹ depending on cropyears, agrotechnical elements and genotypes. In our long-term experiments the winter wheat varieties could be classified into 4 types according to their fertilizer-demand, -utilization and -response. If we used variety-specific fertilizer doses in winter wheat production we could avoid the NO₃-content accumulation in the soil. The baking quality parameters improved by using variety-specific optimum fertilizer doses.

Our long-term experiments proved the appropriate variety-specific fertilization provides optimum yield, good yield-stability and excellent yield quality, so we could get better agronomic and economic efficiency in environmental friendly winter wheat production.

Introduction

Agriculture has traditionally an important role in Hungarian economy and rural development. About 70 % of Hungary's total territory is under agricultural land use, which is internationally an outstandingly high proportion. It is especially large rate of arable land use, which is 50 % of country's area. Because of ecological conditions and production traditions cereals have the greatest importance in Hungarian crop production.

Between 1960-1980 years Hungarian crop production (mainly cereal production) increased very rapidly. The country average-yields of wheat have increased more than three times (from 1,5-2,0 t ha⁻¹ to 5,0-5,5 t ha⁻¹). This yield increasing was based on intensive using of external inputs originating from industrial sector. Although this so called "industrial-like" crop production resulted large increases in productivity and quantity of cereals, but they often been accompanied

by detrimental side effects (decreasing agronomic and economic efficiency, environmental problems, low quality etc).

Nowadays the modern wheat production has to meet the issues of new policy agenda, which means the sustainability, the environmental protection, the agronomic and economic efficiency and high quality standards. For the above mentioned main aims it is necessary to harmonize the interactions of agroecological, biological and agrotechnical elements. In agrotechnical elements the nutrient-supply and fertilization have central and decisive role because of their interactive (direct and indirect) effects on the other technological factors. So fertilization is one of the critical elements of wheat production. Strong correlation exists between yields and the quantity of fertilizers used (Bocz 1963). In the references connected to fertilization a wide range data can be found regarding the specific nutrient demand of winter wheat. In the most of cases the optimum species-specific dose of fertilizers varies within the rang of 300-500 kg ha⁻¹ of NPK (Láng 1974, Ruzsányi 1975, Bocz 1976, Golceva 1977, Harmati-Szemes 1977, Koltay-Balla 1982, Jolánkai 1982, Plesakova et al. 1983, Pepó 1997).

It is important to identify the demand of nutrients and the responses of genotypes in wheat production because of increasing agronomic and economic efficiency, decreasing the harmful environmental effects (variety-specific fertilization). In the last two decades some references indicated the importance of variety-specific fertilization (mainly N-fertilization) in wheat production (Hera et al. 1981, Harmati 1982, Jolánkai 1982, Pepó et al. 1989, Carvalho-Basch 1996, Podolska 1997, Pepó 1999a, Pepó 1999b).

Material and Methods

Our long-term experiments were carried out in eastern part of Hungary on calcareous chernozem soil. It has average N and P content and high K content (humus content =2,8-3,0 %, total N= 0,14-0,18 %, AL-P₂O₅ = 130-200 mg kg⁻¹, AL-K₂O = 240-280 mg kg⁻¹). The depth of humus layer is 70-90 cm. The pH value is 6,2, the “Arany-type” physical texture is 43. The ground water level is under 3 m. The minimum water holding capacity (WHCmin) of the soil is 27-29 volume %. The water storage capacity of the soil is 275 mm in the 0-100 cm profile and 265 mm in the 100-200 cm profile. The disponible WHC is 157 mm and 150 mm in the 0-100 cm and 100-200 cm profile, respectively.

In our long-term experiments we used a constant ratio of 1 N: 0,75 P₂O₅ : 0,88 K₂O. The basic total dosage was 158 kg ha⁻¹ NPK, containing 60 N, and we used 1-2-3-4-5-fold amounts of the

basic dosage with a non-fertilised control (from 1997 the basic total dosage is 79 kg ha⁻¹ NPK, containing 30 kg ha⁻¹ N, the ratio N:P₂O₅:K₂O is the same).

The trial was set up in strip arrangement with four replications. There were 6 random fertilizer treatments in each replication.

In our long-term project yields, different phenological, phenometrical and agronomic traits, quality-parameters, soil characters etc were measured.

The results of 1999-2002 years are published in our paper. Each cropyears can be characterized by the followings:

1999. year: rainy autumn, hard winter, rainy spring and early summer (average cropyear)

2000. year: favourable autumn – winter – spring and dry early summer (good cropyear)

2001. year: dry autumn, mild winter, favourable spring and early summer (good cropyear)

2002. year: dry autumn – winter – spring (average cropyear)

Results and Discussion

In Hungary the agroecological conditions of winter wheat production are fairly different (soil conditions: from chernozem soil to meadow and sandy soils) and changable (climatic conditions: basically continental ones modified by humid and mediterrian effects). Our long-term experiments proved that in the eastern part of Hungary (Great Hungarian Plain) which could be charaterized by typical continental climatic conditions the weather factors of cropyears deeply modify the yield-level of wheat even on chernozem soil which has excellent water- and nutrient-husbandry. The 12 year results of GK Öthalom variety pointed out that in favourable cropyear and optimum fertilizer treatment the yield-level was 7,5-8,0 t ha⁻¹ and in unfavaurable cropyear (under continental climatic conditions it means mainly shortage of precipitation and its unfavourable distribution in vegetation period) in optimum fertilizer treatment we obtained 4,9-5,0 t ha⁻¹ yields. The fluctuation of yields comparing favourable and unfavourable cropyears were even bigger in non-fertilized control treatment. In our long-term experimental data show that it is possible to reduce the effects of climatic conditions on the yields of winter wheat if we use appropriate fertilization (and other agrotechnical elements) under continental climatic circumstances.

In extreme (like continental) climatic conditions it is very important to reduce, to minimise the harmful climatic effects on crop (wheat) production. With the appropriate fertilization and the

precise application of other agrotechnical elements we could reduce the unfavourable effects of ecological factors. Our scientific results pointed out that the optimum fertilization could increase the yield stability. In control treatment the fluctuation interval of yield was much higher (72 %) than in the optimum fertilizer application (49 %). The appropriate fertilization could increase the water-utilisation of crops (wheat). In optimum fertilization the yield-surpluses per one unit precipitation in different periods of vegetation time were much higher comparing with control coefficients (in control 5-20 kg mm⁻¹ rainfall, in optimum NPK doses 15-28 kg mm⁻¹ rainfall).

Our long-term experiment was carried out in Trans-Tisza (eastern part of Hungary) on chernozem soil characterized by excellent water- and nutrient- (nitrogen) husbandry. In harmonized fertilization (N+PK and other elements) the most important element is the nitrogen because of its very active role in the physiological processes in plants and its special mineralization in soils. The results of our long-term experiments proved that there were big differences among the nutrient and fertilizer (mainly N) demand and utilization of genotypes, so we have to use so called variety-specific fertilization in environmental friendly, sustainable wheat production. The determination of variety-specific fertilization system the following parameters were used in our long-term experiment:

- the natural nutrient utilization of genotypes (yields in control treatments)
- the specific fertilizer utilization of genotypes (yield-increasement per one unit NPK)
- the maximum yield of genotypes in optimum fertilizer treatment
- the optimum fertilizer doses of genotypes (NPK kg ha⁻¹)

The yields of control treatment showed the natural nutrient utilization of wheat genotypes. The control yields of genotypes varied between 3-4 t ha⁻¹ in our long-term experiments in 1999-2002 cropyyears. The control yields were slightly modified both by the cropyyear and the genotype. In the average of varieties the control yield was 4042 kg ha⁻¹ in 1999, 4041 kg ha⁻¹ in 2000, 3193 kg ha⁻¹ in 2001 and 4466 kg ha⁻¹ in 2002, respectively. The differences of genotypes regarding the control yield were 959 kg ha⁻¹ in 1999, 999 kg ha⁻¹ in 2000, 1075 kg ha⁻¹ in 2001 and 1147 kg ha⁻¹ in 2002, respectively which could demonstrate the differences of wheat varieties in natural nutrient utilization.

According to our long-term experimental results we can state that the cropyyear strongly modified the maximum yields of varieties. In the average of varieties the maximum yield was 6,5 t ha⁻¹ in the average cropyyears (in 1999 was 6598 kg ha⁻¹, in 2002 was 6555 kg ha⁻¹ respectively). In the favourable, good cropyyears we obtained much bigger maximum yields, but

there were differences between the cropyears characterized by favourable agrometeorological parameters. The maximum yield (in the average of genotypes) was 8296 kg ha⁻¹ in 2000 and 7226 kg ha⁻¹ in 2001, respectively. The maximum yield differences of varieties were significant in average and good cropyears too (table 1.).

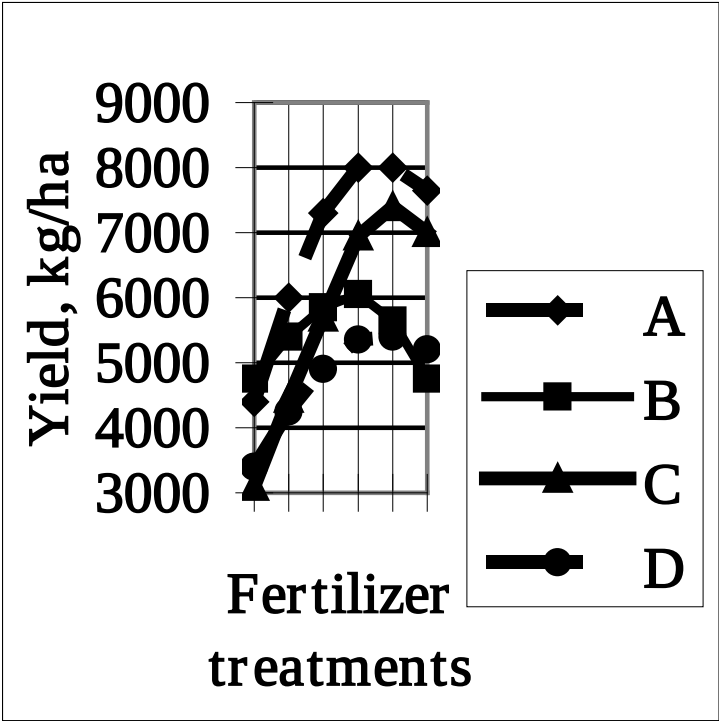
Table 1. Maximum yields of winter wheat varieties and their fertilizer doses (yield kg ha⁻¹, N_{opt.} kg ha⁻¹, chernozem soil)

Variety	1999	2000	2001	2002	Average
<i>GK Öthalom</i>	6572 ₍₉₀₎	7658 ₍₁₂₀₎	7562 ₍₁₂₀₎	6247 ₍₁₂₀₎	7010
<i>Fatima</i>	6299 ₍₉₀₎	8560 ₍₉₀₎	7875 ₍₉₀₎	6903 ₍₉₀₎	7409
<i>Mv Kucsma</i>	-	8790 ₍₁₂₀₎	7485 ₍₁₂₀₎	7213 ₍₁₂₀₎	7829
<i>Mv Magvas</i>	6697 ₍₆₀₎	8640 ₍₉₀₎	7460 ₍₉₀₎	-	7599
<i>Mv Emese</i>	-	-	6617 ₍₉₀₎	5870 ₍₁₂₀₎	6244
<i>Mv Palotás</i>	-	-	7436 ₍₉₀₎	6967 ₍₁₂₀₎	7202
<i>Mv Csárdás</i>	-	-	7183 ₍₁₂₀₎	5980 ₍₉₀₎	6582
Average	6523	8412	7374	6530	7125
Yield interval, t ha⁻¹	6,3-6,7	7,7-8,8	6,6-7,9	5,9-7,2	6,2-7,8
Min-Max, %	97-103	91-104	90-107	90-110	88-110
Interval of yield fluctuation, %	6	13	17	20	22
Interval of N_{opt.} kg ha⁻¹	60-90	90-120	90-120	90-120	80-113
LSD_{5%}	265	263	353	381	-

The variety-specific fertilization response could be demonstrated from two aspects (in the given cropyear):

- we obtained the same maximum yields by using different optimum fertilizer doses (N+PK)
(for example in 2001 cropyear the Mv Kucsma's maximum yield was 7485 kg ha⁻¹ and the Mv Magvas's maximum yield was 7460 kg ha⁻¹, but the optimum N+PK doses were different: 120 kg ha⁻¹ N+PK and 90 kg ha⁻¹ N+PK, respectively)
- we obtained different maximum yields by using the same optimum fertilizer doses (N+PK)
(for example in 2001 cropyear we used 90 kg ha⁻¹ N+PK as the optimum doses in the cases of Fatima and Mv Emese varieties but we obtained different maximum yields: 7875 kg ha⁻¹ and 6617 kg ha⁻¹, respectively).

Figure 1: Types of fertilizer response in winter wheat varieties (Peter Pepó, 1989, chernozem soil)



The meteorological characters (mainly water supply) of vegetation period determined the agronomical efficiency of fertilizers applied in our long-term wheat experiments (figure 1.). The optimum dose of fertilizers (N+PK) varied in narrow interval in the examined cropyyears (optimum N+PK in the average of genotypes):

in 1999	N ₈₈ +PK
in 2000	N ₁₀₉ +PK
in 2001	N ₁₀₃ +PK
in 2002	N ₁₀₇ +PK

The efficiency of fertilizers was determined by the water supply of the cropyyears. The yield surpluses by fertilization proved the efficiency of fertilization were better in the favourable cropyyears (in 2000 and 2001) than in the average cropyyears (in 1999 and 2002). The yield-surpluses by fertilization comparing with the control (in average of varieties) were 4255 kg ha⁻¹ in 2000 and 4033 kg ha⁻¹ in 2001 (good cropyyears) and the yield-surpluses were 2556 kg ha⁻¹ in 1999 and 2089 kg ha⁻¹ in 2002 (average cropyyears) on chernozem soil.

The appropriate fertilization could effectively modify not only the yield quantity but quality as well (table 2.). Our long-term experimental results proved that the fertilization (mainly N and harmonized PK) could strongly increase the wet gluten content and averagely the farinograph indexes and slightly the falling number. Our result proved that the changes of quality parameters were variety-specific. The water supply of cropyears also modified the quality parameters. In 2000 cropyear (better water supply in grain filling period) we obtained better quality parameters than in 2002 (very dry periods in spring and early summer in air and soil too).

Table 2: Effect of fertilization and cropyear on the wheat quality parameters
(Debrecen, variety: GK Öthalom)

Fertilizer doses kg ha ⁻¹	2000			2002		
	wet gluten (%)	Farinograph index	Falling number (s)	wet gluten (%)	Farinograph index	Falling number (s)
0	26,48	56,27	344	23,23	41,93	327
N ₃₀ +PK	26,21	57,70	336	24,26	43,58	324
N ₆₀ +PK	31,22	59,08	320	28,08	47,73	333
N ₉₀ +PK	31,79	58,80	341	29,34	51,65	341
N ₁₂₀ +PK	34,20	59,50	350	29,93	52,15	338
N ₁₅₀ +PK	34,84	59,98	362	32,13	52,75	342

Acknowledgement

The work has partially carried out with funding from the Hungarian Scientific Research Foundation (OTKA T 037 442).

References

- Bocz, E. 1963. Szerves és műtrágyák korszerű alkalmazása a szocialista nagyüzemben. (Application of manure and fertilizers in large scale farming) MTA Agrárt. Oszt. Közl., 22. 468-471.
- Bocz, E. 1976. Trágyázási útmutató (Fertilization handbook) Mezőgazdasági Kiadó, Budapest
- Carvalho, M., Basch, G. 1996. Optimisation of nitrogen fertilization. Relationship between precipitation and expected yields. Fertilizers and Environment. Int. Symp. 43:1-3, 127-130.
- Golceva, O.F. 1977. Dejszvie minarelnüh udobrenij na urozsaj ozimoz psenic v zaviszimoszti ot norm vüszeva, szorta. (Effect of fertilizers on yield of winter wheat depending on quantities of fertilizers and varieties) Agrohimja, 4.57-63.
- Harmati, I. 1982. A búza fajtaspecifikus trágyázása (Variety specific fertilization in winter wheat) MÉM NAK Kiadvány, Budapest.
- Harmati, I., Szemes, D. 1977. Búzafajta kísérletek eredményei meszes talajokon 1976-ban és 1977-ben. (Results of wheat trials on lime soil in 1976 and 1977 years) Magyar Mezőgazdaság, 32. 40.
- Hera, C., Burlacu, G., Gracium, C., Ionescu, F., Nastase, D. 1981. A nitrogén műtrágyák hatása néhány őszi búzafajta különböző típusú talajon. (Effect of fertilizers on yield of winter wheat varieties on different soils) Anal. Inst. Cerc. Cereale Pl. Teh. Fund. Bucuresti. 159-167.
- Jolánkai, M. 1982. Őszi búzafajták tápanyag- és vízhasznosítása. (Nutrient element and water utilization of winter wheat varieties). Kandidátusi értekezés.
- Koltay, Á., Balla, L. 1982. Búzatermesztés és nemesítés. (Wheat production and breeding) Mezőgazdasági Kiadó, Budapest.
- Láng, G. 1974. A trágyázás hatékonyságának néhány kérdése. (Some questions of fertilization efficiency) Agrártudományi Közl. 34.
- Pépó, Péter 1997. The role of fertilization in sustainable wheat production. CIEC 11th Int. Cong. vol. 1. 454-458.

- Pepó, Péter* 1999a. Termesztéchnológiai fejlesztések a minőségi búzatermesztésben. (Cropping development in quality wheat production). Agrofórum. 10. 11:7-13.
- Pepó, Péter* 1999b. Őszi búza környezetkímélő trágyázása. (Environmental friendly fertilization in wheat production). MTA Stratégiai Kutatások. Növénytermesztés és környezetvédelem. 130-135.
- Pepó, Péter, Bocz, E., Pepó Pál* 1989. A műtrágyázás és öntözés interakciójának vizsgálata őszi búzánál. (Investigation of interaction between fertilization and irrigation in winter wheat). Növénytermelés. 38.4.299-306.
- Pleskova, Sz.V., Mjaszinikova, L.K., Ajrumov, L.P.* 1983. Az őszi búza terméshozamának összefüggése a műtrágyaadagokkal és a vetési normával, gyepek podzolos talajon. (Effect of fertilization and sowing density of winter wheat on yield). Trudü VIOUA, 63. sz. 63-73. p. Moszkva.
- Podolska, G.* 1997. Response of winter wheat cultivars and lines to certain agrotechnical factors III. Effect of nitrogen fertilization on grain yield and yield components of new winter wheat cultivars and lines. Biuletyn Instytutu Hodowli i Aklimatyzacji Roslin. No 204. 169-172.
- Ruzsányi, L.* 1975. A növényállomány evapotranspirációjának vizsgálata különböző tápanyag-ellátottsági szinten. (Investigation of evapotranspiration in different fertilization levels). Kandidátusi értekezés.

THE INFLUENCE OF FERTILIZATION WITH DIFFERENT AMOUNTS OF NITROGEN ON THE YIELD AND QUALITY OF VIRGINIA TOBACCO*

I. Turšić¹, M. Čavlek² and T. Čosić³

¹Tobacco Institute, Zagreb, Planinska 1, Zagreb, Croatia, e-mail: tursic@usa.net

²Ministry of Science and Technology, Croatia

³Faculty of Agriculture, University of Zagreb, Croatia

Summary

Two year research has carried out at the experimental field of the Tobacco Institute, Zagreb in Pitomača. The trial was set up on luvisol; typical for the tobacco growing area in Croatia. The trial was set up according to the block method with four replications rates of 0, 20, 30, 40 and 50 kg N ha⁻¹ were applied in fertilization. In both years, as the rate of nitrogen increased from 40 to 50 kg N ha⁻¹ average yield and length and width of middle leaf also increased, but usually estimated quality of cured leaf decreased. At the same time, with the increased fertilization (> 40 kg N ha⁻¹) the content of reducing sugar decreased.

Keywords: virginia tobacco, nitrogen fertilization, tobacco yield and quality

Introduction

The main flue-cured (virginia) tobacco area is in northern Croatia, where this tobacco type is grown on sandy soil. Nitrogen has an important role in nutrition of flue-cured tobacco, since it has strongest effect on tobacco ripening, yield and quality (1, 2, 6, 7, 8). Nitrogen mineralization from organic matter, its uptake from the soil and translocation tobacco plants in closely related to the quantity and distribution of precipitation during the growing season (1, 6, 7, 8). In this respect, during two year period, 2000 and 2001, the influence of increasing rates of nitrogen in fertilization in agroecological conditions in Croatia on yield and quality was investigated.

Materials and Methods

The trial was set up in the autumn of 1999, after the winter wheat harvest on the experimental station of the Zagreb Tobacco Institute in Pitomača and included five treatments:

1. Control (Ø kg N)
 2. 20 kg N ha⁻¹
 3. 30 kg N ha⁻¹
 4. 40 kg N ha⁻¹
 5. 50 kg N ha⁻¹
-

Phosphorus and potassium rates applied in the trial were constant and amounted to 50 kg P₂O₅ and 150 kg K₂O per hectare. Stationary field trials was carried out at random block method in four repetitions. The size of the experimental plots was 4,4×20 m. The tobacco cultivar in the experimental plot was VaD. The planting interval was 110 × 45 cm. Four raws of tobacco were planted and the yield and the other properties were measured on the two middle raws on each plot. Research was conducted during two vegetation periods (1999/2000, 2000/2001). The results obtained were statistically analysed using the variants analyses.

Results and Discussion

Soil properties

The experiments were conducted on the soil that is typical for the area where tobacco is grown on about 6000 hectares in northern Croatia. According to the texture, it was sandy loam in A_p and E horizons (Table 1).

Table 1: Mechanical composition of Luvisol from experimental plot

Soil horizon	Depth (cm)	Percent of particles				Texture
		Coarse sand (2-0.2 µm)	Fine sand (0.2-0.02 µm)	Silt (0.02-0.002 µm)	Clay (< 0.002 µm)	
A _p	0-26	15	58	17	10	sandy loam
E	26-45	18	61	15	6	sandy loam
B _t	45-90	21	36	22	21	loam

Horizon E had small penetration capacity and it was compacted. It had small capacity for water in A_p horizon and small capacity for air in E horizon (Table 2).

Table 2: Physical properties of Fluvisol from experimental plot

Soil horizon	Depth (cm)	Total porosity	Water capacity	Air capacity	Bulk density gcm ⁻³
		vol. %			
A _p	15-20	48.0	33.5	14.5	1.47
E	30-35	39.6	32.0	7.6	1.57
B _t	50-55	42.3	31.0	11.3	1.51

Soil reaction was acid, content of organic matter low, and provision of available phosphorus and potassium was moderate to good (Table 3).

Table 3: Chemical properties of Luvisol from experimental plot

Soil horizon	Depth (cm)	pH in		Organic matter %	Available, mg/100 g soil	
		H ₂ O	KCl		P ₂ O ₅	K ₂ O
A _p	0-26	4.9	4.2	1.21	12.9	23.8
E	26-45	5.6	4.6	0.38	8.6	8.4
B _t	45-90	6.0	5.0	0.41	5.4	7.1

Meteorological data

The climate conditions during tobacco vegetation have influence on the yield, especially on the quality of tobacco (1, 6, 8). According to the data obtained from the meteorological station situated in the immediate vicinity of the experimental plot, there were considerable differences in the amount and distribution of precipitation (Table 4). A precipitation of 288.5 mm was recorded during the vegetation period in 2000, and 399.6 mm in 2001. An average amount of precipitation during the tobacco vegetation period (May to September) over several years amounts to 378.4 mm. In all year there were periods of drought which were worse in the first year. No negative temperatures, i.e. no late spring or early autumn frosts were registered during the tobacco vegetation periods.

Table 4: Meteorological data, Pitomača 2000-2001

Month	Year	Air temperature (°C Mean)		Sunshine h	Rainfall mm	Rainy days ≥ 5 mm
		Max.	Min.			
May	2000	21.4	10.5	192	19.4	1
	2001	19.7	9.4	207	151.7	9
June	2000	24.3	12.5	264	26.7	3
	2001	22.0	12.3	201	59.8	5
July	2000	28.9	14.7	338	31.8	3
	2001	27.2	15.0	266	24.9	3
August	2000	27.2	13.3	298	114.9	6
	2001	25.2	14.9	215	120.6	8
September	2000	21.9	10.2	196	92.7	4
	2001	20.8	10.4	173	42.6	3
Total (V-IX)	2000			1288	285.5	17
	2001			1062	399.6	28

In the production conditions of northern Croatia, without irrigation inprotant effect on chemical properties of flue-cured tobacco has quantity and distribution of precipitation (1, 6, 7, 8). Nitrogen application (> 30 kg N ha⁻¹) resulted in a significant increase of tobacco yield (3, 5, 12). The effects of fertilization with nitrogen was evident in statistically significant longer and

broader leaves and higher tobacco stalks in both years the experiments were carried out (Table 5).

Table 5: Some morphological properties of tobacco in dependence on fertilization with nitrogen.

Fertilization kg ha ⁻¹	Heights of plants, cm		Lenght of middle leaf		Width of middle leaf	
	2000	2001	2000	2001	2000	2001
N - P ₂ O ₅ - K ₂ O						
Ø - 50 - 150	107.3	109.6	35.4	36.3	20.3	20.4
20 - 50 - 150	109.1	118.2	37.3	38.4	20.5	23.1
30 - 50 - 150	118.2	121.4	41.2	47.2	23.1	25.6
40 - 50 - 150	126.4	136.7	42.3	48.1	25.6	27.3
50 - 50 - 150	131.0	141.8	48.5	49.4	26.3	28.1
LSD, 5%	11.3	13.4	5.8	6.1	N.S.	4.1

Also, in both years as the rate of nitrogen increased from 0 to 50 kg N ha⁻¹ yield increased (3, 4, 5, 9, 10, 11, 12). At the same time with increased fertilization from 40 to 50 kg N ha⁻¹ significantly decreased the leaf quality (Table 6).

Table 6: Effect of nitrogen fertilization on the yield and quality of flue-cured tobacco, 2000-2001

Fertilization	Yield kg ha ⁻¹		Quality index	
	2000	2001	2000	2001
N - P ₂ O ₅ - K ₂ O				
Ø - 50 - 150	1980	2030	100	100
20 - 50 - 150	2010	2080	105	108
30 - 50 - 150	2360	2160	126	121
40 - 50 - 150	2483	2380	93	89
50 - 50 - 150	2536	2410	77	68
LSD, 5%	354	286	14	17

Also, with the increased fertilization with nitrogen (> 40 kg N ha⁻¹), the content of nicotine increased and the content of reducing sugars decreased (4, 5, 8, 11).

Table 7: Effect of nitrogen fertilization on the content of nicotine and reducing sugars in tobacco leaves

Fertilization	Nicotine %		Reducing sugars %		S/N ratio	
	2000	2001	2000	2001	2000	2001
N - P ₂ O ₅ - K ₂ O						
Ø - 50 - 150	1.73	1.84	21.31	20.04	12.5	10.9
20 - 50 - 150	1.70	1.93	19.17	18.17	11.3	9.4
30 - 50 - 150	1.96	2.01	17.03	18.16	8.7	9.0
40 - 50 - 150	2.13	2.36	14.17	15.03	6.6	6.4
50 - 50 - 150	2.77	2.81	12.06	13.14	4.3	4.7
LSD, 5%	0.17	0.21	3.17	2.13		

Furthermore, the associations of higher content of nicotine and total nitrogen, and conversely, of lower content of reducing sugars in the dried tobacco leaves by increasing the rates of fertilizer, are well established. Leaves with excess N is chemically unbalanced, especially the sugar/nicotine ratio (1, 2, 4, 8).

Conclusion

In both years increased fertilization rate resulted in higher tobacco yield. Rates over 40 kg N ha⁻¹ significantly decreased the leaf quality.

References

- Akehurst, B.C. Tobacco. Second edition. Long Inc. London and New York, 1981.
- Chauteau, I., Fauconnier, D. Fertilizing for high quality and yield tobacco. Int. potash Institute Bern, 11:10-15, 1998.
- Čavlek, M., Turšić, I., Berdin, M. The effect of applied fertilization on certain properties of flue-cured tobacco. I Agronomic properties. *Tutun/Tobacco* 38(7-8):223-232, 1988.
- Čavlek, M., Turšić, I., Filipović, B. The effect of applied fertilization on certain properties of virginia tobacco varieties. II Chemical properties, *Tutun/Tobacco* 38(11-12):347-360, 1988.
- Ćosić, T., Poljak, M., Turšić, I., Čavlek, M. The effect of fertilization with NPK nutrients and their level in the leaf of flue-cured tobacco *Tutun/Tobacco* 46(7-12):105-115, 1996.
- Hawks, S.N. Principles of flue-cured tobacco production, Raleigh, 1970, 58-203.
- McCants, C.B., Woltz, W.G. Growth and mineral nutrition of tobacco. *Advances in Agronomy* 19:211-265, 1967.
- Tso, C.T. Physiology and biochemistry of tobacco plants. Inc. Strasbourg, 1972, 27-34.
- Turšić, I., Kozumplik, V. Response of flue-cured tobacco of the soil menagement and fertilization. 8th Coresta Int. Sci. Cong. Vienna, 137, 1984.
- Turšić, I., Kozumplik, V., Čavlek, M. The effect of mineral fertilization and chemical form of nitrogen on yield and quality of flue-cured tobacco. *Tutun/Tobacco* 36(5-6): 125-133, 1986.
- Turšić, I., Vuletić, N., Čavlek, M. The reaction of flue-cured tobacco to fertilization by organic and mineral fertilizers. *Tutun/Tobacco* 38(9-10):291-301, 1988.
- Turšić, I., Mesić, M., Čavlek, M. Influence of soil compaction and fertilization on the growth and development of flue-cured tobacco. 13th Inter. Sym. of the Int. Sci. Centre of Fertilizers, CIEC, Tokat, Turkey, 2002.

Section 3

Fertilization, environmental quality and sustainability

IMPACT OF CATCH CROP IN AN INTENSIVE CROP ROTATION

P. Cepuder

Institute of Hydraulics and Rural Water Management,
Universität für Bodenkultur Wien (University of Natural Resources and Applied Life Sciences, Vienna)
Muthgasse 18, A-1190 Vienna, Peter.Cepuder@boku.ac.at

Introduction

It has been widely reported that water resources are severely prone to be contaminated by point and diffuse sources within agricultural watersheds. Non-point source agriculture pollution of groundwater has become a real threat to the environment over the last 30 to 40 years. The relationship between nitrogen pollution and agricultural practices is more or less uncontested. Nitrogen in the form of nitrate is one of the fundamental nutritive substances for plants. Nitrates are very soluble in water and therefore very mobile within soil solution. Nitrogen transformation in soil is very complex and dynamic. In this way nitrogen is lost from agricultural areas and pollutes the groundwater. In Austria, the Ministry of Environment has fixed the amount of nitrate in drinking water to 50 mgNO₃/l (equivalent to 11,3 mgN/l). In 1998 more than 27% of the measurements in Lower Austria including the Marchfeld plain exceeded the limiting value.

National standardized groundwater quality monitoring started in December 1991 following the amendment of the Austrian Water Act. Groundwater quality monitoring is currently carried out at 2000 groundwater monitoring sites in tertiary and quaternary sediments and karst and fissured rocks. The monitoring network for groundwater is designed to monitor adverse impacts from diffuse pollution sources. Samples are taken quarterly. The threshold value for NO₃-N is 10,2 mgN/l. A reduction of nitrate in 149 contaminated aquifers was detected within the years 1998 to 2001. As possible reasons for this positive trend the application of various programs like the Austrian Agri-Environmental Program (ÖPUL), the program for Integrated Production of Vegetables, and the Use of Plant Available Nitrogen measurements were mentioned.

The Institute of Hydraulics and Rural Water Management investigated the impact of six intensive crop rotations with carrots, potatoes, sugar beet, and onions as well as barley and winter wheat on groundwater contamination with nitrogen in the Marchfeld. In a three year field experiment catch crops were implemented in the crop rotations whenever a period longer than three months between two crops occurred. On two out of six examined measurement sites no catch crops were planted. The nitrogen leaching was measured with small lysimeters and suction cups.

Material and Methods

The field measurements were carried out on the Marchfeld plain, approximately 30 km north-east of Vienna. The climate of the Marchfeld plain features much sunshine, high temperatures during the growing period, and relatively low precipitation. From 1960 to 1990 the average annual temperature was 9,5 °C and the average annual precipitation was 532 mm. In the year 1999 the annual total amount of precipitation was 599 mm, in 2000 it was 611 mm, and in 2001 only 499 mm. For these three years the average precipitation was 570 mm.

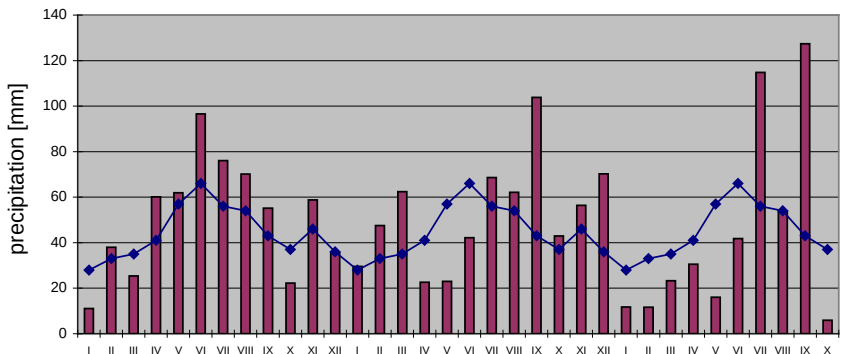


Figure 1: Monthly amounts of precipitation during the years 1999-2001.

Table 1: Monthly average temperature [°C] (1961-1990).

Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
-1,8	0,5	4,7	9,9	14,5	17,6	19,7	19,1	15,3	9,8	4,2	0,2

The soil type is czernosem with local differences of thickness and lime-content. The upper soil layer (0- 30 cm) is silty loam consisting of 20-35% sand, 40-55% silt, and 15-25% clay. The particle size distribution of the deeper soil layer (30 and 110 cm) depth contains 40-70% sand, 40-60% silt, and 10-15% clay. This deeper-layered soil is loamy sand. Below 110 cm soil depth gravel dominates. The organic carbon content within the first 30 cm varies from 1,6 to 2,6%. The plant available water storage capacity of the soil ranges from 115 mm/m to 147 mm/m.

Crop rotations of the six measurement sites (1999 to 2001) are shown in Tab. 2. In 1998 on measurement site 1 to 5 catch crops were planted.

Table 2: Crop rotations and fertilization (kg N/ha) during the years 1999- 2001.

Measurement site	1999	2000	2001
1	P- WW(CC)- SB		
	Potatoes 115	Winter wheat, catch crop 47	Sugar beet 113
2	C- B(CC)- O		
	Carrots 58	barley, catch crop 50	Onion 84
3	B- O- P		
	Barley 57	Onion 54	Potatoes 0
4	O(CC)- P- WW(CC)		
	Onion, catch crop 113	Potatoes 54	Winter wheat, catch crop 76
5	SB- C- B(CC)		
	Sugar beet 96	Carrots 50	Barley, catch crop 59
6	WW- SB- C		
	Winter wheat 89	Sugar beet 91	Carrots 37

As Austria has a very strict Water Act several programs like the Austrian Agri-Environmental Program (ÖPUL), the Integrated Production of Vegetables Program, and Use of Plant Available Nitrogen Measurements were considered to fulfil these regulations. According to those programs measures like planting catch crops as well as crop depending fertilisation were taken.

The standard crops in the Marchfeld plain are cereals as more than 75% of the properties are planted with winter wheat, durum wheat, and barley. The main other crops are sugar beet and corn. However, with an increasing need of vegetable in the catchment area of the city Vienna, more and more vegetables were included in the crop rotations.

The research project investigated six different intensive crop rotations with a 50 % split of vegetable crops with and without catch crops on six measurement sites. For comparison, measurement sites 3 and 6 were without catch crops while all other sites contained catch crops whenever the period between two crops exceeded more than three months. As catch crops a mixture of phacelia, clover, mustard, and radish was used.

Concerning the different programs, fertilisation was applied according to plant available nitrogen in soil and plant requirements. Catch crops were never fertilised. Catch crops should consume the remaining and mineralised nitrogen after harvest. Before winter, catch crops were incorporated into the soil which should supply nutrients for the following crop.

Irrigation was applied on carrots, potatoes, sugar beet, and onions. Depending on precipitation, crop water uptake, and in particular on the farmer’s experience the irrigation varied from 49 mm to 318 mm per year. Standard sprinkler irrigation systems (5 mm nozzle, 3 bar) were used to reach natural precipitation conditions. According to soil conditions and plant requirements they varied between 20 and 40 mm. Onions and carrots should not exceed more than 20 mm during one irrigation event, potatoes not more than 30 mm and sugar beet not more than 40 mm. Application of more water could result in a rise in percolation.

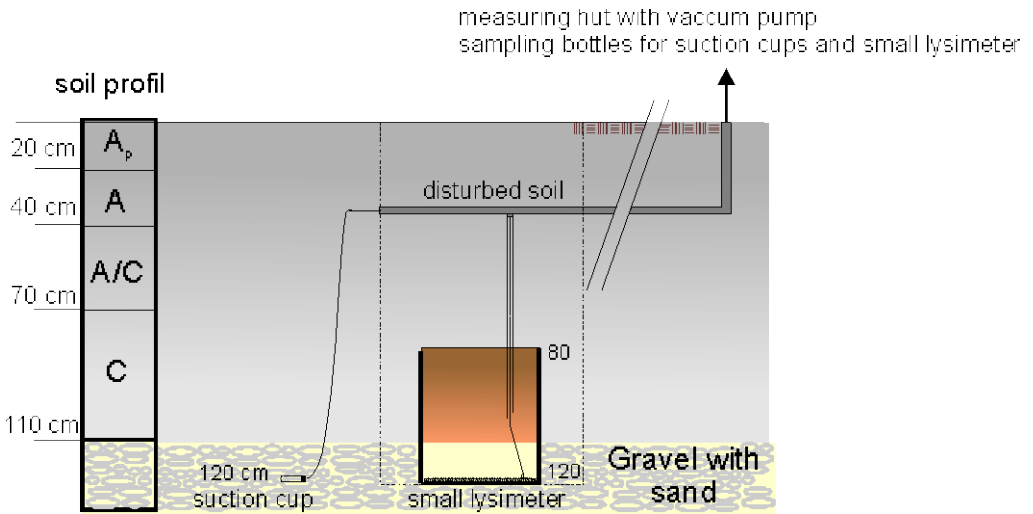


Figure 2: Scheme of small lysimeter and suction cups

At each measurement site two field measuring devices were built and provided with small lysimeter and suction cups. At a depth of 120 cm two suction cups were placed into undisturbed soil in order to measure nitrate concentration of the percolating soil water. To measure percolation below root-zone, small lysimeters were installed at the same depth. For easier installation they are placed in a disturbed soil area. The small lysimeter consists of a high flow ceramic suction plate within a PVC tube and a closed base. A tube connects the suction plate to the measuring unit where the samples are collected (Fig. 2). From the obtained values the nitrogen leaching is calculated. At each measuring site the results of the two replications were verified and averaged.

Results

During the three years of investigation crop yield, nitrogen uptake, percolation and nitrogen leaching were measured at each site with two replicates.

In the first year (1999) of the research project very low nitrate concentrations as well as relatively low amounts of leached nitrogen were determined at each measurement site except site 6. The reason for those measured values were that catch crops were planted on measurement sites 1 to 5 in the previous year. The absence of catch crops on site 6 results in an increase in leached nitrogen. The average nitrate concentration was more than four times higher. Despite huge fertilization to onions on measurement site 4 a reduction of percolation and consequently of nitrogen leaching was achieved by planting catch crops after the harvest. However, in the second year higher values of leached nitrogen and nitrate concentration were observed on sites 1 to 5. Although a catch crop was planted on site 4 an enormous rise in the average nitrate concentration could not be prevented.

Table 3 gives the average yield in dry matter of each site and the nitrogen content of the harvested yield. Yield of potatoes varied from 68 to 101 dt/ha and yield of sugar beet varied from 132 to 198 dt/ha depending on the different yearly weather conditions. All other irrigated crops delivered more or less the same yield. The use of cover crops did not effect the yield. Due to dry weather conditions in spring 2000 the yield of winter wheat and barley was less fruitful.

The nitrogen uptake by crops was equal to usual nutrient uptake and ranges from 46 to 54 kg/ha for barley to 119 to 166 kg N/ha for potatoes.

Table 3: Yield in [dt/ha] dry matter and nitrogen uptake [kgN/ha]

Measurement site	Crop rotation	1999		2000		2001	
1	P- WW(CC)- SB	68	119	45	82	132	69
2	C- B(CC)- O	86	64	25	49	63	116
3	B- O- P	46	56	52	78	89	139
4	O(CC)- P- WW(CC)	43	90	101	166	57	137
5	SB- C- B(CC)	194	132	80	96	54	105
6	WW- SB- C	64	114	198	113	62	84

Estimations of the average yearly groundwater recharge delivers about 50 mm, in other words approximately 10% of the annual rainfall will percolate through the soil. Tab. 4 contains the amounts of percolation, which were gathered with small lysimeters. As four of the six crops were irrigated every year, the average percolation of the non-irrigated crops (winter wheat and barley) was 52 mm in 1999, 48 mm in 2000, and 9 mm in 2001 more or less depending on the rainfall. The measurement sites with irrigation had values between 51 and 87 mm. On measurement site 3 the farmer irrigated too much. Therefore 210 mm were detected in the year 2000 and 122 mm of percolation were measured in 2001. Daily irrigation of about 85 mm on the onion-field resulted in an increase in percolation and therefore also in leached nitrogen in

2000. In contrast to measurement site 3, the cultivation of cereals followed by catch crop on sites 4 and 5 resulted in very low percolation and consequently low nitrogen leaching.

Table 4: Yearly percolation in [mm]

Measurement site	Crop rotation	1999	2000	2001
1	P- WW(CC)- SB	50	37	8
2	C- B(CC)- O	57	58	75
3	B- O- P	60	210	122
4	O(CC)- P- WW(CC)	34	21	4
5	SB- C- B(CC)	64	83	11
6	WW- SB- C	44	35	31

From weekly measured nitrate concentrations gained by suction cups and percolation detected by lysimeters nitrogen leaching was calculated and summed up to yearly amounts (Tab. 5). In 1999 no relation between intensive crop rotation and nitrogen leaching could be observed. The highest amount of nitrogen leaching was measured on site 6 which was covered with winter wheat. In 2000 an increase of nitrogen leaching could be seen in the vegetable plots 3 (onions) and 4 (potatoes). Over-irrigation was the reason for these higher values. Onions and potatoes were planted again in the year 2001 which resulted in alarming nitrogen leaching on sites 2 and 3. The maximum value was determined on site 3, although this site was not fertilized in 2001. Due to the lack of catch crops during the whole examination period as well as planting vegetables with high irrigation rates, nitrogen could not be kept in the upper soil layers and caused severe danger to groundwater.

Tab. 5: Yearly amount of leached nitrogen in [kg/ha]

Measurement site	Crop rotation	1999	2000	2001
1	P- WW(CC)- SB	1,7	5,2	0,1
2	C- B(CC)- O	2,9	8,1	19
3	B- O- P	2,8	40	52
4	O(CC)- P- WW(CC)	3,6	17	4,0
5	SB- C- B(CC)	4,3	8,4	2,9
6	WW- SB- C	13	5,5	2,1

Tab. 6 gives an overview of the annual average nitrate concentration in the percolation water. An increasing trend can be related to a rising intensity of crop rotation and irrigation. During these 3 years of investigation the highest values were reached on sites with two vegetable crops.

Table 6: Yearly average nitrate concentration in [mg NO₃/l]

Measurement site	Crop rotation	1999	2000	2001
1	P- WW(CC)- SB	10	62	6
2	C- B(CC)- O	21	76	111
3	B- O- P	20	86	189
4	O(CC)- P- WW(CC)	49	356	446
5	SB- C- B(CC)	29	38	77
6	WW- SB- C	131	69	27

Summary

Irrigation and precipitation had a considerable effect on the amount of percolation and consequently leached nitrogen. Catch crops reduced the percolation and helped to lower the amount of leached nitrogen. The field experiment illustrated the importance of catch crops especially for crop rotations with a high rate of vegetables in order to prevent the groundwater from being polluted.

During the three years of field experiments, 76 mm of percolation water and 16 kg/ha of leached nitrogen were measured on an annual average below the root zone in the vegetable fields. Fields covered with conventional crops like cereals and sugar beet delivered about 35 mm of percolation water and 5 kg/ha leached nitrogen per year.

Although all measures to reduce nitrogen leaching were taken into consideration, double the amount of deep percolation and a threefold increase in the amount of leached nitrogen were measured in fields under vegetable production.

As an outcome of this research project, constant and accurate measurements of the plant available nitrogen content in soil at regular intervals can be recommended. Furthermore the Agri-Environmental program measures - like crop depending maximum fertilization and catch crops - should be used. Moreover, it is also important to properly assess the effect of vegetable crop irrigation in order to prevent an unduly increase in deep percolation. Furthermore, regular and precise control of the plant available nitrogen in the soil are essential to calculate the accurate amount of fertilizer needed for the regarded crops. Other ÖPUL-measures like threshold values for fertilization as well as mulching techniques would also have a positive effect on the reduction of nitrogen leaching.

FERTILIZATION IN THE CZECH REPUBLIC THE CONSUMPTION OF FERTILIZERS AND CONTENT OF NUTRIENTS IN THE SOIL

P. Čermák¹ and M. Budňáková²

¹Central Institute for Supervising and Testing in Agriculture (ÚKZÚZ Brno),
Hroznová 2, 656 06 BRNO, Czech Republic, e-mail: pavel.cermak@ukzuz.cz

²Ministry of Agriculture of the Czech Republic, Těšnov 17, 117 05 PRAHA 1,
Czech Republic, e-mail: budnakova@mze.cz

Introduction

The plants need specific conditions of nutrition for their growth and evolution. The amount of the yield of crops namely depends on nutrient supply. The accepts and requires of organism for all life functions are called nutrient matters. The nitrogen, phosphorus and potassium together are considered as the most important mineral nutrients.

The nitrogen numbers among basic structural elements, which form the most significant part of living substance – the protein. The nitrogen, together with magnesium, forms central part of chlorophyll. The nitrogen is a nutrient which largely influences of yield of crops.

The phosphorus is indispensable and irreplaceable by other element. The phosphorus is installed in complex of DNA and RNA structures, which keep and interpret genetic information and due to control all living processes in plants, animals and human. It is a base component of energy transport system in all cells.

The potassium is most important cation in plant physiology from point of view of its content in plant tissue and its influence on physiological and biochemical functions. The very important attribute is its high degree of acceptance by plant tissue.

The consumption of nutrients in The Czech Republic

The Czech agriculture went through the large structural changes approximately since 1990. These changes have been effected by many factors. The most expressive factor is systematic decreasing of consumption of mineral fertilizers. Together with a reduction of livestock levels the produce of organic fertilizers has decreased. The organic fertilizers are also important source of nutrients, which come into the soil.

The expressive reduction of mineral fertilizing in the Czech Republic (especially by phosphorus and potassium) after 1991 has not got influence on the yield of growing crops in the meantime (by reason of persistence of soil fertility), but it has got evident incidence on the content of available nutrients in the soil. Present agricultural practice minimizes especially the phosphorus and potassium fertilization or uses no phosphorus and potassium fertilizers, namely without

attainments of lower limits of application rates. The plant nutrition is supported from old soil power.

The consumption of nutrients in last years drastically dropped down (72,3 kg N . ha⁻¹; 12,3 kg P₂O₅ . ha⁻¹; 7,7 kg K₂O . ha⁻¹)-(data of The Ministry of Agriculture of Czech Republic).

The consumption of pure nutrients in the Czech Republic in kg,ha⁻¹ of agricultural land

Table 1

<i>The year</i>	N	P₂O₅	K₂O	Σ of nutrients	Liming materials
Ø 1981-85	102,0	75,9	82,8	260,7	2 316 000
Ø 1986-90	95,0	65,1	63,8	223,8	2 645 000
1991	46,0	11,0	8,0	65,0	702 000
1992	48,2	10,5	7,1	65,8	262 000
1993	40,0	13,0	10,5	63,5	205 000
1994	57,6	10,2	13,0	80,8	268 000
1995	55,4	14,6	12,8	82,8	323 000
1996	61,3	11,8	8,0	81,1	321 000
1997	55,1	11,7	10,1	76,9	246 000
1998	53,3	12,6	7,3	73,2	240 000
1999	51,1	8,6	5,9	65,6	241 000
2000	58,9	10,8	6,2	75,9	243 000
2001	72,6	12,3	7,3	92,2	212 000
2002	72,3	12,3	7,7	92,3	estimation 210 000

(Source: The Ministry of Agriculture of Czech Republic, 2001)

Limited application of mineral fertilizers approved oneself after 1990 in the content of available nutrients in the soil. The content of available nutrients in the soil in the Czech Republic have been monitored in regular periods of Agrochemical Soil Testing (thereinafter AST).

The nitrogen is a nutrient that is most influencing of yield of crops, but the content of soil mineral nitrogen is not monitored, because of its very unstable value in dependence on many factors – namely soil and climatic conditions.

The phosphorus and potassium as next essential nutrients have been determined since 1961, in last three periods of ATS by the Mehlich method.

The development of content of available phosphorus and potassium in the Soil

PHOSPHORUS : At the beginning 60. years the content of available phosphorus in arable land was on low level – more than 2/3 of areas (70 %) had very low and low content.

The increment of phosphoric fertilizer consumption and the improvement of the soil reaction at the same time led to the increase of share of areas with good and high content of phosphorus. This trend is clearly evident till the beginning of ninetieth.

Again begins express oneself the influence of very limited consumption of mineral fertilizers and again the share of soils with very low and low rises reserve of available phosphorus (see graph No. 1).

POTASSIUM : The content of potassium in arable land of the Czech Republic was at the beginning 60. years on higher level, than for phosphorus – very low and low content was at 40,5 % of soils, suitable at 39,2 % of soils and good at 20,4 % of soils.

With higher doses of potassium fertilizers the content of available potassium in arable land increased too. It primarily resulted in reduction of areas with a low content. In 80. years the decrease of areas with a very low and low content stopped in dependence on stagnation and subsequently on decrease of consumption of potassium fertilizers. Farther the share of soils with high content of potassium grew only. Among particular categories was no expressive moving. Of late years due to a very limited application of mineral fertilizers the grew of categories with high and very high content of available potassium stopped. (see graph No. 2).

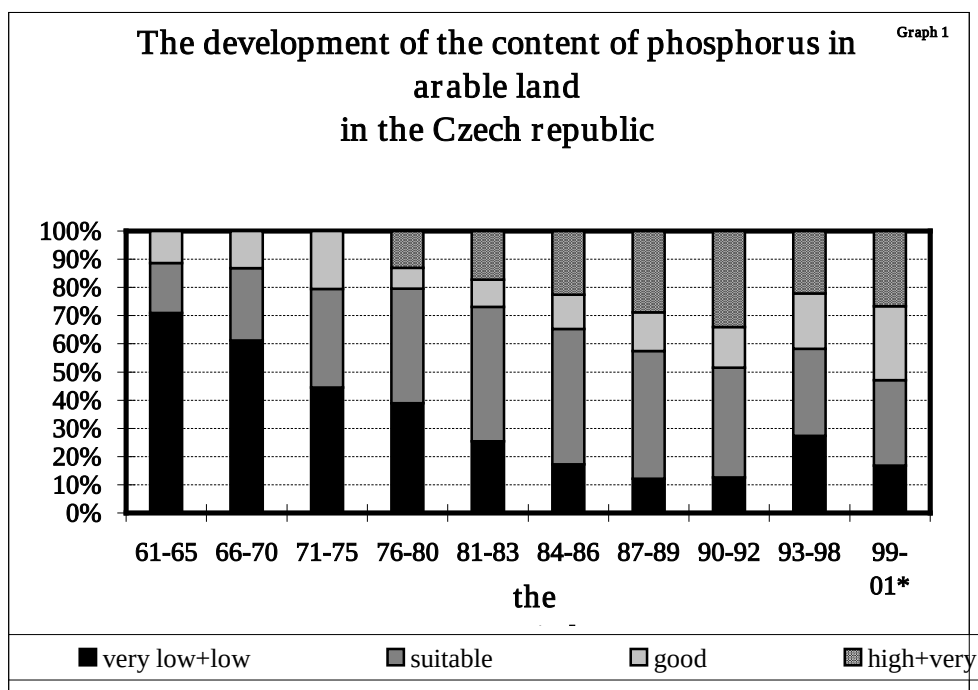
In connection with the Mehlich III method (since 1999) the new criteria of valuation of available nutrients in the soil has been used in the Czech Republic. These criteria show the sinking of shares of arable soils with very low and low contents of phosphorus and potassium in last years.

In this case it is necessary to compare the real values of weighted averages of phosphorus and potassium in the soil. In two last finished periods and for half present period of AST expressive loss of nutrients in the soil were determined – ca about 10 – 20 % (Table 2). The most considerable loss of phosphorus and potassium is at arable land, which takes the largest share of land area in the Czech Republic.

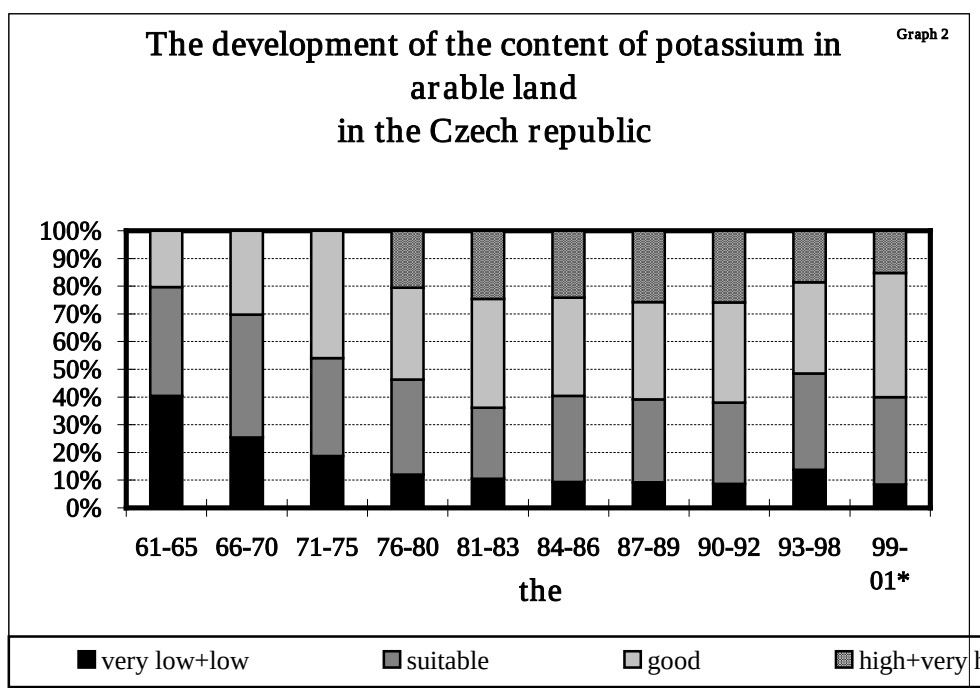
Table 2: The content of phosphorus and potassium (in mg.kg^{-1} of soil) by method Mehlich III

The period of ATS	Arable land		Grassland	
	Phosphorus mg.kg ⁻¹ of soil	Potassium mg.kg ⁻¹ of soil	Phosphorus mg.kg ⁻¹ of soil	Potassium mg.kg ⁻¹ of soil
1990-1992	107	280	76	213
1993-1998	101	256	76	192
1999-2001*	96	223	73	194

* the data from half period of ATS 1999-2004



* the data from half period of ATS 1999-2004



* the data from half period of ATS 1999-2004

Results

The consumption of mineral fertilizers in the Czech Republic is on low level. With the exception of nitrogen the consumption of phosphorus and potassium in agriculture is practically imponderable. With regard to reduction of amount of farm animals the return of nutrients from organic manures to the soil declined, too.

The reduction of consumption of mineral fertilizers makes itself felt depression of the content of essential nutrients (phosphorus and potassium) in the soil. This trend is clearly evident not only in the course of comparison of real values of weighted averages, but also at the valuation of categories of nutrient supply.

This unfavourable situation makes itself felt to the reducing of yields of growing plants and it makes a difference for all economic situations of agricultural enterprises. It can act for next development of Czech agriculture not only, but at the integrating the Czech Republic into European economic structures.

References

- Cigánek, K. – Čermák, P. : „Vliv fosforečného hnojení na výnos a kvalitu produkce, bilance fosforu, obsah fosforu v půdě“. Sborník z konference v Poznani "PHOSPHORUS IN AGRICULTURE", 2001.
- Cigánek, K. – Čermák, P. : Vliv fosforečného hnojení na výnos a kvalitu produkce, bilance fosforu a obsah fosforu v půdě. In: Proceedings of Workshop „Związki fosforu w chemii, rolnictwie i medycynie“. Wrocław, Polska, 2001.
- Čermák, P.: Nutrient balances and present state of available nutrients in the soil. In: Proc. XIVth International Plant Nutrition Colloquium „Plant Nutrition - Food security and sustainability of agro-ecosystems through basic and applied research“. Hannover, Germany: 868 – 869, 2001.
- Čermák, P.: Soil testing in the Czech Republic. Fertilizers and fertilization, Pulawy: 6 – 10, 2/2000.
- Čermák, P. – Mezuliáník, M.: Soil testing in the Czech Republic. Fertilizers and fertilization, Pulawy: 14 – 21, 3b/2000.
- Macháček, V. – Čermák, P. – Klír, J.: Development of potash fertilizer input and the consequences for soil fertility and crop production in the Czech Republic. Country Report, 61 p., 2000.
- Shepherd, M.: Nutrient losses from manure after application. Fertilizers and fertilization, Pulawy: 51 – 62, 2001.
- Trávník, K.: Výsledky dlouhodobých pokusů deklarujících účinnost a účelnost hnojení. In: Sborník z konference „Racionální použití průmyslových hnojiv“, ČZU Praha: 26 – 35, 1995.
- Trávník, K.: Vliv stupňovaných dávek hnojiv na výnosy a obsah živin v půdě - výsledky dlouhodobých pokusů ÚKZÚZ. In: Sborník z konference „Význam a perspektivy dlouhodobých polních pokusů v České republice“. MZLU-Brno: 168 – 175, 1996.

THE INFLUENCE OF P FERTILIZING STRATEGIES ON YIELDS AND P PARAMETERS IN SOIL.

B. Eichler

University of Rostock, Department of Agroecology
Justus von Liebig-Weg 6, D 18051 Rostock, Germany, bettina.eichler@auf.uni-rostock.de

Introduction

The major part of European agriculture currently operates on the base of a net P surplus, and the contribution agricultural sources of P make towards the nutrient content of surface and groundwaters is increasing. In contrast to this situation many east European regions have a negative annual P balance, and are looking for possibilities to sustain the P supply in agriculture (FROHBERG 2001, LOCH & SZÁSZ 2001). Even now a lot of soils in this region e.g. in Hungary have an insufficient nutrient content. Due to the lack of mineral fertilizers and the increase of their prices the search for alternative strategies becomes necessary. This includes the use of plants with high nutrient sufficiency as well as measures of crop husbandry.

In order to warrant the P supply of plants on a P poor soil different fertilizing strategies were investigated within a field trial in Rostock.

Materials and Methods

A field trial for analysing the effect of different fertilizer strategies under low P supply was established at the experimental station in Rostock in autumn 1998. The impact of 3 factors (table 1) were tested on a loamy sand which had an initial P_{DL} content of $5.2 \text{ mg P } 100 \text{ g}^{-1} \text{ soil}$. The soil sampling was carried out before main cropping (summer rape, summer barley and summer wheat) and after the harvest of the main crops in the upper soil layer (0-30 cm).

The organic fertilization was carried out at the beginning of the trial in autumn 1998. The mineral fertilization took place annually, whereas Triple-Super was fertilized in autumn and Nitrophoska directly before sowing the main crop.

Nitrogen to the main crops (in all 140 kg N ha^{-1}) was divided into 2 dispensations. There was a compensation of Nitrogen and Potash for those plots which did not fertilize with Nitrophoska. The total amount of K was 100 kg ha^{-1} . The catch crops remained on the plots during the winter period and were mixed into the soil in spring.

The P uptake of catch crops and main crops were estimated. Furthermore the P_{DL} content of soil (HOFFMANN 1991), the oxalate soluble content of Al, Fe and P in soil (P_{ox} , Al_{ox} , Fe_{ox})

(SCHWERTMANN, 1964) were analysed. With this contents the P sorption capacity ($PSC = (Al_{ox} + Fe_{ox}) / 2 \text{ [mmol kg}^{-1}\text{]})$ and the degree of P saturation ($DPS = P_{ox} / PSC * 100 \text{ [%]}$) (SCHOUMANS 2000) were calculated. Moreover the total P content of soil (P_t) and the Ortho P content in soil solution (P_{sol}) [$mg PO_4^{3-} l^{-1}$] were measured. In addition to these parameters the content of $CaCl_2$ soluble P, K, NH_4^+ , NO_3^- (HOUBA et al. 1986), and the content of ammonium lactate soluble P (P_{Al}) (HOUBA et al. 1997) were estimated for the soil samples of spring 1999 by the University of Debrecen.

Table 1: Proved factors in the Rostock field trial (4 repetitions)

organic fertilization	mineral fertilization	catch crops
without	without	without
manure (300dt ha ⁻¹); DM 28.7 % N _{total} = 2.86 % DM P _{total} = 1.34 % DM	in autumn with TripleSuper-P; 21.8 kg Pha ⁻¹	Oilradish (<i>Raphanus sativus</i>)
compost (300dt ha ⁻¹); DM= 74.0 % N _{total} = 1.23 % DM P _{total} = 0.28 % DM	in spring with Nitrophoska (20+8+8); 21.8 kg Pha ⁻¹	Buckwheat (<i>Fagopyrum esculentum</i>)
		Serradella (<i>Ornithopus sativus</i>)
		Ryegrass (<i>Lolium westerwoldicum</i>)
		Phacelia (<i>Phacelia tanacetifolia</i>)

Results and Discussion

The organic fertilization had a positive influence on the yields of summer barley and summer wheat but astonishingly not on rape, while the mineral fertilization influenced only the yield of this crop (table 2). The tendentious higher yields of barley and wheat after mineral fertilization do not justify that economic effort. The cultivation of some of the catch crops caused higher yields of the main crops. This is true especially for Phacelia and Serradella, but not for Ryegrass which resulted in lower yields of main crops in comparison to yields without catch cropping. The positive influence of catch cropping on soil fertility is described by other authors too (MERBACH et al. 1997), and the direct positive impact on yields is a further reason encouraging this. This cropping system should be considered as an essential part of sustainable crop production supplying main crops with nutrients and enriching the content of organic matter in soil, and the use of catch crops can be very successful like results from Cuba certified (SÁNCHEZ et al. 1995, BORGES et al. 2002, GONZÁLES et al. 2002). Further advantage is the reduction of erosion and the fixing of nutrients.

Table 2: Influences of the proved factors on yields and P uptake of the 3 main crops

factor	steps	Summer Rape		Summer Barley		Summer Wheat	
		yield dt ha ⁻¹	P uptake kg P ha ⁻¹	yield dt ha ⁻¹	P uptake kg P ha ⁻¹	yield dt ha ⁻¹	P uptake kg P ha ⁻¹
org. fertilizer	0	27.3 a	20.4 a	71.4 a	25.3 a	62.9 a	23.7 a
	manure	28.6 a	21.8 a	75.4 b	26.5 b	64.1 ab	23.9 a
	compost	27.5 a	20.8 a	74.9 b	26.2 b	65.1 b	24.2 a
min. fertilizer	0	26.7 a	20.1 a	73.0 a	26.1 a	63.5 a	23.6 a
	in autumn	28.3 b	21.4 b	73.1 a	26.2 a	64.2 a	24.2 a
	in spring	28.4 b	21.5 b	75.5 a	25.8 a	64.4 a	24.2 a
catch crops	0	27.9 a	21.0 ab	71.3 a	25.2 a	65.4 de	24.4 a
	Oilradish	27.7 a	20.6 ab	77.0 b	26.0 a	63.9 bc	23.9 a
	Buckwheat	26.8 a	20.2 a	71.5 a	26.1 a	63.5 b	23.6 a
	Serradella	28.4 a	21.8 bc	76.5 b	26.4 a	66.3 d	23.7 a
	Ryegrass	27.4 a	19.8 a	69.6 a	25.5 a	60.2 a	23.6 a
	Phacelia	29.2 a	22.6 c	77.2 b	27.0 a	64.8 cd	24.5 a

* different letters label significant differences between the variants (ANOVA, $\alpha=0.05$)

All of the 3 fertilizing strategies influenced the investigated P parameters in the soil. For compost application and mineral fertilization in autumn the highest values were measured. Again Phacelia and Serradella were the catch crops which had the highest positive impact on this P parameters.

Table 3: Influence of the proved factors on P parameters in soil (average of 6 sampling dates, from spring 1999 to autumn 2001)

factor	steps	PO ₄ -P mg P l ⁻¹ soil solution	P _{DL} mg P 100 g ⁻¹ soil	P _{ox} mg P 100 g ⁻¹ soil	PSC mmol kg ⁻¹ soil	DPS %
org. fertilizer	0	0.24 a	4.12 a	40.02 a	29.16 a	44.93 a
	manure	0.28 b	4.79 b	42.60 b	30.24 c	45.63 b
	compost	0.33 c	5.02 c	42.28 b	29.74 b	46.03 b
min. fertilizer	0	0.24 a	4.34 a	40.90 a	29.35 a	45.39 a
	in autumn	0.34 c	4.85 b	42.08 b	29.85 a	45.51 a
	in spring	0.28 b	4.74 b	42.45 b	29.94 a	45.70 a
catch crops	0	0.28 c	4.56 a	42.19 b	29.95 a	45.66 b
	Oilradish	0.25 b	4.79 b	41.48 a	29.45 a	45.83 b
	Buckwheat	0.30 cd	4.41 a	41.08 a	29.61 a	45.05 ab
	Serradella	0.32 c	4.80 b	41.22 a	29.64 a	45.23 ab
	Ryegrass	0.22 a	4.40 a	40.89 a	29.90 a	44.47 a
	Phacelia	0.35 d	4.91 b	42.98 c	29.71 a	46.96 c

*different letters label significant differences between the variants (ANOVA, $\alpha=0.05$)

The PSC values varied rarely. The same was true for the DPS values, but even little differences were statistically significant. For the several sampling dates in many cases no influence of fertilizing strategies on the soil parameters was found.

In co-operation with the Debrecen University in Hungary a comparison of different analysis methods of soil samples was carried out. Therefore not each of the factors could be taken into consideration (table 4). For the general linear model (3 factorial) a statistically significant influence of the organic fertilization was found on phosphorus which was extracted by CaCl_2 , double lactate, oxalate as well as of P in soil solution. For P_{Al} no influence of the organic fertilizers was found but the mineral fertilization in autumn caused an increase in these content as well as of P_{CaCl_2} and P in soil solution.

The positive effect of Phacelia especially became obvious for the $\text{PO}_4\text{-P}$ in soil solution. This could be caused by changing the cation/anion-relation while the ion uptake (EICHLER 1997).

There were no effect of the different fertilizing strategies on the P sorption capacity.

Table 4: Influence of some of the proofed factors on P parameters in soil in spring 1999

factor	steps	P_{CaCl_2} mg P 100 g ⁻¹ soil	P_{Al} mg P 100 g ⁻¹ soil	$\text{PO}_4\text{-P}$ mg P l ⁻¹ soil sol.	P_{DL} mg P 100 g ⁻¹ soil	P_{ox} mg P 100 g ⁻¹ soil	PSC mmol kg ⁻¹ soil	DPS %
org. fertilizer	0	0.27 a	11.41 a	0.25 a	4.41 a	40.25 a	26.85 a	30.38 a
	manure	0.31 ab	11.52 a	0.27 a	5.04 b	43.65 b	26.70 a	32.77 a
	compost	0.34 b	12.10 a	0.36 b	5.05 b	41.55 ab	26.05 a	31.91 a
min. fertilizer	0	0.28 a	11.04 a	0.28 a	4.58 a	41.15 a	26.50 a	31.18 a
	in autumn	0.33 b	12.30 b	0.31 a	5.08 b	42.50 a	26.56 a	32.20 a
catch crops	0	0.32 ab	11.76 a	0.27 a	4.71 a	43.05 a	26.27 a	32.87 a
	Oilradish	0.35 b	12.27 a	0.27 a	4.97 a	41.60 a	26.68 a	31.50 a
	Buckwheat	0.27 a	11.38 a	0.27 a	4.64 a	40.80 a	26.45 a	31.10 a
	Ryegrass	0.26 a	10.92 a	0.26 a	4.71 a	40.40 a	26.68 a	30.41 a
	Phacelia	0.33 ab	12.04 a	0.41 b	5.12 a	43.25 a	26.57 a	32.56 a

*different letters label significant differences between the variants (ANOVA, $\alpha=0,05$)

Apart from the P parameters the N and K contents were measured (see material and method). It became visible that the proofed factors had a stronger influence on the K than on the P parameters. For catch cropping again Phacelia was found to cause the highest values.

Within the comparison of different analysis methods no relation between the sorption parameters and other parameters in soil was found. This was true for P in soil solution as well

(table 5). The P_{ox} values correlated with the K but not with the P values. There were highly significant correlations between the P_{DL} , P_{CaCl_2} , and P_{Al} values.

The highest content was found for P_t followed by $P_{ox} > P_{Al} > P_{DL} > P_{CaCl_2} > P_{sol}$. Usually water extracts more than 0,01 M $CaCl_2$ because Ca^{2+} enhances sorption of P (PIERZYNSKI 2000).

There was a relation between the K values and most of the other parameters of soil.

There are difficulties in estimating phosphate fractions in soil. The results of such methods are not always transferable from one soil to another and are influenced by different factors. The methods are not always comparable with one another (JAZSBERÉNYI & LOCH 1996, EHLERT 2001). Thus fertilizer recommendations and predictions with respect to P losses from agriculture are more or less inaccurate. There are problems for estimation the plant available phosphorus too, because the methods express the current content but neglect the continuously passing mobilization and fixation processes. Also adaptation mechanisms of plants and plant soil interactions are often underestimated (SCHILLING et al. 1998).

Table 5: Relation between chosen parameters of soil (correlation of mean values, Pearson Correlation Coefficients)

	pH	NO ₃	NH ₄	Nt	N _{org}	P CaCl ₂	K CaCl ₂	P _{Al}	K _{Al}	P _{sol}	P _{DL}	PSC	P _{ox}	DPS
pH	1	0.09	0.39	0.26	0.46	0.21	0.29	0.42	0.25	-0.12	0.53	-0.13	-0.18	-0.03
NO ₃	0.09	1	0.67	0.84	0.39	0.27	0.54	0.35	0.56	0.12	0.41	0.03	0.51	0.43
NH ₄	0.39	0.69	1	0.81	0.46	0.29	0.57	0.32	0.55	-0.18	0.29	-0.10	0.24	0.29
Nt	0.26	0.84	0.81	1	0.39	0.18	0.51	0.31	0.51	0.11	0.38	-0.06	0.32	0.32
N _{org}	0.46	0.39	0.46	0.39	1	0.73	0.71	0.65	0.70	0.19	0.66	-0.19	0.11	0.21
P _{CaCl}	0.21	0.27	0.29	0.18	0.73	1	0.76	0.78	0.73	0.41	0.52	-0.15	0.41	0.43
K _{CaCl}	0.29	0.54	0.57	0.51	0.71	0.77	1	0.71	0.98	0.40	0.59	-0.24	0.52	0.59
P _{Al}	0.42	0.35	0.32	0.31	0.65	0.78	0.71	1	0.68	0.32	0.77	0.05	0.40	0.40
K _{Al}	0.25	0.56	0.55	0.51	0.70	0.73	0.98	0.68	1	0.41	0.58	-0.28	0.54	0.63
P _{sol}	-0.12	0.12	-0.19	0.11	0.19	0.41	0.40	0.32	0.41	1	0.35	-0.02	0.39	0.32
P _{DL}	0.53	0.41	0.29	0.38	0.66	0.52	0.59	0.77	0.58	0.35	1	-0.06	0.30	0.31
PSC	-0.13	0.03	-0.10	-0.06	-0.19	-0.15	-0.24	0.05	0.28	-0.02	-0.06	1	0.12	-0.49
P _{ox}	-0.18	0.51	0.24	0.32	0.11	0.41	0.52	0.40	0.54	0.39	0.30	0.12	1	0.80
DPS	-0.03	0.43	0.29	0.32	0.21	0.43	0.59	0.40	0.63	0.32	0.31	-0.49	0.80	1

Conclusions

Both, the mineral and organic fertilization, and the catch cropping have an influence on important soil parameters and yields of main crops. Especially the organic fertilization and the cultivation of *Phacelia* had positive effects. That means, even without mineral fertilization a sufficient nutrient supply of plants can be warranted. There is no P input by using catch crops as green fertilizer. Despite the total phosphate reserves in soils attention must be paid in avoiding long-term negative P balances in agriculture.

Since many different soil testing methods exist it is decisive that the selected analysis is appropriate to the geographic region and the investigated soil. Nevertheless, the chemical extraction methods often underestimate the influence of chemical and physical factors as well as organic compounds in soil, the micro organisms and the ability of plants to influence the availability of nutrients. Therefore fertilizer recommendation based on chemical extraction methods can be inaccurate. There is the need for the development of feasible models simulating this processes in soil better. The different results of the used methods emphasize the complexity of nutrient dynamics in soils. The results of the different extraction methods are not unrestrictedly comparable. This fact has to be considered when evaluating international studies.

References

- Borges, J., Leyva, O., López, R. (2002): Abonos verdes en la producción de posturas de cafetos en áreas cafetaleras de Guantánamo. XIII Congreso Científico del INCA, 12.-15. Noviembre 2002, La Habana, Cuba
- Ehlert, P. (2001): Evaluation of long-term trials with IMPHOS. Fate of phosphorus in soil.
In: EU-COST action 832: Quantifying the Agricultural Contribution to Eutrophication. Minutes of the 3rd meeting of Working Group 1 'Phosphorus inputs from agriculture'. University of Rostock, Germany 22-24 March, 2001
- Eichler, B. (1997): Phosphoraufnahme von Zwischenfrüchten und ihr Beitrag zur Nutzung akkumulierter Phosphate im Boden unter Low-Input-Bedingungen. Dissertation, Univ. Rostock
- Frohberg, K. (2001): Wirtschaftliche Ausgangssituation für die Integration der MOEL unter den Bedingungen einer gemeinsamen Landwirtschaft. 113. VDLUFA-Kongress September 2001, Kongressband Teil I, Vorträge zur Plenartagung, 33-54
- González, C., Sánchez, C., Cupull, R., Rodríguez, R. (2002): Comparación de tres especies de abonos verdes como precedentes a la plantación del café. XIII Congreso Científico del INCA, 12.-15. Noviembre 2002, La Habana, Cuba
- Hoffmann, G. (1991): Die Untersuchung von Böden. VDLUDFA-Methodenbuch Bd. 1, 4. Aufl. VDLUFA-Verlag Darmstadt.
- Houba, V.J.G., Novozamski, I., Huibregts, A.W.N., van der Lee, J.J. (1986): Comparison by soil extractions by 0,01M CaCl₂, by EUF and by some conventional extraction procedures. *Plant and Soil* 96, 433-437
- Houba, V.J.G., van der Lee, J.J., Novozamski, I. (1997): Soil analysis procedures. Dep. of Soil Sci. Plant Nutr. Agric. Univ. Wageningen, the Netherlands
- Jázberényi, I., Loch, J. (1996): Soil Phosphate Adsorption and Desorption in 0,01M Calcium Chloride Electrolyte. *Commun. Soil Sci. Plant Anal.*, 27 (5-8), 1211-1225
- Loch, J. & Szász, G. (2001): Das Ökologische Potential und die Pflanzenproduktion in Ungarn. 113. VDLUFA-Kongress September 2001, Kongressband Teil I, Vorträge zur Plenartagung, 87-96
- Merbach, W., Wurbs, A., Jacob, H.J., Latus, C. (1997): Temporary biological conservation by winter oilseed turnip (*Brassica Rapa* L.) and its influence on following crops and N-percolation. *Isotops Environ. Health Stud.* 33, 39-43
- Pierzynski, G.M. (2000): Methods of Phosphorus Analysis for Soils, Sediments, Residuals, and Waters. Southern Cooperative Series Bulletin No. 396, North Carolina State University

- Sánchez C., Kumba B., Caro, P. (1995); Utilización de los abonos verdes en interrelación con los biofertilizantes en el Escambray. En Jornada Científica de la Estación de Investigaciones de café y Cacao. Resúmenes. Tercer Frente. Santiago de Cuba: Ministerio de la Agricultura, 1995. p. 8.
- Schilling, G., Gransee, A., Deubel, A., Lezovic, G., Ruppel, S. (1998); Phosphorus availability, root exudates, and microbial activity in the rhizosphere. *Z. Pflanzenernähr. Bodenk.* 161, 465-478
- Schoumans, O.F. (2000); Determination of the Degree of Phosphate Saturation in Non-Calcareous Soils. Methods for Phosphorus Analysis for Soils, Sediments, Residuals, and Water (Pierzynski, G.M., ed), Southern Cooperative Series Bulletin 396, 31-34, North Carolina
- Schwertmann, U. (1964); Differenzierung der Eisenoxide des Bodens durch Extraktion mit Ammoniumoxalatlösung. *Z. Pflanzenernähr. Bodenk* 105, 194-202

PHYTO-EXTRACTION OF ZN AND CO FROM CONTAMINATED SOIL

I. M. Elwan¹, F. M. Abdou¹, M. F. Abdel-Sabour² and Y. J. Al-Salama³

¹Soil Sci. Dept. Fac. Of Agric., Ain Shams University, Egypt.

²Soil and water Dept, Nuclear Research Center, Egypt.

³Soil Sci. Dept. 2nd Fac. Of Agric., (Der Ezzor) Aleppo University, Syria

Abstract

This experiment was carried out under greenhouse conditions to determine the ability of some plant species grown on the examined soils to extract heavy metals and to assess the recovery percentage of Zn and Co. Three contaminated soils (B, D and E) were used in this experiment, Four Kg of each air-dried surface soil sample (0-20cm) were packed in plastic containers. Four plant species were tested in this study namely, Sorghum (*Sorghum vulgar L.*), Clover (*Trifolium pratense L.*), Panikum (*Panicum antidotal*) and Canola (*Brasica napous*); in a complete randomized block experimental design.

The data obtained from this experiment showed that:

Soil properties, plant species and their interactions significantly affected the dry matter yields of the tested plants. For example, after 60 days, the obtained dry matter yield could be arranged in the following descending order: Canola > Sorghum > Panikum > Clover. However, the cumulative biomass after three clippings showed that sorghum exhibited the highest cumulative biomass. Moreover, plants grown on the fine texture soil exhibited the highest dry matter yield compared to those grown on the coarse texture soils.

Shoot concentrations of Zn were as high as 2010 mg/kg dry matter for canola, followed by panikum and sorghum then clover with a range of Zn between 190 to 1490 mg/kg dry matter. The highest Zn uptake was observed in case of canola (either after 60 days or 85 days) compared with other tested species for any investigated soil. Panikum showed higher Zn accumulation affinity compared to sorghum or clover especially in case of soil E.

Calculation of recovery percentage based on Zn removed from the soil after cultivation (calculated on 4 kg soil bases) ranged between 12.8 to 36.3 % of total initial Zn. However, The percentage of Zn-removed by plant shoots from the initial total varied between 17.0 to 30.5% of the removed Zn, whereas the lowest values were observed in case of clover and the highest values were in case of canola. It is worth to mention that roots tend to accumulate from 69 to 81.1% of the Zn removed from soil. The highest values were noticed in case of clover and sorghum, which accompanied by less accumulation in shoots. On the contrary, the lowest recovery percentage in case of canola and panikum roots was accompanied by higher accumulation in shoots (24.9 -30.5 % of Zn removed).

Shoot concentrations of Co were as high as 111mg/kg dry matter of canola, followed by panikum and sorghum then clover with a range of Co between 9 to 94 mg/kg dry matter. Canola shoots exhibited the highest Co uptake compared to other tested species for any investigated soil. A highly significant effect of soil on Co uptake was observed. It could be noticed that Co uptake was higher in the fine textured soil E and D compared to soil B at any tested plant species or different clippings. Again, the order of Co uptake by different tested species could be arranged in the following order: Canola > Panikum> Sorghum> Clover. In contrast to Zn uptake, Co uptake increased significantly with subsequent clippings.

Calculation of recovery percentage based on Co removed from the soil after cultivation (calculated on 4 kg soil bases) ranged between 10.1 to 40.7 % of the total initial Co. However, The percentage of Co-removed by plant shoots from the initial total varied between 23.5 to 53 % of the removed Co, whereas the lowest values were observed in case of clover and sorghum but the highest values were in case of canola and panikum. Again plant root showed tendency to accumulate Co by several folds (ranged from 43.2 to 71.5% of the Co removed from soil). However, the recovery percentage of Co by root was lower than relevant percentage for Zn for different plant species and any investigated soils.

Introduction

Microorganisms and plant take up not only the elements they need for growth but also non-essential ones. Agronomists have shown that living organisms are able to take up amounts of elements large than those chemically extracted. Some plant populations, including metal-hyperaccumulating plants, can colonize these environments. Hyperaccumulation is an ecophysiological adaptation to metalliferous soils. These plants often accumulate only a specific metal; they grow slowly and have a small biomass. Interest in metal-hyperaccumulating mechanisms has come from developments in phytoremediation, a new technology that uses high biomass metal-accumulating plants to extract toxic metals from contaminated soils. The mechanisms of metal accumulation, which involve extracellular and intracellular metal chelation, precipitation, compartmentalization and translocation in the vascular system, are poorly understood. Well known metal-binding proteins include metallothioneins, metalloenzymes, and various metal storage, carriers, and channel/transport proteins (**Ebbs and Kochian, 1997**). In fact, living organisms produce specific molecules, which can mobilize some fixed elements. Some plants are able to take up a large amount of toxic elements without any visible toxicity effect (i.e. hyperaccumulators). These species are defined as those whose leaves contain > 100 mg Cd Kg⁻¹, 1000 mg Ni and Cu Kg⁻¹ or > 10000 mg Zn and Mn Kg⁻¹ (dry

weight basis) when grown on metal-rich soils (**Baker and Brooks, 1989 and Baker et al., 1994**).

Hyperaccumulator plants can thus be used to remediate soils contaminated with toxic elements. This technique appears to be an elegant one, conditional that the yield and metal accumulation are large enough to finish the remediation within a reasonable period (e.g. 5 years). Characteristics of plants able to perform Phytoextraction include (1) the ability to accumulate and tolerate high concentration of metals in harvestable tissue, (2) rapid growth rate, and (3) high biomass production.

According to **Ebbs and Kochian (1997)**, the ideal plant species to remediate a heavy metal-contaminated soil would be a high biomass crop that can both tolerate and accumulate the contaminants of interest. Some of the most likely plant species for phytoremediation are members of the *Brassicaceae* family. Some members of the mustard family from the genus *Brassica*, however, may show promise for use in remediation of metal-contaminated sites. *Brassica juncea* (Indian mustard), for example, has been shown to accumulate moderate levels of Se (**Banuelos and Meek, 1990; Banuelos et al., 1993**) Pb, Cr, Cd, Ni, Zn and Cu (**Nanda-Kumar et al., 1995**). Other *Brassica* sp., namely *B.napas* and *B.rapa*, have shown a similar tendency to accumulate moderate levels of heavy metals. Since these *Brassica* crop species produce a relatively high biomass, they must be suitable for use in phytoremediation. **Brown (1995)** mentioned that one of the earliest examples of a hyperaccumulator was the Italian serpentine plant (*Alyssum bertolonii*); another more recently identified hyperaccumulator is the alpine pennycress *Thlaspi caerulescens*. *Thlaspi caerulescens*, for instance, is a known Zn hyperaccumulator and some of its ecotypes can tolerate much as 40000 ppm Zn in the dry shoots (**Chaney, 1983**). Despite this ability to hyperaccumulate and tolerate Zn, the suitability for use of *T. Caerulescens* in the field is often limited because the individual plants are extremely small and slow growing (**Black, 1995**).

Felix (1997) reported that the wild species *Thlaspi caerulescens* and *Alyssum murale*, and the tree *Salix viminalis* showed strong ability to accumulate Zinc and Cadmium. However, phytoremediation of investigated soils contaminated with Cadmium (6.6 ppm) or Zinc (810 ppm) lasts too long. **Knight et al., (1997)** grew the hyperaccumulator *Thlaspi caerulescens* J and C-presl in seven different soils collected from around Europe that had been contaminated with heavy metals by industrial activity or the disposal of sewage sludge to land. Zinc accumulation ratio (shoot concentration / initial soil solution concentration) ranged from 3500-85000 with a mean value of around 36000. This compares with mean accumulation ratio of 636, 66 and 122 for Cd,

Ca and Mg, respectively. The concentration of Zn in the shoots was much greater than in the roots. The total removal of Zn and Cd ranged from 8 to 30 and from 0.02 to 0.5 mg/kg soil, respectively.

Recently, **Kamel (1999)** found that Barnyard Grass has a high ability for detoxification of the Pb and Cd polluted soil. The amount of Pb and Cd removed by the plant represents 50 % of the total content of these elements in the contaminated soils of Egypt.

The aim of the work was to studies the ability of some plant spieces to extract some heavy metals from contaminated soils.

Material and Methods

Soil sampling

Three soil samples were chosen from different locations at north greater Cairo, Egypt to represent different textured soils as well as contaminated with different sources of wastewater *i.e.* sewage and industrial effluent as follows:

Soil B: Polluted soil from El-Gabal El-Asfar farm. (subjected to sewage effluent irrigation for more than 75 years)

Soil D: Polluted soil from Bahtem area (subjected to sewage effluent irrigation for more than 30 years).

Soil E: Polluted soil from Mostorud area (irrigated with contaminated water for more than 30 years due to direct discharge of industrial wastewater to irrigation water canals). The non-polluted soil of this group is soil C.

Soil samples were collected from depth (0-20cm). The samples were air-dried, crushed to pass a 2.0 mm sieve then subjected to different physical and chemical analyses.

The following analyses were carried as described by **Jackson (1973)**:

- CaCO_3 content using Collin's calcimeter.
- Organic matter using Walkley and Black method.
- Soluble ions in the extract of the saturation soil paste.
- Electrical conductivity was determined in the extract of the saturated soil paste by using electrical Conductivity Bridge.

- Soil pH in the extract of the saturated soil paste by using pH meter.
- Particle size distribution was carried out according to **Piper (1950)**.
- Cation exchange capacity was determined using sodium acetate for saturation and ammonium acetate for displacement (**Richards, 1954**).
- Available Co and Zn were determined by DTPA method according to **Lindsay and Norvell (1978)**. Total soil heavy metals (Co and Zn) were determined by using the same procedure as mentioned by **Jackson (1973)**. Co and Zn concentrations for all extractants were determined by atomic absorption spectrophotometer (AAS).

Table 1 shows some physical and chemical properties of the tested soil samples

Phyto-extraction experiment

Three soils (B, D and E) were used in this experiment, four Kg of each air-dried surface soil sample (0-20cm) were packed in plastic containers (20 cm internal diameter and 20 cm in height) in three replicates. Four plant species tested in this study namely, Sorghum (*Sorghum Vulgar L.*), Clover (*Trifolium pratense L.*), Panikum (*Panicum antidotal*) and Canola (*Brasica Napous.*), were grown on each tested soil in a complete randomized block experimental design.

Nitrogen and phosphorus fertilizers were applied to each soil, before the cultivation of the plants, at the recommended rates. Twenty-five seeds per pot of each tested plant species were planted. After 7 days, the plants were thinned to 15 plants/pot for sorghum, clover and panikum but 5 plants/pot for the canola specie. The soils were irrigated to maintain soil moisture at about 80 % of the soil field capacity during the 6 months period of the experiment.

Plant shoots were harvested every 60 days (three cuts) by cutting the stems approximately 5cm above the soil surface for sorghum, clover and panikum. In case of canola plants, the shoots were harvested after 60 days (vegetative stage) and 85 days (fruiting stage). The roots of all species as well as all replicates were collected after the final cut. Soil samples were taken at the end of the experiment for Co and Zn analyses using AAS.

Plant samples (shoots and roots) were dried, weighed, dry ash digested (**Chapman and Pratt, 1961**) and analyzed for Co and Zn concentrations using atomic adsorption spectrophotometer technique (AAS).

Statistical analysis

Data (in all experiments) were statically analyzed using software according to the standard statistical methods (**Power, 1985**).

Result and discussion

Dry matter accumulation

The mean dry matter yield from all clippings of sorghum, clover, and panikum (at 60 days intervals) and the two samples of canola (after 60 and 85 days) grown on the tested soils (B, D and E) are shown in Table (2). The dry matter yield was significantly affected by soil properties, plant species and their interactions. For example, after 60 days the obtained dry matter yield could be arranged in the following descending order:

Canola > Sorghum > Panikum > Clover. However, the cumulative biomass after three clippings showed that sorghum exhibited the highest cumulative biomass. Moreover, plants grown on fine texture soil exhibited the highest dry matter yield compared to those grown on coarse texture soil .

Heavy metals uptake

Zinc phyto-Extraction

Data in Table (3) show that the shoot concentrations of Zn were as high as 2010 mg/kg dry matter of canola, followed by panikum and sorghum then clover with a range of Zn between 190 to 1490 mg/kg dry matter. These results agree with those obtained by **Kabata-Pendias and Pendias (1992)**. They found that forms of Zn are readily available to the plant and the uptake of Zn has been reported to be liner with Zn concentration in the nutrient solution and in soils. The rate of Zn uptake differs greatly among both plant species and growth media. They added that the background content of Zn in grass and clover (grown on non-contaminated soils) throughout the world ranged from 12 to 47 ppm (dry weight). **Ebbs et al., (1997)** indicated that *Brassica spp* were more effective in removing Zn from contaminated soils than other plant species.

As shown in Table (3), the highest Zn uptake was observed in case of canola (either after 60 days or 85 days) compared with other species at any tested soil. Panikum showed higher Zn accumulation affinity

Table 2: Dry matter yield of different harvestings of the tested plant species grown on the contaminated soils.

Plant species	Soil	Harvesting				Total * (g/pot)
		60 days	85 days	120 days	180 days	
Sorghum	B	94.8	--	80.6	77.2	252.6
	D	120.6	--	106.8	93.2	320.6
	E	141.0	--	125.2	115.2	381.4
LSD(0.05)						3.97
Clover	B	33.3	--	44.2	60.1	137.6
	D	41.2	--	57.6	70.2	169.0
	E	58.9	--	68.0	78.2	205.1
LSD(0.05)						1.89
Pankium	B	44.2	--	39.2	35.2	118.6
	D	56.8	--	43.6	42.1	142.5
	E	71.2	--	52.3	49.3	172.8
LSD(0.05)						2.82
Canola **	B	97.8	116.2	--	--	116.2
	D	115.4	137.2	--	--	137.2
	E	172.4	205.6	--	--	205.6
LSD(0.05)						1.49
LSD(0.05)						
Soil		1.62				2.45
Plant		1.70				2.35
Soil X Plant		2.94				4.07

* Accumulative dry mater.

** Harvested After 60 and 85 days only.

compared to sorghum or clover especially in case of soil E. Moreover, Zn uptake of panikum, sorghum and clover generally decreased with subsequent clippings (120 and 180 days).

A small number of plant species have been identified that are not only capable of growing on polluted soils, but also accumulating those pollutants to high concentration in their shoots (**Brooks et al., 1977**). Members of the *Brassicaceae* family were reported as hyper-accumulators especially for Zn and Cd (**Brown et al., 1994 and Baker et al., 1994**).

Soils total -Zn before and after cultivation are shown in Table (4). Calculation of recovery percentage based on Zn removed from the soil after cultivation (calculated on 4 kg soil bases) ranged between 12.8 to 36.3 % of total initial Zn. However, the percentage of Zn-removed by

plant shoots from the initial total varied between 17.0 to 30.5% of the removed Zn, whereas the lowest values were observed in case of clover and the highest values were in case of canola.

It is worth to mention, that roots tend to accumulate from 69 to 81.1% of the Zn removed from soil. The highest values were noticed in case of clover and sorghum, which accompanied by less accumulation in shoots. On the contrary, the lowest recovery percentage in case of canola and panikum roots was accompanied by higher accumulation in shoots (24.9 -30.5 % of Zn removed). Tissue concentration alone, however, should not be used to evaluate the ability of a species to extract metals from the growth media because it does not take plant biomass into consideration. For photo-remediation, the emphasis is better placed on the total amount of contamination removed from the growth media and translocated to the plant shoots. Similar results were obtained by **Kabata-Pendias and Pendias (1992)**. They found that roots often contain much more Zn than do shoots, particularly if the plants are grown on Zn-rich soils. They added that with luxury levels of soil Zn, Zn may be translocated from roots and accumulate in shoots. They added that Zn contents of plants grown on contaminated soils have already reached the magnitude of 0.X % (dry weight) and are a real health risk.

Cobalt phyto-Extraction

Numerous studies have been made to investigate plant uptake of Co from soils, and it has been shown that enrichment of the soil with Co has led to increase Co levels in plant roots and shoots. Shoot concentrations of Co were as high as 111mg/kg dry matter of canola, followed by panikum and sorghum then clover with a range of Co between 9 to 94 mg/kg dry matter (Table 5). Plants are known to accumulate large amounts of Co and to develop a mechanism of Co tolerance which is basically similar to that occurring in many metalliferous plant species (**Kabata-Pendias and Pendias, 1992**).

Data in Table (5) show that the canola shoots exhibited the highest Co uptake compared to other tested species at any investigated soil. A high effect of soil texture and plant species on Co uptake was observed. It could be noticed that Co uptake was higher in the fine texture soils C and B compared to soil A at any tested plant species or different clipping. Again the order of Co uptake by different plants species could be arranged in the following order:

Canola > Panikum > Sorghum > Clover.

On contrast to Zn uptake, Co uptake increased with subsequent clipping (Table 20). Legumes are known to accumulate more Co than grass. The mean Co content of clover from different countries was reported to range from 0.10 to 0.57 ppm (DW), whereas this value for grass was

0.03 to 0.27 ppm (DW). The Co content of plant foodstuffs varies from around 8 to 100 ppm (DW), with cabbage being in the upper range and corn apple in the lower range (**Kabata-Pendias and Pendias, 1992**).

Values of soil total-Co before and after cultivation are shown in Table (6). Calculation of recovery percentage based on Co removed from the soil after cultivation (calculated on 4 kg soil bases) ranged between 10.1 to 40.7 % of total initial Co. However, The percentage of Co-removed by plant shoots from the initial total varied between 23.5 to 53 % of the removed Co, whereas the lowest values were observed in case of clover and sorghum but the highest values were in case of canola and panikum. These results agree with those obtained by **Nanda-Kumar et al., (1995)** They reported that *Brassica napus* and *Brassica rape* have been shown to accumulate most heavy metals.

Again plant root showed tendency to accumulate Co by several folds (ranged from 43.2 to 71.5% of the Co removed from soil). However, the recovery percentage of Co by root was lower than relevant percentage for Zn in different plant species and any investigated soil.

Heavy metal contaminated soils at many locations need to be remediated. Extensive land areas have become so contaminated that they have been difficult, or impossible, to pay for removal and replacement of contaminated soils. Phytoremediation is not just attractive as a “green” solution to remediation of the environment. One important factor that drives the development of the new technology is the cost. Although real costs will be not available until a mature technology is utilized commercially, scientists agree that phytoremediation can be a cost-effective approach compared with conventional technologies. Also, there is great deal of money involved to attract investment and financial support for developing this technology for super-fund sites.

The ability to hyperaccumulate the metal for phytoremediation is of great importance. However, the biomass of the plant must be related to its metal content in assessing its suitability for phytoextraction. Thus it is emphasized that future development in phytoextraction must strive for hyperaccumulation rather than simply increased biomass without high metal accumulation. Recently, phyto-mining and metal farming have been used to describe the phytoextraction procedure commercially. Economic considerations rather than remediation of metal contaminated sites are an important factor with respect to phytomining. Discovering new metal hyperaccumulators and improving economically important hyperaccumulators are the future direction for phytoextraction and /or phytomining.

References:

- Baker, A. J. M. and R. R. Brooks (1989).** Terrestrial higher plants which hyperaccumulate metallic elements: A review of their distribution ecology and phytochemistry. *Biorecovery*, 1:81-126.
- Baker, A.J.M.;R.D.Reeves and A.S.M.Hajar (1994).** Heavy metal accumulation and tolerance in British populations of the metallophyte *Thlaspi caerulescens* J.E&C-Presl (*Brassicaceae*). *New Phytol.* 127:61-68.
- Banuelos, G.S. and D.W. Meek (1990).** Accumulation of selenium in plants grown on selenium-treated soil. *J. Environ. Qual.*, 19: 772-777.
- Banuelos, G.S.; G.E. Cardon; C.J. Phene; L.Wu; S. Akohoue and S. Zambruski (1993).** Soil boron and selenium removal by three plant species. *Plant and Soil*, 148: 253-263.
- Black, H. (1995).** Absorbing possibilities: Phytoremediation. *Environ. Health Perspec.*, 103:1106-1108.
- Brooks, R.; R. Lee, R.D.Reeves and T.Jaffre (1977).** Detection of nickel-ferrous rocks by analysis of herbarium specimens of indicator plants. *J. Geochem. Explor.* 7:49-58.
- Brown, K.S.(1995).** The green clean. *Bio. Sci.*, 45: 579-582.
- Brown, S.L.;R.L.Chaney; J.S.Angle and A.J.M.Baker (1994).** Zinc and Cadmium uptake by the hyper-accumulator *Thlaspi caerulescens* grown in nutrient solution. *Soil Sci. Soc. Am. J.* 59:125-133.
- Chaney, R.L.(1983).** Zinc phytotoxicity. P.135-150. In A.D. Robson (ed.) "Zinc in soils and plants". Kluwer Academic publishers, Dordrecht, the Netherlands.
- Chapman, H. D. and P.F. Pratt (1961).** Methods of analysis for soils, plants and waters. Berkeley, Univ. California, Division of Agric. Sci.
- Ebbs, S.D. and L.V. Kochian (1997).** Toxicity of zinc and copper to Brassica species. Implications for phytoremediation. *J. Environ. Qual.* 26: 776-781.
- Ebbs, S.D.; M. M. Lasat; D. J. Brady; J.Cornish; R. Gordon and L.V. Kochian (1997).** Phytoextraction of Cadmium and Zinc from a contaminated soil. *J.Environ. Qual.* 26: 1424-1430.
- Felix, H.(1997).** Field trials for in situ decontaminating of heavy metals polluted soil using crops of metal-accumulating plants. *Z. Pflanzenernahr. Bodenkd.*, 160: 525-529.
- Abdel- Sabour M.F. and R.O. Aly (2000).** Bioremediation of heavy metal contaminated soils in dry land:Case studies in Egypt. In D.L. Wise et al. (eds.). *Bioremedition of contaminate soils*: Marcel and Dekker, INC.,New York, pp 677-691.
- Baker, A.J.M.;R.D.Reeves and A.S.M.Hajar (1994).** Heavy metal accumulation and tolerance in British populations of the metallophyte *Thlaspi Caerulescens* J.C. Presl (*Brassicaceae*). *New Phytol.* 127:61-68.
- Brooks, R.R.,J.Lee, R.D.Reeves and T.Jaffre (1977).** Detection of nickel-ferrous rocks by analysis of herbarium specimens of indicator plants. *J.Geochem.Explor.* 7:49-58.
- Brown, S.L.;R.L.Chaney. J.S.Angle and A.J.M.Baker (1994).** Zinc and Cadmium uptake by the hyper-accumulator *Thlaspi Caerulescens* grown in nutrient solution. *Soil Sci Soc.Am.J.* 59:125-133.
- Jackson, M.L. (1973).** "Soil chemical analysis". Prentice Hall of India Private limited, New Delhi.
- Kabata- Pendias, A. and H. Pendias (1992).** Trace Elements in Soil and Plant. (2nd Ed.). CRC Press, London.
- Kamel, M. M.(1999).** Studies on the remediation of heavy metal polluted soils. Ph.D. Thesis, Fac. Agric., Cairo Univ., Egypt.
- Knight, B.; F.J. Zhao; S.P. McGrath and Z.G. Shen (1997).** Zinc and Cadmium uptake by the hyperaccumulation *Thlaspi caerulescens* in contaminated soils and its effects on the concentration and chemical speciation of metals in soil solution. *Plant and Soil*, 197:71-78.
- Lindsay, W. L. and W. A. Norvell (1978).** Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.*, 42: 421-426.
- Nanda-Kumar, P.B.A.; V. Dushenkov; H. Motto and I.Raskin (1995).** Phyto-extraction: the use of plants to remove heavy metals from soils. *Environ. Sci. Technol.* 29: 1232-1238.
- Piper, C.S. (1950).** "Soil and plant analysis". Inter Science publications, Inc. New York.
- Power, P. (1985).** Users guide to MSTAT (ver. 3.0), Michigan State Univ. USA.
- Richards, L.A. (1954).** Diagnosis and improvement of saline and alkali soils. U.S.Dept.Agric. Handbook. No.60.

Table 3: Zn concentration (mg/kg dry shoots) and Zn uptake (mg/pot) for different harvestings time of tested plant species grown on the contaminated soils.

Plant species	Soil	Harvesting								Total uptake
		60 days		85 days		120 days		180 days		
		Conc.	uptake	Conc.	uptake	Conc.	uptake	Conc.	uptake	
Sorghum	B	460	43.61	--	--	360	29.02	280	21.62	94.25
	D	300	36.18	--	--	280	29.90	210	19.57	85.66
	E	520	73.32	--	--	480	60.10	320	36.86	170.28
LSD(0.05)										5.78
Clover	B	610	20.31	--	--	495	21.88	280	16.83	59.02
	D	300	12.36	--	--	210	12.10	190	13.34	37.79
	E	630	37.11	--	--	450	30.60	320	25.02	92.73
LSD(0.05)										2.23
Pankium	B	1420	62.76	--	--	1260	49.39	490	17.25	129.40
	D	860	48.85	--	--	720	31.39	325	13.68	93.92
	E	1490	106.09	--	--	1350	70.61	540	26.62	203.32
LSD(0.05)										3.08
Canola	B	1820	178.0	2010	233.56	--	--	--	--	233.56
	D	1360	156.94	1240	170.13	--	--	--	--	170.13
	E	1390	239.64	1620	333.07	--	--	--	--	333.07
LSD (0.05)										3.20
LSD(0.05)										
Soil			4.60							2.86
			2.42							3.44
Plant										
Soil X Plant			5.20							5.96

Table 4: Recovery percentage of Zn removed from the tested soils by different plant species.

Plant Species	Zn Initial (Total) (A) (mg/pot)	After cultivation (B) (mg/pot)	Zn Removed (A-B) (mg/pot)	Removal * (A-B/A)*100 (%)	Zn uptake by shoot (C) (mg/pot)	Removal ** by shoots [C/(A-B)]*100 (%)	Zn uptake by root (D) (mg/pot)	Removal ** by roots [D/(A-B)]*100 (%)
Sorghum								
B	2392	1998	394	16.5	94.2	23.9	290	73.6
D	1700	1326	374	22.0	85.7	22.9	281	75.2
E	3036	2362	674	22.2	170.3	25.2	495	73.4
Clover								
B	2392	2086	306	12.8	59.0	19.3	239	78.2
D	1700	1478	222	13.1	37.8	17.0	180	81.1
E	3036	2525	511	16.8	92.7	18.1	395	77.3
Panikum								
B	2392	1883	509	21.3	129.4	25.4	368	72.3
D	1700	1322	378	22.2	93.9	24.9	277	73.4
E	3036	2227	809	26.6	203.3	25.1	593	73.3
Canola								
B	2392	1546	846	35.4	233.6	27.6	595	70.3
D	1700	1082	618	36.3	170.1	27.5	441	71.4
E	3036	1943	1093	36.0	333.1	30.5	754	69.0

* : Percentage of total removed from the initial metal in soil.

** : Percentage removed by shoots or roots from the total remove.

Table 5: Co concentration (mg/kg dry shoots) and Co uptake (mg/pot) at different harvesting times of the tested plant species grown on the contaminated soils.

Plant species	Soil	Harvesting								Total uptake	
		60 days		85 days		120 days		180 days			
		Conc.	uptake	Conc.	uptake	Conc.	uptake	Conc.	uptake		
Sorghum	B	14	1.33	--	--	17	1.37	18	1.39	4.09	
	D	9	1.09	--	--	20	2.14	27.5	2.56	5.78	
	E	12.5	1.76	--	--	21	2.63	31	3.57	7.96	
LSD(0.05)										0.16	
Clover	B	11.5	0.38	--	--	16.5	0.73	16	0.96	2.07	
	D	13.5	0.56	--	--	21	1.21	27	1.90	3.66	
	E	16.5	0.97	--	--	23.5	1.60	35	2.74	5.31	
LSD(0.05)										0.12	
Pankium	B	55.8	2.47	--	--	43.5	1.71	35	1.23	5.40	
	D	46.2	2.62	--	--	41.4	1.81	36	1.52	4.94	
	E	94.2	6.71	--	--	89.8	4.70	87.2	4.30	15.70	
LSD(0.05)										0.16	
Canola	B	90.1	8.81	96.4	11.20	--	--	--	--	11.20	
	D	74.3	8.57	88.2	12.10	--	--	--	--	12.10	
	E	96.3	16.60	111.2	22.86	--	--	--	--	22.86	
LSD (0.05)										0.28	
LSD(0.05)											
Soil			0.77								0.16
			0.78								0.17
Plant											
Soil X Plant			1.35								0.29

Table 6: Recovery percentage of Co removed from the tested soils by different plant species.

Plant Species	Co Initial (Total) (A) (mg/pot)	After cultivation (B) (mg/pot)	Co Removed (A-B) (mg/pot)	Removal * (A-B/A)*100 (%)	Co uptake by shoots (C) (mg/pot)	Removal ** by shoot [C/(A-B)]*100 (%)	Co uptake by roots (D) (mg/pot)	Removal ** by root [D/(A-B)]*100 (%)
Sorghum								
B	84.0	71.4	12.5	14.9	4.1	32.7	7.6	60.5
D	100.0	82.8	17.2	17.2	5.8	33.6	10.8	62.7
E	105.8	78.2	27.7	26.2	8.0	28.8	18.1	65.5
Clover								
B	84.0	75.5	8.4	10.1	2.1	24.5	6.0	70.5
D	100.0	85.8	14.2	14.2	3.7	25.8	9.6	67.3
E	105.8	83.3	22.6	21.3	5.3	23.5	16.1	71.5
Panikum								
B	84.0	70.9	13.1	15.6	5.4	41.3	6.7	51.3
	100.0	84.8	15.2	15.2	5.9	39.1	8.1	53.3
D								
E	105.8	75.7	30.2	28.5	15.7	52.1	13.1	43.4
Canola								
B	84.0	56.5	27.5	32.7	11.2	40.8	15.2	55.2
D	100.0	70.6	29.5	29.5	12.1	41.0	15.9	53.9
E	105.8	62.7	43.1	40.7	22.9	53.0	18.6	43.2

* : Percentage of total removed from the initial metal in soil.

**: Percentage removed by shoots or roots from the total remove.

Table 1: Some physical and chemical properties of the experimental soils.

Soil Samples	Particle size distribution (%)				Soil texture	pH	E.C. ds/m	CaCO ₃		CEC meq/100 g/soil	Total heavy metals (mg/kg)			
	Coarse sand 2-0.2 (mm)	Fine sand 0.2-0.02 (mm)	Silt 0.02-0.002 (mm)	Clay <0.002 (mm)				O.M (%)	Cs		Co	Cr	Zn	
B Polluted	58.02	21.81	0.84	19.33	Sandy loam	6.91	1.23	0.70	6.17	13.3		20.9		598
D Polluted	5.67	21.53	20.80	52.00	Clayey	7.73	4.05	2.19	4.80	32.2		25.0		425
E Polluted	17.62	13.87	24.31	44.20	Clayey	6.74	8.43	1.60	7.99	37.4		26.5		759

Table 1 continued:

Soil	Samples location	Ca ⁺⁺	Soluble ions (meq/Liter)						CO ₃ ⁻⁻	DTPA extractable elements(ppm)			
			Mg ⁺⁺	Na ⁺	K ⁺	SO ₄ ⁻⁻	HCO ₃ ⁻	Cl ⁻		Cs	Co	Cr	Zn
B	El-Gabal EL-Asfar polluted	3.5	2.4	5.2	1.2	2.0	6.3	4.0	--	0.80	0.70	3.80	38.15
D	Bahtem polluted	16.2	12.5	10.3	1.5	20.2	7.3	13.0	--	2.10	0.54	2.40	1.42
E	Mostorud polluted	34.7	24.1	22.9	2.6	62.4	4.4	17.5	--	2.20	0.44	3.50	10.56

CHANGES OF ACIDIFICATION PRESSURE, THE USE OF FERTILISERS AND SOIL REACTION IN POLAND DURING LAST 45 YEARS

T. Filipek¹, M. Fotyma² and W. Lipiński³

¹University of Agriculture, 20-950 Lublin, ul. Akademicka 15, Poland

²Institute of Soil Science and Plant Cultivation, 24-100 Puławy, ul. Czartoryskich 8, Poland

³Agrochemical Laboratory, 20-810 Lublin, ul. Sławinkowska 5, Poland

Introduction

Soil acidification is one the most difficult problems in Polish agriculture and the environment. The majority of soils in Poland (about 60% of the area) are acidic because of natural and anthropogenic reasons (Dechnik and Kaczor 1994, Motowicka-Terelak and Terelak 1994) . Acid soil came into being mainly on post-glacial rocks, which in majority of cases were of acid character. Intensive glacial phenomena connected with the effect of running water caused not only segregation of soil material but also its elution. Among the natural factors of soil acidification, the direct and indirect effects of CO₂ are important. It penetrates soil from the atmosphere but it is also created in soils as a result of root respiration as well as the mineralisation of organic matter. It increases the solubility of CaCO₃ and leaching of bases into the soil profile. Especially intensive elution of base cations : Ca²⁺, Mg²⁺ and K⁺ occurs in bare soils, which is proved by lysimetric studies and the chemical composition of draining waters. The place of the eluted base cations is initially taken by H⁺ and then, in case of advanced chemical degradation, by Al³⁺ and Mn²⁺ (Blake et al. 1994, Filipek 1994, Goulding and Blake 1998, Haynes 1986, Robson 1989) .

Natural processes occurring in soil and contributing to the acidification are not usually so intensive that they lead to degradation. The real chemical degradation of soil occurs when the natural factors are combined with anthropopressure (Badora 1998). Strong soil acidification leads to significant increase of concentration of Al³⁺ and other Al species in soil water. Unfavourable influence of water soluble and exchangeable aluminium on plants is evidenced, above all with changes in size and morphology of the root system (Foy 1988). Visible symptoms of the toxic effect of aluminium ions observed on plants are not specific. Aluminium induces the deficiency of phosphorus, calcium, magnesium, iron and potassium for plants (Gorlach and Curyło 1990, Foy 1988, Porębska and Mulder 1994) .

The aim of the paper is to estimate changes of loads of anthropogenic origin protons into the agriecosystems with the comparison of the share of acidic soils in Poland during last 45 years.

Methods

The proton loads were calculated on the base of nitrogen fertilizers utilization and SO_2 and NO_x deposition on the land surface of Poland. The amounts of N fertilizers and emission of sulfur dioxide and nitrogen oxides were taken from Main Statistical Bureau (GUS). Nitrogen fertilization use were taken of the following structure: ammonium sulfate – 12%, ammonium nitrate – 47%, urea – 31% and nitro-chalks – 10%. Acidifying action of 1 kg of nitrogen of particular fertilizers was calculated on the base of N – fertilizers acidification coefficients. One kilogram of nitrogen as ammonium sulfate produces 110 moles of H^+ , as ammonium nitrate and urea – 36 moles of proton. Nitro-chalks have neutral effect on soil acidification. The total proton amount of atmosphere pollution origin was estimated with assumption of equality of sulfur dioxide and nitrogen oxides emission and deposition on the Polish territory. One mole of SO_2 creates 2 moles of protons, whereas due to biochemical and chemical changes of one mole of NO_x one mole of H^+ is produced.

Investigations of soil reaction in Poland have been carried out according to uniform methods since 1955. The measurement of pH is made potentiometrically in soil suspension with the solution of 1 mole $\text{KCl} \cdot \text{dm}^{-3}$. The ratio of soil to solution is equal 1 : 2.5. These investigations have been made by Agrochemical Stations on the whole territory of Poland (PN-ISO 10390, 1997-12, SCHR 2000)

Results and Discussion

The use of mineral nitrogen fertilizers in Poland was started after World War I and was based on products from four factories built between the wars. After World War II, three of old factories were closed, one reconstructed and four new, big ones were built. The nitrogen consumption increased sharply during 60's and reached its top plateau in 70's and 80's, when it ranged from 60.0 to 70.0 $\text{kg N} \cdot \text{ha}^{-1}$ in total agriculture annually (table 1). However this consumption was close to 100.0 $\text{kg N} \cdot \text{ha}^{-1}$ in state own farms, while in private farms it was close to 50 $\text{kg N} \cdot \text{ha}^{-1}$. After economical and political changes in Poland the use of fertilizers decreased substantially, but it concerned more potassium and phosphorus fertilizers consumption, than nitrogen ones [Sapek and Sapek 1998]. The nitrogen fertilizers use was fallen down to 33 $\text{kg N} \cdot \text{ha}^{-1}$ in 1991/1992, mainly due to the disturbances in agricultural production that resulted from the transition into market economy, which caused the decrease in food consumption and competition with imported products. The decision makers responsible for agriculture development and environmental protection in Poland as well as most scientists

assume this level of nitrogen fertilizers use to be low, as compared to west European countries, and that this level does cause no environmental risk, particularly to water or air quality.

Table 1: The use of fertilizers ($\text{kg}\cdot\text{ha}^{-1}$) and the load of protons – H^+ ($\text{mol H}^+\cdot\text{ha}^{-1}$) in Polish agrieosystems

Year	NPK $\text{kg}\cdot\text{ha}^{-1}$	N		CaO	
		$\text{kg}\cdot\text{ha}^{-1}$	$\text{mol H}^+\cdot\text{ha}^{-1}$	$\text{kg}\cdot\text{ha}^{-1}$	$\text{mol H}^+\cdot\text{ha}^{-1}$
1953	15.3	4.5	+210	6.0	-216
1960	39.1	13.3	+460	8.0	-288
1965	75.6	31.4	+1370	12.0	-432
1970	131.8	42.1	+1860	92.0	-3312
1975	168.4	60.1	+2660	103.0	-3708
1980	192.9	69.6	+3060	133.0	-4788
1985	175.2	66.1	+2910	139.0	-5004
1990	192.3	68.9	+3030	182.0	-6552
1991	95.1	39.9	+1760	139.0	-5004
1992	62.1	33.9	+1490	117.0	-4212
1993	65.8	37.7	+1660	115.0	-4140
1994	71.1	42.0	+1850	105.0	-3780
1995	79.7	46.0	+2100	132.0	-4752
1996	84.5	47.6	+2210	124.0	-4464
1997	88.3	49.9	+2340	139.0	-5004
1998	89.6	49.8	+2310	131.0	-4716
1999	87.6	48.4	+2280	104.0	-3744
2000	85.8	48.4	+2280	95.0	-3420

The application of mineral fertilizers, especially nitrogen ones plays a decisive role in the acidification of soils in the majority of agricultural areas. The application of nitrogen in the form of ammonium NH_4^+ , or urea $\text{CO}(\text{NH}_2)_2$ which hydrolyses in soil to ammonium, causes the acidification of soil solution both through biological oxidation, i. e. nitrification, and through uptake by the root system. The reduction of protons pool in agrieosystems of Poland effected by the use of lime surpassed average loads of H^+ caused by nitrogen fertilization.

Acidification due to acid-forming gaseous air pollutants, mainly sulfur (IV) oxide SO_2 and nitrogen oxides NO_x , but also ammonia NH_3 and carbon oxides CO_2 and CO is of a great interest among experts for environmental protection as well as agriculture and forestry.

Anthropogenic emissions (table 2) of industrial origin also play a great role in acidification of soils. Acid and acid-forming substances, first of all SO_2 and NO_x emitted into the atmosphere by power plants, industrial activities, motorization, household fire-places and burning litter dominate among them. These pollutions fall on soils and plants in gas form (dry deposition) or in the form of acid rainfalls. In both forms they cause unfavourable changes in soils and plants, and in extreme cases they may lead to the total degradation of plant-soil cover.

Table 2: Loads of gaseous pollutants and protons in Poland (average on territory)

Years	SO_2		NO_2		Summ
	$\text{kg}\cdot\text{ha}^{-1}$	$\text{mol H}^+\cdot\text{ha}^{-1}$	$\text{kg}\cdot\text{ha}^{-1}$	$\text{mol H}^+\cdot\text{ha}^{-1}$	$\text{mol H}^+\cdot\text{ha}^{-1}$
1975	100.0	3130	5.7	120	3250
1980	132.4	4140	12.1	260	4400
1985	127.5	3980	43.4	940	4920
1990	102.9	3190	40.9	890	4080
1992	83.3	2600	36.1	780	3380
1994	76.2	2380	35.8	780	3160
1996	75.9	2370	35.5	770	3140
1998	60.8	1900	31.8	690	2590
2000	57.1	1780	29.1	630	2410

Comparing to 1980, emission and fall of sulfur (IV) oxide (SO_2) in Poland has been reduced substantially since 1990 . Average SO_2 imission in Poland in 1994 decreased by about 50% in relation to the level in 1980. In the same period the sulfur compounds fall in Cracow region was decreased over three times. Such significant SO_2 deposit reduction was a result first of economical recession and then of new ecological policy of a country. However, it should be stressed that comparing to other European OECD countries, Poland is characterized by very high emission and imission of sulfur (IV) oxide (SO_2) levels. SO_2 emission recounted onto Gross National Product (PKB) and onto 1 inhabitant was several times higher than that of OECD countries in 1992.

Very high dynamics of nitrogen oxides imission can invoke an anxiety. In Poland especially in 1975-1990 those compounds fall increased about seven times. Current level of nitrogen

compounds emitted recounted onto 1 inhabitant in our country is approximately the same as in OECD countries. However, the fact that those countries are of much wider engine vehicles utilization should be taken into account. We must bank that motorization development in Poland is going to affect the further nitrogen compounds deposit increase in the following years.

Anthropogenic nitrogen oxides emission almost exclusively comes from energetic raw materials combustion, mainly coal and crude oil derivatives. Recently, attention is often paid for NO_x type nitrogen compounds emission from agricultural sources. They arise due to microbial processes taking place in cultivated soils and animal wastes.

Although the energetic and transport needs fulfilling is almost exclusive anthropogenic source of nitrogen and sulfur oxides emission, the food-stuff production is a general source of ammonia emission. Nowadays the food production requires more bonded nitrogen than natural processes can ensure. To obtain sufficient production, two sources of bonded nitrogen are applied - from industrial synthesis and binding the nitrogen by cultivation of papilionaceous plants as well as rice. At the end of twentieth century, the former one gives over 80 million tons N and the latter one - about 40 million tons N per year. Over 50 per cent of this amount is emitted into atmosphere as an ammonia. At present, the amount of nitrogen emitted with ammonia from animal production is significantly higher than that emitted with nitrogen oxides due to energetic raw materials combustion.

Ammonia easily reacts with acids in the air forming aerosol of ammonium sulfate or ammonium nitrate which cause the pH increase of a fall. Thus, the fall reaction is not fully the measure of its acidification extent, though in numerous researches the pH of a wet fall is accepted as a measure of a potential acidification. Mean efficiency of ammonia with acids reaction in the atmosphere is about 30% of ammonia concentration in the air per one hour. Such high ammonia reactivity with acids seriously results in an environment because NH₄⁺ aerosol is not effectively removed along with the dry falls and if it is not raining, it can translocation within long distance.

Ammonia in the air comes from numerous sources of a small emission intensity. That is why the ammonia and ammonium ion concentrations in atmosphere near the ground are high within several hundreds of kilometers and thus NH₃ ⇌ NH₄⁺ deposit is also high. Acidification of ammonium ion appear in the soil due to microbial oxidation (nitrification) due to which in turn 2 mole H⁺ are formed from 1 mole NH₄⁺.



Additionally, there is found the increase of H^+ concentration, which is of physiological origin due to NH_4^+ uptake by plant's root system.

Drop of mineral fertilizers utilization in Poland in 1991-1993 was mainly referred to phosphorus and potassium ones. The nitrogen contribution in so-called pure component (NPK) increased from about 36% within 1975-1985 up to about 60% during past several years. Hence, the decrease of acidifying action of mineral fertilization in recent period is not proportional to fertilizers utilization decrease.

Among analyzed anthropogenic factors, SO_2 imission is the largest source of hydrogen ions in a country scale. In analyzed period - except from 1990 - H^+ amount due to sulfur compounds deposit was kept on a similar level Fig. 1. The share of nitrogen fertilization and gaseous air pollutants ($SO_2 + NO_x$) in anthropogenic load of proton in agrieosystems and it was 52-55% of the total acidification contribution (Kaczor 2002).

The percentage of nitrogen fertilization in soil acidification is 30-45%, on the average in Poland. Since 1975 to 1992 there have been observed the decrease of nitrogen fertilization share in anthropogenic acidification. At present, the increase of acidification due to nitrogen fertilizers is noted. It varies substantially with the pollution of regions. In heavily industrialized region of Poland –southern part of the country the share of anthropogenic load of protons caused by fertilizers is about 30%, whereas in rural areas –north-eastern regions N-fertilizers are the source of H^+ at about 80%.

Unfortunately, significant reduction of anthropogenic factors of soil acidification did not considerably effect soil reaction in Poland (fig. 2). The share of acidic soils was rather stable (Fotyma and Pietruch 2001, Lipiński 2000) and it may be concluded that the level of soil acidification depends mainly on mother rock, climate and biocenose.

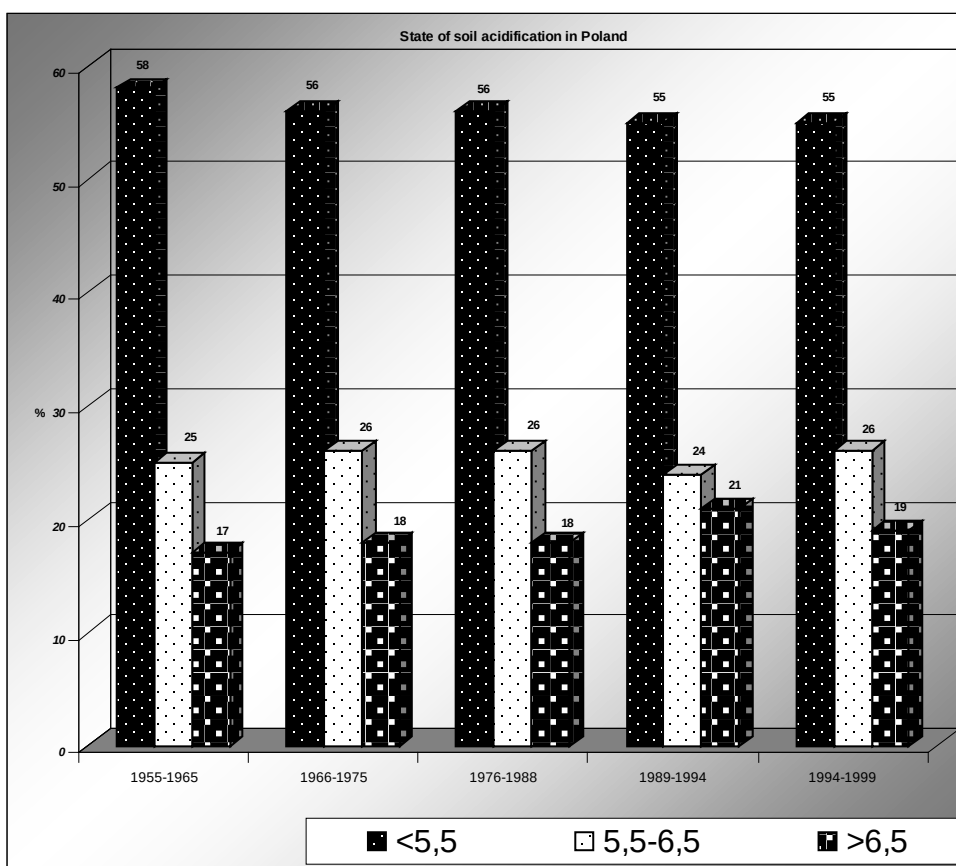


Figure 2: The share of acid ($\text{pH} < 5.5$), light acid ($\text{pH} 5.5 - 6.5$) and neutral ($\text{pH} > 6.5$) soils in Polish agriecosystems

Conclusion

In spite of substantial decrease of anthropogenic origin loads of protons caused by gaseous air pollutants (SO_2 , NO_x , NH_3) and N – fertilization which has been stated since political and economical transformation in Poland, the share of acidic soils turned out to be stable. At present the percentage of acid arable soils ($\text{pH} < 5.5$) is about 55%, light acid ($\text{pH} 5.5 - 6.5$) – 26% and neutral – 19%. So soil acidification is still one of the most difficult problems in Polish agriculture and the environment.

References

- Badora A., 1998: Influence of pH and organic substances on the zinc and cadmium binding by the polynuclear Al_{13} . ZPPNR, 456, 393-398.
- Blake L., Johnston A. E., Goulding K.W.T., 1994: Mobilisation of aluminium in soil by acid deposition and its uptake by grass cut for hay – a Chemical Time Bomb, *Soil and Management*, 10, 51-55.
- Dechnik I., Kaczor A., 1994: The after – effect of simulated acid rain on some properties of brown soil. *Polish J. of Soil Sci.*, XXVII, 1, 11-18.
- Filipek T., 1994.: The Content of exchangeable aluminium in soils and plant growth. *Journal of Ecological Chemistry*. vol. 4, Special issue, no 3, 367-375.
- Fotyma M., Pietruch Cz., 2001: Aktualny stan zakwaszenia gleb i zapotrzebowanie na nawozy wapniowe w Polsce. *Nawozy i Nawożenie*. z. 3, 27 – 50.
- Foy C.D., 1988: Plant adaptation to acid, aluminium toxic soils. *Comm. Soil Sci. Plant Anal.*, 19, 959-987.
- Gorlach E., Curyło T., 1990: Comparison of the Effect of soil pH on the uptake of heavy metals by various plant species. *Acta Agr. et Sil.*, 29, 83-92.
- Goulding K.W.T., Blake L., 1998: Soil acidification and the mobilisation of toxic metals caused by acid deposition and fertilizer application. ZPPNR, 456, 19-27.
- Haynes R.I., 1986: Effect of soil acidification and subsequent leaching on levels of extractable nutrients in soil. *Plant and Soil*, 95, 327-336.
- Kaczor A., 2002: Dynamika zmian antropogenicznych przyczyn zakwaszenia gleb w Polsce w ostatnim 25-leciu, ZPPNR, 482, 235-244.
- Lipiński W., 2000: Odczyn i zasobność gleb w świetle badań Stacji Chemiczno-Rolniczych. *Nawozy i Nawożenie* 3a, 89-109.
- Motowicka-Terelak T., Terelak T., 1994: Residual effect of acid rain on the soil, ZPPNR, 413, 235-240.
- Porębska G., Mulder J., 1994: Effect of long-term nitrogen fertilisation on soil aluminium chemistry. *J. Ecol. Chemistry*, special issue, no 3, 285-294.
- PN-ISO 10390, 1997-12. Jakość gleby. Oznaczanie pH
- Robson A.D., 1989: Soil acidity and plant growth. Academic Press Australia, 1-306.
- Sapek A. Sapek B., 1998: Działalność rolnicza a gazowe zanieczyszczenia powietrza jako źródła zakwaszenia gleb. ZPPNR, 456, 41 – 54.
- SCHR: 2000. Badania odczynu i zawartości makro- i mikroelementów w glebach Polski. Zestawienie wyników badań wykonywanych w latach 1994-1999. Wesola.

REGIONAL DIFFERENTIATION OF SOIL FERTILITY AND CHANGES OF NUTRIENT BALANCES IN POLAND

J. Igras ¹, J. Kopiński ¹ and W. Lipiński ²

¹ Institute of Soil Science and Plant Cultivation, Czartoryskich 8 st., 24-100 Puławy, Poland

² Agrochemical Station, Sławinkowska 5 st., 20-810 Lublin, Poland

Abstract

The paper presents regional differentiation of available phosphorus and potassium content in the soil and nutrient balances at national and regional level in Poland. The available phosphorus and potassium content in Polish soils was very diverse. In the north-western, western and south-western part of Poland agrochemical parameters of soils were much better than in central and eastern Poland. The regional differentiation of potential soil degradation, which can be indicated by nutrient balance, is presented on the maps. Balances of nitrogen and phosphorus seem to be sustainable but potassium balance is negative in the whole country.

Key words: soil fertility, soil surface nutrient balance, regional differentiation,

Introduction

The modern agriculture apart from production and economic targets must pursue wide-range ecological aims, understood as the protection of the natural environment against different kinds of pollution (Kopiński 1999). The aim of fertilisation is not only to provide plants with required amount of nutrients but also to increase soil fertility with poor nutrient resources to the level of their average content (considered as optimum with regard to fertilisation efficiency) (Bujnovsky & Fotyma 2001). The transformational changes of Poland's economy that were initiated in 1990 brought about dramatic decrease of fertilizer consumption up to 62 kg ha⁻¹ in 1992 and reduced supply of manure, caused by the decline of animal stock what had a negative influence on soil fertility.

The actual status of soil fertility with respect to pH and soil fertility in Poland is executed by Agrochemical Service. Polish soils show considerably differentiation in the content of mineral elements.

The common, indirect procedure for measuring nutrient losses from agriculture is to calculate nutrient balances. The most recommended method for nutrient budgeting is the soil surface nutrient balance. This method is proposed by international organisations such as PARCOM (PARCOM 1995) and OECD (OECD 2001). Poland is an associated OECD member and is obliged to prepare nutrient balances every year and provide OECD Secretariat with the nitrogen balance.

The aim of this paper was to present the regional differentiation of soil fertility and changes of basic nutrients balances in the framework of administrative division of Poland. The regional differentiation of nutrient balances is presented on the maps.

Material and Methods

The regional diversity of phosphorus and potassium content was elaborated by Agrochemical Stations on the basis of series of analyses from the years 1999-2001. The area of soils in classes of available phosphorus and potassium content in provinces is presented on the figures. Provinces are drawn up according to smaller available phosphorus and potassium content in soil. The nitrogen, phosphorus and potassium balances were calculated basing on annual statistical data for the years 1999-2001 (GUS 1999-2001; GUS 2000-2002). Values of particular balance elements were estimated as averages for the country according to OECD method (OECD 1999) modified for Polish conditions with using SFOM model (Jadczyzyn et al. 2000). Explanation of balance elements and way of their calculation are presented in table 1 and expressed for agricultural land (AL). Their quantity is related to regional differentiation of agricultural production intensity. The balances are given for nutrients expressed in an elementary form and the framework of administrative division of Poland.

Table 1: Elements of soil surface nutrients balance

Mark	Element of balance	Methodology of nutrients balance elements calculation
S_{org}	Manure	Using SFOM model (Jadczyzyn et al. 2000)
S_{fer}	Fertilizer	Quantity of nutrients in mineral fertilizers (GUS 2000-2002)
S_{sat}	Seeds and tubers	Quantity of nutrients in seeds and seed-potatoes, quantity of the material relative to the sown area, standard values of NPK content in seeds and seed-potatoes (GUS 1999-2001)
N_{sym}	Symbiotic fixation	Quantity of symbiotic nitrogen fixation according with the area of harvested legume crops and legume pasture systems multiplied by coefficients of nitrogen fixation (Kerschberger 1997)
N_{atm}	Atmospheric deposits	Quantity of atmospheric nitrogen deposition (Szponar et al. 1996)
S_{caf}	Uptake by crops and forage	Quantity of nutrients taken by crops and forage (GUS 2000), standard values of NPK content in yield (GUS 1999-

		2001)
SO _N	Nitrogen outputs	Total quantity of outputs $SO_N = S_{org} + S_{fer} + S_{sat} + N_{sym} + N_{atm}$
SO _{PK}	Phosphorus and potassium outputs	Total phosphorus and potassium outputs $SO_{PK} = S_{org} + S_{fer} + S_{sat}$
SSNB _N	Soil surface nitrogen balance	$SSNB_N = S_{org} + S_{fer} + S_{sat} + N_{sym} + N_{atm} - S_{caf}$
SSNB _{PK}	Soil surface phosphorus and potassium balance	$SSNB_{PK} = S_{org} + S_{fer} + S_{sat} - S_{caf}$

Results

The available phosphorus content in Polish soils was very diverse. About 38 % of soils of arable land shows low and very low phosphorus content, 27 % of soils shows medium and 35 % - high and very high content of this element (fig. 1). The large diversity of available phosphorus content was found in all provinces. The greatest share of high and very high phosphorus content was recorded in the northern, north-western, western and south-western Poland. The central, eastern and south-eastern part of Poland present the poorest content of available phosphorus in soils.

The status of available potassium content in Polish soils is worse than phosphorus, more than 50 % of soils of arable land shows high potassium deficit (fig. 2). Only 27 % of soils is characterized by medium and 24 % by high and very high available potassium content.

Within Poland and some other UE countries, mineral (commercial) fertilisers are the most important source of nitrogen (Hansen 2000), whereas phosphorus and potassium are mainly applied as organic fertilisers. Quantity of commercial and organic fertilisers applied to the soils depends mainly on the both side nutrient balances, inputs and outputs. They are also essential to agricultural production, and integral to raising productivity (OECD 2001). The elements of the nitrogen, phosphorus and potassium balance are presented in table 2, but total balance in table 3.

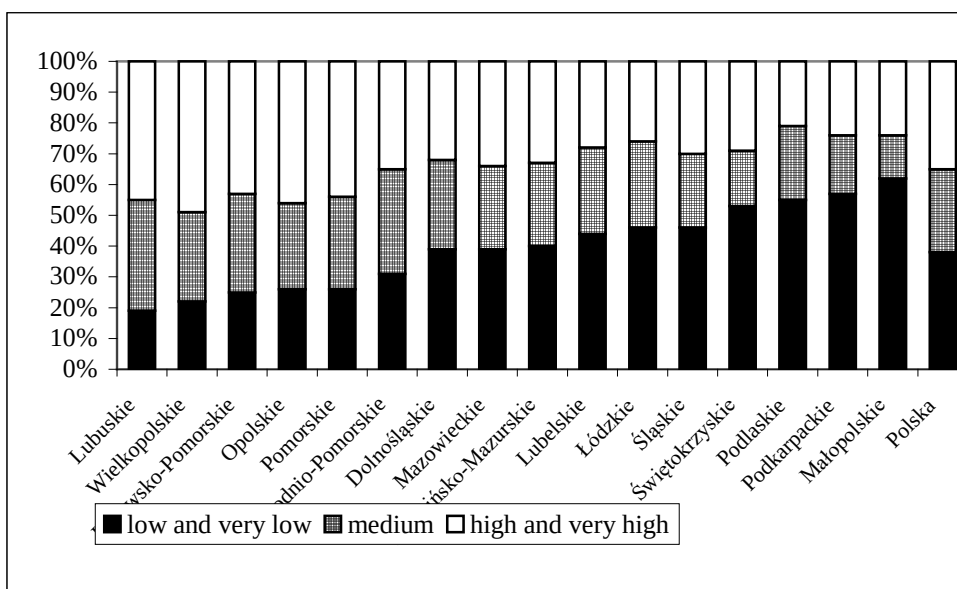


Figure 1: Area of soils in classes of available phosphorus content in provinces

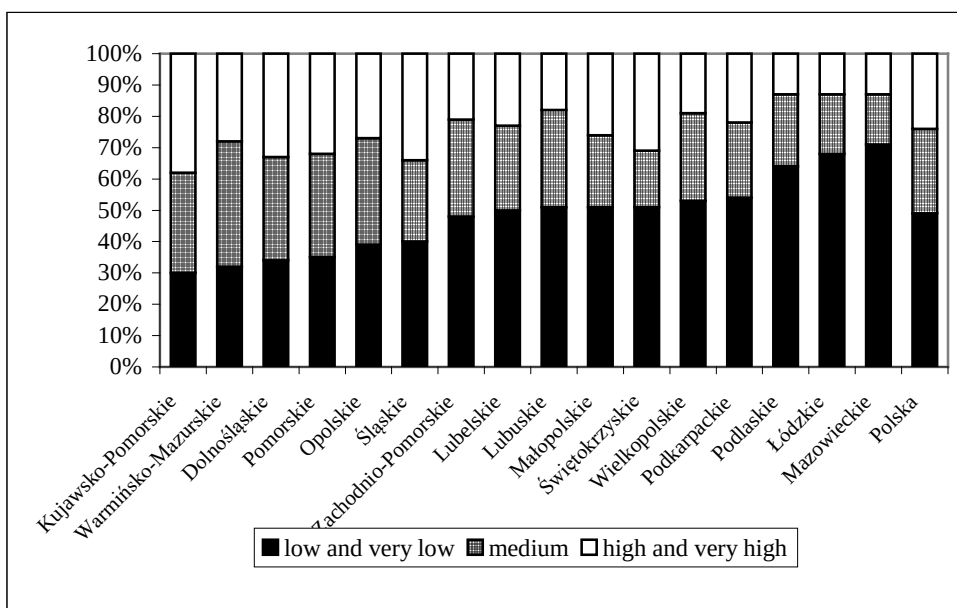


Figure 2: Area of soils in classes of available potassium content in provinces

Table 2: Values of nutrients balance elements for 16 voivodeships of Poland (1999-2001)

Voivodeship	Balance elements kg ha ⁻¹ (inputs/outputs)					
	SO _N	S _{cafN}	SO _P	S _{cafP}	SO _K	S _{cafK}
Dolnośląskie	73,8	67,4	11,5	13,4	33,5	71,2
Kujawsko-pomorskie	134,5	74,0	15,0	14,1	57,2	75,7
Lubelskie	89,8	66,2	13,5	11,4	49,3	63,0
Lubuskie	86,2	44,2	10,7	8,5	30,4	45,7
Łódzkie	104,1	60,1	12,2	10,5	51,1	60,4
Małopolskie	95,4	82,2	15,3	10,8	59,0	69,5
Mazowieckie	89,4	63,1	14,5	10,6	56,8	60,9
Opolskie	116,3	88,2	16,5	18,2	59,4	97,7
Podkarpackie	75,8	68,5	11,1	9,6	44,6	60,2
Podlaskie	103,7	74,6	14,8	10,6	63,8	66,0
Pomorskie	105,7	62,1	18,2	10,8	58,3	58,5
Śląskie	84,5	63,2	11,0	10,3	42,1	60,3
Świętokrzyskie	89,8	59,0	12,6	9,6	47,2	55,0
Warmińsko-mazurskie	92,5	66,4	10,2	9,8	41,4	57,2
Wielkopolskie	130,8	77,6	17,9	14,7	66,1	81,2
Zachodnio-pomorskie	101,6	56,7	10,4	10,8	38,0	56,0
Poland	99,3	67,2	13,7	11,5	51,5	65,2

The soil surface nitrogen and phosphorus balance in Poland in the years 1999-2001 was sustainable, but potassium balance showed greatest deficit of about -14 kg K ha⁻¹ of agricultural land (Tab. 3). The results present high regional differentiation, caused in particular by the natural and economic conditions. The regional differentiation of nutrient balance is also affected by animal and crop production intensity.

Table 3: Soil surface nutrients (NPK) balance for 16 voivodeships of Poland (1999-2001)

Voivodeship	Soil surface balance in kg ha ⁻¹ AL		
	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Dolnośląskie	6,3	-1,8	-37,7
Kujawsko-pomorskie	60,5	0,9	-18,5
Lubelskie	23,6	2,1	-13,8
Lubuskie	42,0	2,2	-15,3
Łódzkie	44,0	1,7	-9,3
Małopolskie	13,2	4,5	-10,5
Mazowieckie	26,2	3,9	-4,1
Opolskie	28,1	-1,7	-38,3
Podkarpackie	7,3	1,5	-15,7
Podlaskie	29,1	4,1	-2,2
Pomorskie	43,6	7,4	-0,2
Śląskie	21,3	0,7	-18,2
Świętokrzyskie	30,8	2,9	-7,9
Warmińsko-mazurskie	26,1	0,3	-15,8
Wielkopolskie	53,3	3,2	-15,1
Zachodnio-pomorskie	44,9	-0,3	-18,0
Poland	32,1	2,2	-13,8

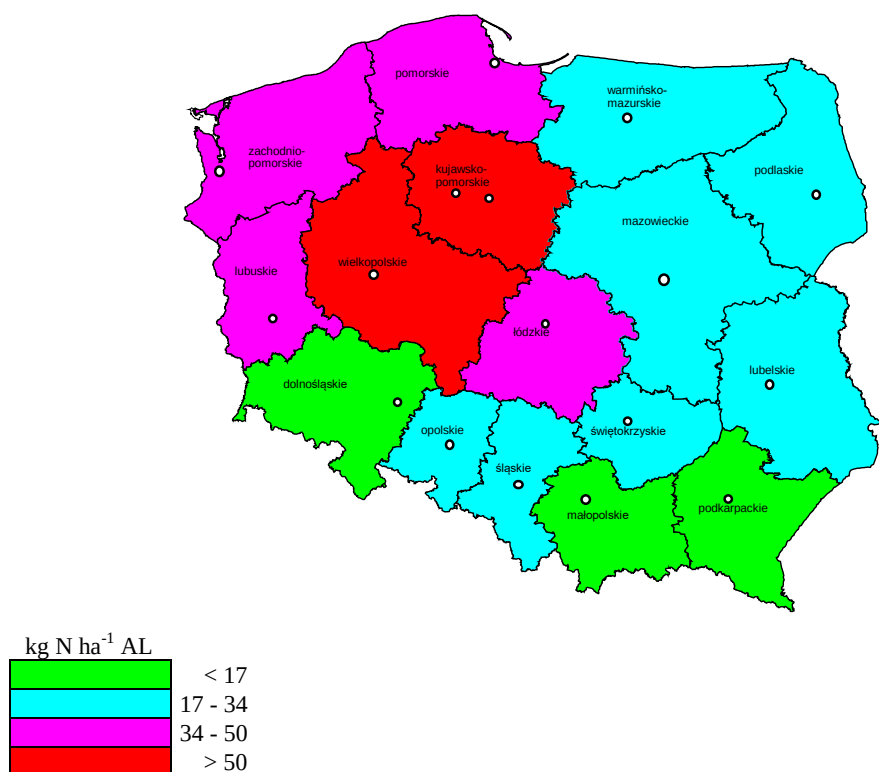


Figure 1: Soil surface nitrogen balance in Poland

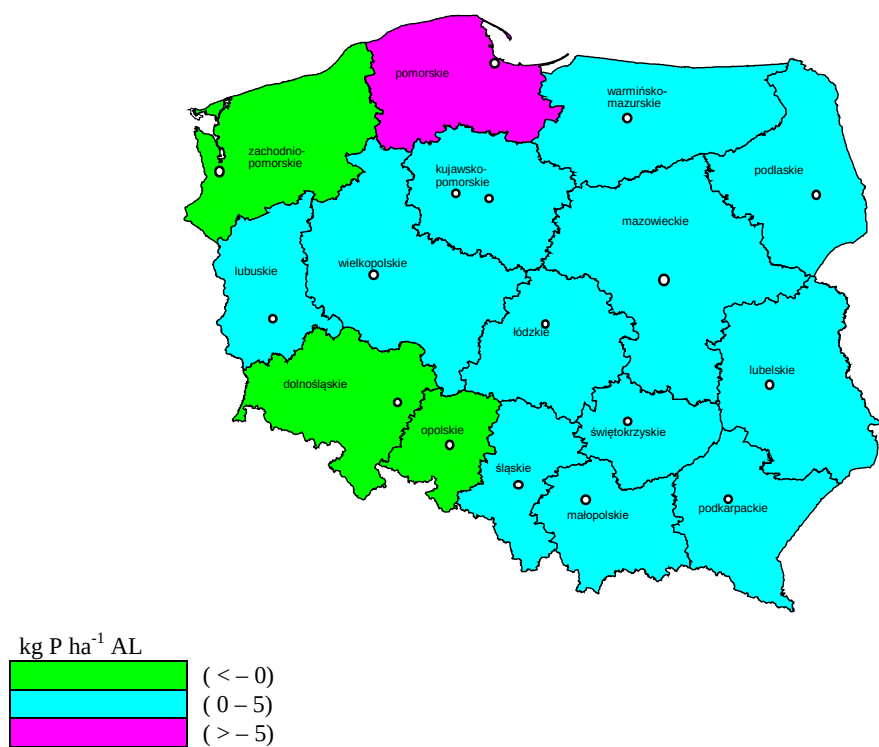


Figure 2: Soil surface phosphorus balance in Poland

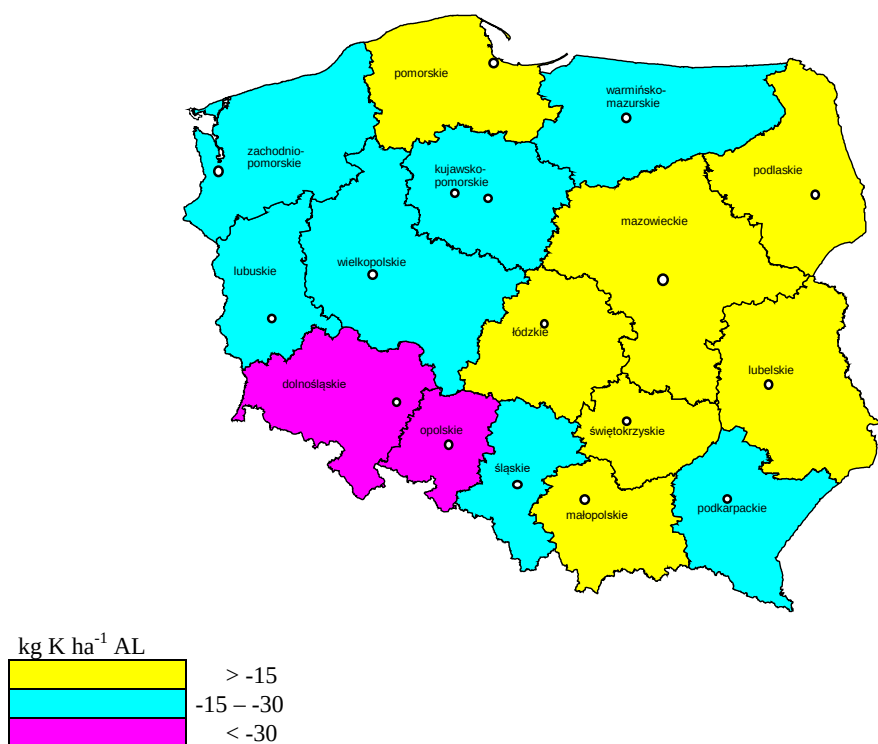


Figure 3: Soil surface potassium balance in Poland

The nitrogen, phosphorus and potassium balances presented on the maps (Fig. 1, 2, 3) showed the country's regional differentiation over the last three years.

Nitrogen balance was positive in the whole country and the greatest surplus was found in Kujawsko-pomorskie and Wielkopolskie provinces. These regions were characterised by very intensive animal production and high level of mineral fertilizer consumption. The least surplus of nitrogen was found in Dolnośląskie, Małopolskie and Podkarpackie voivodeships. The main reason for that was the reduction in inorganic and organic fertilizer use (nitrogen input).

The total phosphorus balance in the majority of voivodeships is sustainable, however, not all amount of phosphorus is utilised by crops. The greatest surplus was found in Pomorskie voivodeship. This region presented a very intensive level of animal production and high level of mineral fertilizers consumption. The highest phosphorus deficit was found in Dolnośląskie, Opolskie and Zachodnio-pomorskie voivodeships. Surplus or deficit of phosphorus balance during last period did not directly affect available phosphorus content in soils in Poland.

The potassium balance was negative in the whole country (Fig. 3). The highest deficit was found in Dolnośląskie and Opolskie voivodeships, which is almost -38 kg K ha^{-1} . The

permanent potassium deficit in the long run may lead to soil degradation. Central and northern provinces present a relatively small potassium deficit – less than 15 kg ha⁻¹. These voivodeships have a very low level of crop and animal production intensity.

Conclusions

Nitrogen balance was positive in the whole Poland and the greatest surplus was found in Kujawsko-pomorskie and Wielkopolskie provinces.

The soil surface phosphorus balance in Poland is sustainable, except from Dolnośląskie, Opolskie and Zachodnio-pomorskie voivodeships where it was negative.

The potassium balance was negative throughout the whole country. A critical situation for potassium was observed in Dolnośląskie and Opolskie voivodeships where the deficit reached –40 kg ha⁻¹ K.

References

- Bujnovsky R., Fotyma M.: Fertilizer recommendation schemes officially used in Czech Republic, Latvia, Poland, Slovak Republic and United Kingdom. *Fertilizers and Fertilization*, 1/2001, 5-31
- Fotyma M.: Requirement of Polish agriculture for fertilizers. In: *Perspectives of fertilizer market in farming production in Poland*. Puławy, 1999: 87-104 .
- GUS: Production of agricultural and horticultural crops in years 1999-2001. Ed. GUS: Warszawa 1999-2001.
- GUS: Production means in agriculture in 1999-2001. Ed. GUS, Warszawa 2000-2002.
- GUS: Cropping system, sowings area and number of animals in 1999-2001. Ed. GUS, Warszawa 1999-2001.
- Hansen J.: Synthesis of the ERM study on manure coefficients. Luxembourg: Material of the Joint Eurostat/OECD meeting – „Statistics of the environment”, European Commission, ESTAT. 19-20 February 2001.
- Jadczyzyn T., Maćkowiak Cz., Kopiński J.: Model SFOM as a tool for quantity and quality of manure simulation. *Pam. Puł.*, Puławy 2000, 120/I: 169-177.
- Kerschberger M., Franke G., Hess H.: Anleitung und Richtwerte für Nährstoffvergleiche nach Düngeverordnung, Jena: Thüringer Landesanstalt für Landwirtschaft, 1997, 74 ss.
- Kopiński J., Igras J., Głowacki M.: Regional differentiation of phosphorus balance in Polish agriculture. *Fertilizers and Fertilization*, 1/2003.
- Kopiński J.: Simplified nutrient balance in private farms. *Rocz. Nauk Rol.*, Warszawa 1999, G, 88(1): 127-139.
- Kuś J., Jończyk K., Kamińska M.: Regional differentiation of agricultural production in Poland in 1988-1998. *Pam. Puł.*, Puławy 2001, 124/2000: 263-272.
- OECD: Executive summary of the main report. *Environmental Indicators for Agriculture*. Paris: OECD Publication Service, 2001, vol. 3: Methods and Results.
- OECD: National Soil Surface Nutrient Balances: explanatory notes to interpret the data sheets. OECD Secretariat Paris, February 1999.
- PARCOM (Oslo and Paris convention for the prevention of marine pollution): Guidelines for calculating mineral balances, PRAM 95/7/6 – E. Oviedo, 1995, 9 ss.
- Szponar L., Pawlik-Dobrowolski J., Domagała R., Twardy S., Traczyk I.: Nitrogen, phosphorus and potassium balance in Polish agriculture. *Annles IŻŻ*, Warszawa 1996, 80: 10-27.

FERTILIZER RECOMMENDATIONS TO MEET THE REQUIREMENTS OF GOOD AGRICULTURAL PRACTICE

A. Karklins

Department of Soil Science and Agrochemistry, Faculty of Agriculture, Latvia University of Agriculture,
2 Liela Street, Jelgava, Latvia

Abstract

A new comparatively simple fertilizer recommendation model is proposed which could be used for fertilizer planning and follows the principles of the Code of Good Agricultural Practice. The need for a rather simple and easy performable fertilizer planning scheme is actual due to the fulfillment of EU Directives 91/676 – Nitrate Directive and 2000/60 – Water Policy.

Key words: fertilizer recommendations, Code of Good Agricultural Practice.

Introduction

Economically and environmentally reasonable plant nutrient management for balanced crop production is an approach for modern agriculture. Farming becomes more controlled due to the environmental consequences. Reduction of nutrient loads into environment probably is one of most important issues for solution of intensive farming – environment inconsistency. Designation of vulnerable zones, development of Codes of Good Agricultural Practice, environmental legislation – these are compromise solutions between farming as a business sector and food supply channel and other essential and common interests of society: to provide and sustain other life-dependant sources – clean water and air, non-degraded landscape, biodiversity, etc.

Codes of Good Agricultural Practice (GAP) mainly are “political” documents declaring what should or should not be done with very little how to realize it and sustain in current economical situation, which is not very favorable for farmers. Therefore development of new practical methods of fertilizer planning, plant nutrient balance calculation and environmental risk assessment, which could be useful for farmers and their advisors probably are relevant to reach the overall “political” goal.

There are at least three main objectives for fertilizer planning in the modern context of sustainable agriculture:

1. to follow administrative demands,
2. to realize principles of Good Agricultural Practice,
3. to provide economically reasonable crop production.

The first two objectives has very close connection with the fulfillment of European Union Directives 91/676 – Nitrate Directive and 2000/60 – Water Policy (COUNCIL DIRECTIVE ..., 1991, Directive 2000/60/EC..., 2000) and their Latvian equivalents (Noteikumi par ..., 2001; Ūdens apsaimniekošanas likums, 2002). These actions primarily will be binding for farmers located in the vulnerable zones, which already are designed in Latvia, and also – for others who wish to make fertilizer plans as a tool for the improvement of farm management. In the nearest future, for many farmers plant nutrient calculations will be necessary to do as annual routine, but for administrators – to make evaluation of farm management including fertilizer planning in respect of how environment regulations are followed. Calculation results are also important for reporting on agroenvironmental indicators of Latvian agriculture for international institutions.

Traditionally, several fertilizer recommendation schemes have been developed and used in Latvia. More popular have been “Augsne – raža” (Daiga et al., 1990) for field crops and “Method of plant nutrition optimization” mainly used for crops grown in greenhouses as well as for horticulture (Ринькис et al., 1989). Despite the great job invested into development of these systems and the long period of their successful practical use, they do not fit into the framework of the modern concept of sustainable agriculture where environmental awareness, protection and conservation are a dominating priority. Based on that, a number of EU directives, international agreements, guidelines and other relevant documents have been developed (Archer, Marks, 2001; Jakobsson, 2001; Sandstrom, 2002; Thyssen, 1998, 2001) and these requirements are already included into the recent Latvian legislation.

Previous recommendation systems cannot provide adequate know-how support and their algorithms mainly cannot be readjusted for this need. A similar problem is experienced in a number of countries and therefore intensive research and development is going on to tailor new requirements into the modern fertilizer recommendation systems (Aarts, 2000; Bujnovsky et al., 2000; Bujnovsky, Fotyma, 2001; Fotyma & Fotyma, 2001; Klir 2001; MacKenzie, 2001; Shepard, 2002).

Material and Methods

The logistics of the proposed fertilizer recommendation model includes several steps. (1) To evaluate **growing conditions** – screening of soil parameters and giving advice to farmers about the possibility to grow a certain crop and obtain the selected yield goal. (2) **Crop nutrient requirement** – determination of NPK requirement for each crop commercially grown in Latvia, based on the selected yield level and PK status in soil, but for nitrogen – net mineralization of

organic nitrogen reserves in the soil. (3) **Plant nutrient adjustment** based on a) **manure**, applied for current crop and/or pre-crop, b) **pre-crop** effect to provide some extra nutrients for the current crop and, c) **green manure** as nutrient source. (4) **Actual plant nutrient need** which should be covered by commercial (mineral) fertilizers. (5) Selection of agronomically and economically **most useful commercial fertilizer**. Figure 1 illustrates the general layout of recommendation scheme and the main steps of calculation.

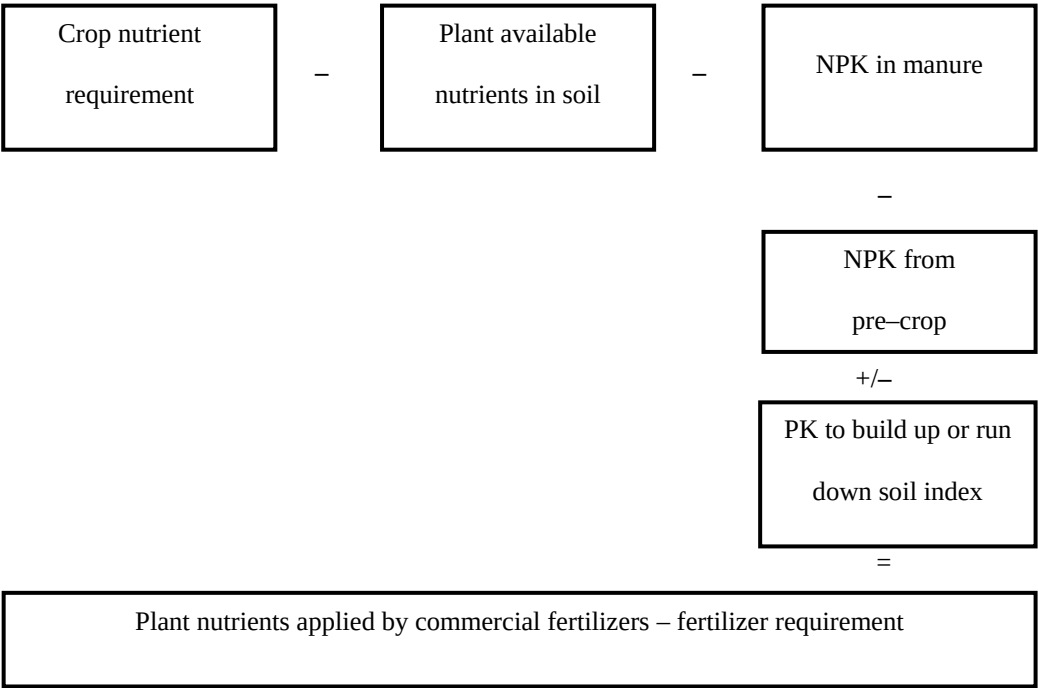


Figure 1: The general layout of fertilizer recommendation system.

Results and Discussion

The main target points for development of new plant nutrient management method should be taken from EU Nitrate Directive, where following guidelines are stated. “Limitation of the land application of fertilizers, consistent with Good Agricultural Practice and taking into account the characteristics of the vulnerable zone concerned, in particular: (a) soil conditions, soil type and slope; (b) climatic conditions, rainfall and irrigation; (c) land use and agricultural practices, including crop rotation systems; and to be based on a balance between: (i) the foreseeable nitrogen requirements of the crops, and (ii) the nitrogen supply to the crops from the soil and from fertilization corresponding to: (*) the amount of nitrogen present in the soil at the moment when the crop starts to use it to a significant degree (outstanding amounts at the end of winter),

(**) the supply of nitrogen through the net mineralization of the reserves of organic nitrogen in the soil, (***) additions of nitrogen compounds from livestock manure, (****) additions of nitrogen compounds from chemical and other fertilizers”.

The presented scheme is covering all these aspects and might be under interest at least for the following reasons. It is simple and easy understandable which in this case is important priority, as many farmers will be obliged to make annual routine calculations. It uses a number of reference values, e.g. plant nutrient removal by yield, manure composition calculation values, etc., which are developed using some international standards and also applied for environmental risk assessment. Therefore, unification of calculation methods, reference values and data interpretation become very important in this context.

Unification causes also some negative aspects. It is extremely difficult to quantify different crops' growing factors and make a reasonable compromise between very detailed datasets, supposed to reflect the local conditions and rather simple unified reference data even for a small country like Latvia. The possible solution is to make them well-explained and consider that they might be easily changed during calculations, if more reliable local information is available.

Similar situation is with parameters of high mobility and heterogeneity, e.g. soil nitrogen supply to crops and soil nitrogen net mineralization. Even direct measurements in the field of recommendations concerned usually do not provide adequate information. Therefore field assessment method for these parameters is more commonly used in combination with or without direct N supply measurements. Synchronization of N supply and uptake is the overall key point of Nitrate Directive but is most difficult for practical realization.

This recommendation scheme does not contain such details as nutrient requirement differentiation based on the crop's variety, targeted quality standards, specifications of fertilizer application technology, etc. Recognizing the importance of these factors, we should accept that they will substantially complicate the whole system and limit its wide use, for which in this case preference is given. But it is surely possible to use such adjustments as an extra component to the proposed general framework.

Besides, presently proposed scheme does not include regional differentiation of reference values used for calculation. The assumption was that for such a small country like Latvia it is not so important due to the more or less similar meteorological conditions for all territory. Of course, this is another approximation used exclusively for simplification of the recommendation

system. Further development and enlargement of the proposed scheme based on relevant research data, which reflect the regional (local) individuality, is highly desirable.

The recommendation system is designed for all field crops commercially grown in Latvia. For practical calculations, several data sets are necessary. The first one, growing conditions, is a criterion to evaluate soil suitability for the selected crop to avoid miscalculations. Example of this data set is given in Table 1.

Table 1: Crops' growing conditions (*example*)

Code	Crop	Limitation factor	Units of measurement	Min. value	Max. value
1	Winter wheat	Physical clay content	%	11	80
		pHKCl	–	5.8	8.0
		Organic matter	%	1.8	10
		P ₂ O ₅ in soil	mg kg ⁻¹	50	999
		K ₂ O in soil	mg kg ⁻¹	80	999

The next data set consists of series of tables developed for each crop (example is not represented). It shows the crop nutrient requirement depending on yield goal, the plant available phosphorus and potassium sufficiency levels, assumptive plant nutrient removal from soil and expected NPK balance. Actually, these are most important tables, which are developed to calculate the plant nutrient requirement, soil nutrient supply, PK necessary for correction of soil nutrient index level, NPK removal with planned yield and its balance. As each of these tables contain some additional information in the form of short comments, they quite well could be used even without other data sets for a simple and fast fertilizer planning or reference.

The last set of tables is devoted to the so-called corrective factors, quantifying the amount of NPK which is available for the current crop but comes from other sources than soil and fertilizers. These sources might be manure applied to the crop directly or some years before, green manure, as well as pre-crop effect.

Information about plant nutrients supplied by manure is taken from so-called normative tables developed for multi-purpose needs (the NPK balance and manure value calculations, environment risk assessment). Example is given in Table 2. This table is joined with another (not represented here), where plant nutrient utilization from different types of manure in the first year (under the current crop) and in the second year (1st year aftereffect) based on soil

texture is given. These values might be considered as function of manure effective nitrogen and its apparent recovery.

Table 2: Draft manure normative for Latvia (per one animal after storage)

Housing system	Manure type	Tons per year	Dry matter, %	Content, kg per ton of manure		
				N	P ₂ O ₅	K ₂ O
Slaughter pig, 20 – 100 kg live weight						
	Slurry					
Slotted floor	washing	8.7	3	1.2	0.6	1.0
	periodical flush	3.4	6	2.7	1.6	3.8
Solid floor	Slurry	3.6	6	3.3	1.6	2.8
	Solid manure	2.6	20	5.7	3.2	6.0

NPK supply from pre-crop and green manure incorporated directly before the current crop or one year before is given in Table 3. These values are supposed to be available for the current crop and therefore fertilizer need can be diminished.

Table 3: Pre-crop and green manure effect, nutrient supply, kg ha⁻¹

Pre-crop effect				Green manure			
Crops	N	P ₂ O ₅	K ₂ O		N	P ₂ O ₅	K ₂ O
Cereals	0	0	0	Green manure, legumes			
Pea	15	0	0	1 st year effect	40	10	20
Potatoes	10	0	5	2 nd year effect	20	0	10
Rape	10	0	0	Green manure, non-legumes			
Clover	20	5	10	1 st year effect	15	10	20
Alfalfa	30	10	15	2 nd year effect	0	0	10
Grasses	10	0	10				
Sugar beet	10	10	20				

Final result is supposed to be the fertilizer requirement – amount of NPK recommended to apply with commercial fertilizers. Recommendation system also might be supplemented with includes data set with all kinds of fertilizers available in Latvia, their composition and possible (expected) selling price. Therefore their selection could be performed taking as a basis

agronomical and economical considerations, as well as eventual fertilization costs might be calculated.

Conclusion

Expected advantages of the proposed method are simple logistics, which meet requirements of Nitrate Directive and possibility of easy change of the reference values if new or more detailed information is available. Together with rather high reliability of output data, this will stimulate its wide application for routine calculations.

References

- COUNCIL DIRECTIVE of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC).
- Aarts, F. (2000) Managing nitrogen in dairy farming systems. In: Nitrogen efficiency in practical agriculture – fundamental processes and how to control them. Kungl. Skogs-och Lantbruksakademiens Tidskrift, 139, Nr. 8, pp. 89–101.
- Archer, J. R., Marks, M. J. (2001) Control of nutrient losses to water from agriculture in Europe. Fertilizers and Fertilization, No. 4(9), pp. 52–78.
- Bujnovsky, R., Cermak, P., Machacek, V. et al. (2000) Soil fertility evaluation in Czech Republic, Latvia, Poland, Slovak Republic and the United Kingdom. Fertilizers and Fertilization, No. 2(3), pp. 5–61.
- Bujnovsky, R., Fotyma, M. (2001) Fertilizer recommendation schemes officially used in Czech Republic, Latvia, Poland, Slovak Republic and United Kingdom. Fertilizers and Fertilization, No. 1(6), pp. 5–31.
- Code of Good Agricultural Practice for Latvia. (1999) Jelgava, 95 pp.
- Daiga, Z., Ozola, M., Vēvers, E., Zakke I. (1990) Informacionālās skaitļošanas sistēmas “Augsne – raža” izmantošana. Rīga, Zinātne, 134 lpp.
- Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000: Establishing a framework for Community action in the field of water policy. Official Journal of the European Communities, L 327, pp. 1–72.
- Fotyma, M., Fotyma, E. (2001) Development of fertilizer recommendation algorithms. Fertilizers and Fertilization, No. 1(6), pp. 81–87.
- Jakobsson, C. (2001) Agenda 21 for the Baltic Sea region – Baltic 21. In: Ecologically improved agriculture – strategy for sustainability. Kungl. Skogs-och Lantbruksakademiens Tidskrift, 140, Nr. 6, pp. 33–42.
- Klir, J. (2001) Balanced fertilization for sustainable agriculture. In: Crop science on the verge of the 21st century – opportunities and challenges. Proceedings of the 50th anniversary conference, Prague, 11–13 September, 2001. Research Institute of Crop Production Prague, pp. 158–159.
- MacKenzie, G. H., Taureau J.-C. (2001) Recommendation systems for nitrogen – a review. Fertilizers and Fertilization, No. 4(9), pp. 5–51.
- Noteikumi par ūdens un augsnas aizsardzību no lauksaimnieciskās darbības izraisītā piesārņojuma ar nitrātiem (Nr. 531). Latvijas Republikas Ministru kabinets, 2001. gada 18. decembrī.
- Sandstrom, E. (2002) Environmental policy of the European Union and the LIFE-instrument. In: Sustainable forestry to protect water quality and aquatic biodiversity. Kungl. Skogs-och Lantbruksakademiens Tidskrift, 141, Nr. 7, pp. 15–19.
- Shepard, M. (2002) Managing mineral N in UK lowland agricultural systems. Fertilizers and Fertilization, No. 1(10), pp. 51–65.
- Thyssen, N. (1998) Environment and agriculture in Europe. In: Framtida svensk svinproduktion I ett globalt perspektiv. Kungl. Skogs-och Lantbruksakademiens Tidskrift, 137, Nr. 14, pp. 47–64.
- Thyssen, N. (2001) Environmental impacts of agriculture with examples from the Baltic region. In: Ecologically improved agriculture – strategy for sustainability. Kungl. Skogs-och Lantbruksakademiens Tidskrift, 140, Nr. 6, pp. 19–31.
- Ūdens apsaimniekošanas likums. (2002) Vēstnesis 140 01.10.2002.
- Г. Я. Ринькис, Х. К. Рамане, Т. В. Пэгле, Т. А. Куницкая. 1989. Система оптимизации и методы диагностики минерального питания растений. Рига: Зинатне, 196 с.

SUSTAINABLE PHOSPHORUS MANAGEMENT IN THE WESTSIK'S CROP ROTATION EXPERIMENT

J. Lazányi

Debrecen University, Centre for Agriculture
H-4032 Debrecen, Böszörményi 138.

Sustainable agriculture seeks solutions for environmental, economic and agricultural problems at the same time. The aim is to develop new production methods, which provide protection for nature. In any sustainable agricultural system, the management of organic matters and, more widely, the whole nutrient management are based on the total self-sufficiency of the farm. The entire cycle of organic matter production and decomposition takes place within the farm boundaries and this is what makes the agricultural production unit an actual biological system pursuing continuous metabolism with its environment. The rate of metabolism and the organic matter cycle are characteristic features of each farm unit and define their activity for a long time.

Demand for food and the change in ecological requirements of agricultural production urges scientists to revise the widely used traditional principles and develop alternative crop production practices. In this respect, they must strive for the maintenance of soil fertility, and at the same time, for environmental goals. Westsik's crop rotation experiment provides great help and thorough scientific basis to the solution of this problem. The experiment models various possible methods of nutrient management (fallow, straw, farmyard and green manure), and assists in answering the questions of sustainability of agricultural production.

Phosphorus was one of first elements discovered to increase yield and farmers added manure, minerals, and manufactured fertilisers to correct deficiency. Resource management requires a complete understanding of the forms of phosphorus in soils and the interactions between soluble phosphorus. After 50-100 years of fertilisation many soils have a sufficient or high content of phosphorus, and the waters that drain from agricultural lands also might have a large amount of phosphorus, increasing the growth of algae and other plants in surface waters. In areas of the world, where farms are managed to obtain maximum yields, environmental concerns are great, as phosphorus has become known as an important factor to eutrophication.

Material and Methods

The treatments of Westsik's crop rotation experiment were intended to increase soil fertility by different organic matter amendments as the original purpose was to evaluate the cumulative effects of organic matters on light sandy soil with a long history of arable cropping.

The F-1 block received no fertilisers and organic material treatment except the rye and potato roots and straw incorporated into the soil. The fallow in this block was a green one and the plant material produced was ploughed into the soil. The F-2 block represents green manure treatment, where lupin was grown as a main crop and incorporated into the soil 4-5 weeks after flowering. The phosphorus and potassium fertilisers in this treatment were applied the previous autumn before the lupin was sown. The F-3 represents lupin root manure treatment, where lupin was grown for grain and the total organic material, except for the grain, was incorporated into the soil (Lazányi, 1994, 1995).

Blocks F-4 - F-7 represent straw manure treatments. In the F-4 block the rye straw was applied as mulch. In blocks F-6 and F-7 straw manure was fermented without nitrogen and in block F-6 with nitrogen addition. The straw manure was incorporated into the soil 4-6 weeks before the sowing of rye.

F-8 is the only block with 4 main crops, where lupin grew twice in 4 years; once as a main crop produced for grain and once as a second crop produced after rye and before potato, for green manure.

In the F-9 block, lupin was grown as a forage crop and harvested 2-3 weeks after flowering. Blocks F-10 and F-11 represent farmyard manure treatments without and with supplementary fertilisers respectively. In block F-12, lupin is grown after a green forage crop and sown in May. This block is also evaluated with farmyard manure treatments to measure the comparative effects of the two treatments.

Blocks F-13, F-14, F-15 represent green manure treatments, where lupin is grown as a second crop after rye and before potato. The F-15 block received no supplementary fertilisers. The difference between blocks F-13 and F-14 can be found in the time of the incorporation of green manure.

Results and Discussion

Ammonium lactate (AL) method was used to provide a reliable result on the phosphorus content of the soil. F probe proved a reliable difference between the two dunes, the locations

and depths of sampling. On the first dune, Al phosphorus content at the depth of 0-60 cm was 8,02, 6,80 and 6,78 mg/100 g soil, on the second dune it was 12,45, 9,59 and 7,27 if samples taken on the side along the Érpatak, on top of dune and on the Eastern side separately (Table 1). In the 40-60 cm soil layer differences are less expressed. Differences are convincing between samples from different depths.

Table 1: AL soluble phosphorus in the soil (P₂O₅ mg/100 g soil)

Soil samples	0-20 cm	20-40 cm	40-60 cm	0-60 cm
West side	11.09	8.41	4.57	8.02
Top of the dune	9.29	6.33	4.79	6.80
East side	9.15	6.81	4.39	6.78
Mean F1-F5	9.84	7.18	4.58	7.20
Mean F6-F8	6.73	5.21	3.60	5.18
West side	15.89	12.58	8.89	12.45
Top of the dune	15.74	8.80	4.24	9.59
East side	11.36	6.16	4.29	7.27
Mean F9-F15	14.33	9.18	5.80	9.77
West side	12.46	9.71	6.39	9.52
Top of the dune	11.79	7.26	4.29	7.78
East side	9.70	6.19	4.19	6.69
Mean F1-F15	11.31	7.72	4.96	8.00

LSD _{p=5%} =1,857 mg/100 g soil

AL soluble phosphorus content was the lowest in control crop rotations F-15, F-7, F-1, while it was significantly high in crop rotations F-10 and F11, using farmyard manure. Al soluble phosphorus content of the crop rotation F-1, F-2 and F-3 was lower than 10 mg/100 g soil, while F-5 had the highest phosphate content on the first dune. Among the treatments of the second dune the phosphate content of crop rotation F-11 is outstanding, many times higher than the similar value of control treatments (Figure 1 and Table 2). On the second dune crop rotation F-15 had the lowest phosphate content.

Table 2: Homogeneity groups of AL soluble phosphorus (P₂O₅ mg/100 g soil), Tukey’s test, F=9.68

	F15	F7	F1	F8	F2	F14	F6	F3	F4	F9	F13	F12	F5	F10	F11
1	2.7	3.8	4.7	5.1	6.1	6.2	6.6	6.9	7.6	7.9	8.2	8.9			
2			4.7	5.1	6.1	6.2	6.6	6.9	7.6	7.9	8.2	8.9	10.7		
3									7.6	7.9	8.2	8.9	10.7	14.1	
4														14.1	20.4

The availability of phosphorus and the potential for adverse environmental effects should also be studied in the Westsik’s crop rotation experiment where organic matter and inorganic

phosphate have been applied since 1929 on sandy soils with light texture. The experiment makes it possible to study the phosphorus balance of different treatments. When the amount of phosphorus applied to the soil exceeds the amount removed in a crop, there is a positive phosphorus balance and phosphorus will accumulate in the soil except when it is lost.

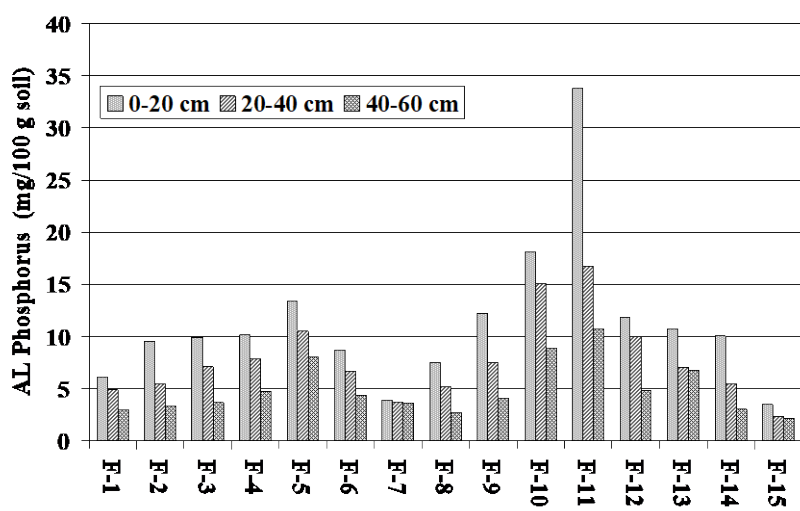


Figure 1: AL soluble phosphorus in the soil of the experiment

Negative balance depletes soil reserves but in Westsik's crop rotation experiment such balance cannot be related to changes in total soil phosphorus. It is also difficult to assess the significance of total phosphorus in plant nutrition, as these results cannot be compared with other parameters. Effects of organic manure treatments can be compared with superphosphate. Fortunately, there are plots without fertiliser treatment (F-1, F-15) which can be used as control. In the crop rotation experiment the total phosphorus content of the soil ranges between 0.05 and 0.10%; it means that the phosphorus reserve in the cultivated soil layer is 1.5-3.0 ton/hectare. Depending on the methods of measurement and soil conditions, the amount of phosphorus varies from 3 to 21 mg/100 g of soil. 10.3 mg/100 g is found in the top 20 cm of the soil profile and 8.1 mg/100 g in the 20-40 cm layer. These data prove that the increase in the phosphorus content of the soil originates from external inputs.

Table 3: Phosphorus uptake by plants between 1931-2000 (kg/ha)

CR	S-1	S-2	S-3	S-4	S-1	S-2	S-3	S-4	Össz.
F-1	Fallow	Rye	Potato			11.1	8.7		19.8
F-2		Rye	Potato			29.1	17.5		46.6
	Lupin								
F-3	Lupin	Rye	Potato		9.8	25.9	16.1		51.9
F-4	Rye	Potato	Rye		22.3	17.6	20.4		60.3
F-5	Rye	Potato	Rye		24.9	19.9	22.7		67.6
F-6	Rye	Potato	Rye		27.8	23.5	25.2		76.5
F-7	Rye	Potato	Rye		16.3	15.8	16.5		48.6
F-8	Lupin	Rye	Potato	Rye	13.6	31.5	25.1	30.9	101.1
F-9	Lupin	Rye	Potato		11.4	29.2	18.6		59.1
F-10	Forage	Rye	Potato		22.5	24.1	20.4		67.0
F-11	Forage	Rye	Potato		28.0	30.0	24.1		82.1
	Rye	Rye	Potato		27.2	29.2	22.9		79.2
F-12									
F-13	Rye	Potato	Rye		26.3	21.8	25.5		73.6
F-14	Rye	Potato	Rye		26.1	21.1	26.5		73.7
F-15	Rye	Potato	Rye		16.1	15.9	14.5		46.4
Mean					21.0	23.0	20.3	30.9	63.6

The crops took up the highest amount of phosphorus in crop rotations F-8, F-11, F-12, and F-13 and in those treatments which received straw manure and included rye more often (Table 3). The amount of phosphorus absorbed by the plants during rotation varied from 17.1 kg/hectare/2 crops (crop rotation F-1) to 110.5 kg/hectare/4 crops (F-11). The amount of phosphorus taken up by the crops in the crop rotation experiment was determined as the product of the actual yields and the amount of phosphorus drawn up by a unit of main product and related by-products. The later figure was taken from the literature and data obtained from the experiment. The lowest phosphorus uptake was assured in crop rotations F-1, F-15 and F-7 where phosphorus supplement was provided exclusively through natural resources. The highest uptake, with 82.1 and 79.2 kg/hectare/3 years, was found in crop rotations F-11 and F-12, respectively.

It could already be inferred from the results of phosphorus analysis that the phosphorus balance of Westsik's crop rotation experiment was in equilibrium or even positive except for the control plots. The greatest phosphorus surplus could be found in crop rotation F-11 where regular fertilisation was performed in addition to the farmyard manure treatments in every third year. Considerable phosphorus surplus can also be found in those treatments where lupin root manure

or green manures were applied and where the utilisation of high phosphorus doses given to the lupin was prevented by the low proportion (33%) of rye in crop rotation.

The increase of the AL-soluble phosphorus content in the treatments with positive balance proves that the fixation of phosphorus, applied either in organic manure or in fertilisers, is not irreversible and provides improved nutrient supply for the plants. The soluble phosphorus content in the soil is in permanent equilibrium and can be considered as an important feature of the condition of the soil. This conclusion can be drawn from the correlation found between the AL soluble phosphorus content and the yields of potato and rye (Figure 2). It is likely that the level of soluble phosphorus depends on the processes controlling the proportion of phosphorus-binding site from which phosphorus can be removed and the speed with which phosphorus can migrate between sites with different binding energies.

Table 4: Phosphorus uptake in treatments of the crop rotation experiment

Years	1931- 1951	1952- 1972	1973- 1993	1994- 2000	1931- 1951	1952- 1972	1973- 1993	1994- 2000
	P ₂ O ₅ kg/plot				P ₂ O ₅ kg/ha			
F-1	5.6	4.6	5.7	6.3	20.8	17.1	20.9	23.2
F-2	14.1	12.7	11.4	10.2	52.1	47.2	42.3	37.7
F-3	14.7	12.7	14.2	14.1	54.3	47.1	52.6	52.2
F-4	14.1	14.8	18.7	15.3	52.3	54.9	69.1	56.5
F-5	15.6	16.7	21.0	17.3	57.7	61.7	77.8	64.1
F-6	17.8	18.4	24.1	21.0	65.9	68.0	89.2	77.8
F-7	13.6	12.1	13.6	13.9	50.3	44.9	50.4	51.6
F-8	23.5	26.8	29.8	28.5	86.9	99.1	110.5	105.5
F-9	14.3	15.9	17.3	18.0	53.1	58.8	64.2	66.7
F-10	17.4	16.3	19.9	19.2	64.5	60.5	73.8	71.0
F-11	19.5	21.6	24.6	23.8	72.1	80.0	91.2	88.3
F-12	22.3	21.0	21.1	19.6	82.4	77.6	78.0	72.5
F-13	19.7	18.7	20.9	21.2	73.0	69.2	77.5	78.5
F-14	18.8	18.7	21.7	21.0	69.5	69.2	80.4	77.9
F-15	15.4	12.8	10.6	8.6	56.9	47.4	39.1	32.0
Mean	16.4	16.2	18.3	17.2	60.8	60.2	67.8	63.7

Table 5: Phosphorus balance of treatments

Years	1931- 1951	1952- 1972	1973- 1993	1994- 2000	1931- 1951	1952- 1972	1973- 1993	1994- 2000
	P ₂ O ₅ kg/plot				P ₂ O ₅ kg/ha			
F-1	-5.6	-4.6	-5.7	-6.3	-20.8	-17.1	-20.9	-23.2
F-2	2.7	12.6	14.0	15.2	9.9	46.8	51.7	56.3
F-3	2.1	12.6	11.2	11.3	7.7	46.9	41.4	41.8
F-4	4.5	3.8	8.6	12.0	16.7	14.1	31.9	44.5
F-5	3.0	2.0	6.3	10.0	11.3	7.3	23.2	36.9
F-6	3.3	2.7	5.6	8.7	12.1	10.0	20.8	32.2
F-7	-9.2	-7.8	-9.3	-9.6	-34.3	-28.9	-34.4	-35.6
F-8	-6.7	-1.6	-4.7	-3.4	-24.9	-6.1	-17.5	-12.5
F-9	2.4	0.9	8.0	7.4	8.9	3.2	29.8	27.3
F-10	0.1	1.2	-2.4	-1.6	0.5	4.5	-8.8	-6.0
F-11	14.8	21.3	18.3	19.1	54.9	79.0	67.8	70.7
F-12	-5.5	4.4	4.3	5.8	-20.4	16.4	16.0	21.5
F-13	-3.0	6.4	4.2	3.9	-11.0	23.8	15.5	14.5
F-14	-2.0	6.4	3.4	4.1	-7.5	23.8	12.6	15.1
F-15	-15.4	-12.8	-10.6	-8.6	-56.9	-47.4	-39.1	-32.0
Mean	-1.0	3.2	3.4	4.5	-3.6	11.8	12.7	16.8

These data of evidence offer an explanation for a concern of many farmers when they find that the level of soluble phosphorus does not change appreciably. It must be expected if only a small proportion of any residue remains soluble, and there is a large positive phosphorus balance over many years to change soluble phosphorus. Increasing yields and therefore phosphorus uptakes, if not balanced by increased application of phosphorus, must result in little change in the fertility of the soil.

Based on the AL-soluble P₂O₅ values, the phosphorus supply of Hungarian sandy soils, similar to the soils of Westsik's crop rotations, can be ranked as follows: very poor under 4.0 mg/100 g, poor between 4.1-7.0 mg/100 g, fair between 7.1-11.0 mg/100 g and good between 11.1-18.0 mg/100 g. The comparison of the labile phosphorus content to the yields shows that the highest yields can be achieved in those rotations where the phosphorus balance has been positive for a long time. This is an unambiguous evidence for the positive interaction between phosphorus and yields, even if we accept that, naturally, yield increase does not result from the phosphorus content exclusively but also from all the other plant nutrients in the soil. The manifestation of the effect of manure is always complex, and the yields of various crop rotations are determined by the differences in the methods of the application of organic manure.

Data obtained from long-term field experiment provide a simple means to demonstrate the net gains of phosphorus from manure. It is generally accepted that phosphorus can transfer reversibility between labile phosphorus and various categories of soil phosphorus held on sites with different binding energies or phosphorus precipitated in some compounds. The speed and extent at which these transfers occur are vital in crop nutrition.

In F-11 farmyard manure treatment, where superphosphate was also added, the increase in soluble phosphorus accounted for only about 50 per cent of the phosphorus balance. The phosphorus content of the soil in treatments F-1 and F-7 were similar although the negative balance in treatment F-7 was twice as much. Treatments F-7 and F-15 provided clear evidence that the soil could be forced to provide more phosphorus for the crops by releasing non-soluble reserved phosphorus. In treatments F-1 and F-15 all the phosphorus removed in the crop came from the non-soluble phosphorus (Table 5).

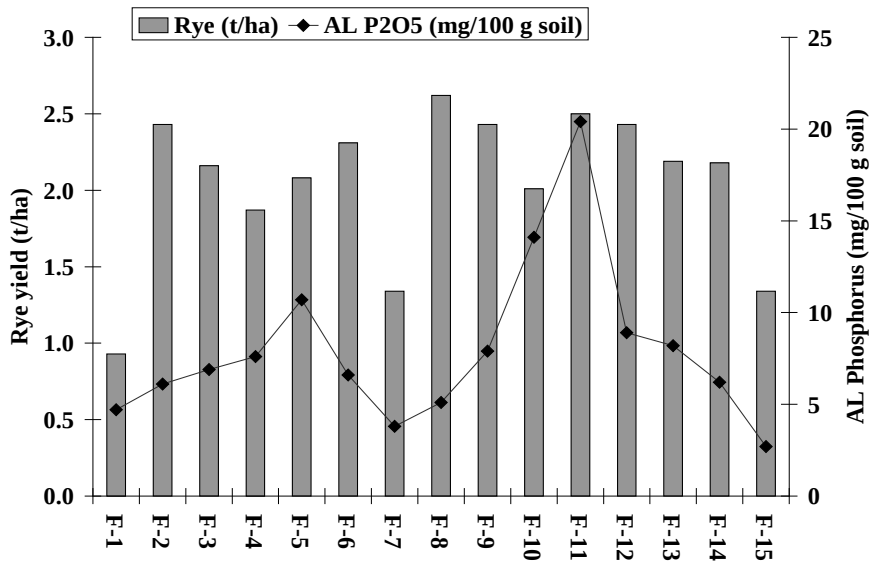


Figure 2: Rye yields in response to the phosphorus content of the soil

Effects of soil organic matter on crop response to soluble phosphorus can also be studied in Westsik's experiment although values did not overlap between sites, low soluble phosphorus was associated with low soil organic matter, on the other hand high soluble phosphorus and high soil organic matter also went together in the treatments. When yield of rye and potato at different levels of soluble phosphorus are plotted there is a strong suggestion that the relationship between them is linear.

Johnston and Poulton 1972 reported that the responses of crops to a single application of phosphorus fertilisers diminished rapidly after the first year, unless very large amount of phosphorus was applied. By the third, and fourth year, the effects were usually too small to measure accurately even though as much as three quarters of the added phosphorus remained in the soil. Although a crop can obtain only little phosphorus from the residue of single dressing applied previously, the total residues may supply much or all of the phosphorus needed by a crop. The largest yields were always obtained on fertilised soils and many agricultural experiments have tended to test the response of crops to the addition of phosphorus fertilisers.

The results of Westsik's experiment show that factors other than soluble phosphorus control yield. The average plateau yield and associated soluble phosphorus values for potato were 14 t/ha and 20 mg P_2O_5 /100g of soil, rye 2,8 t/ha and 20 mg P_2O_5 /100 g of soil. There is no obvious justification for the above except that extra organic matter may well provide additional plant nutrients and improve soil texture. It is almost certain that not all of the increase in yield was due to the extra soluble phosphorus. The effects of soil organic matter on the level of soluble phosphorus and the effect of soil texture are important as they help to explain why the correlation between yield and soil data over a range of soils are often poorer than those found on individual soils.

References

- Johnston, A. E., Poulton, P. R. (1972):** The role of phosphorus in crop production and soil fertility: In: Schultz, J.J. (ed.) Phosphate Fertilisers and the Environment. International Fertilizer Development Centre, Muscle Shoals, USA, pp. 45-64.
- Lazányi, J. (1994):** Homokjavító vetésforgókkal végzett kísérletek eredményei. DATE Kutató Központ. Nyíregyháza, pp. 1-238.
- Lazányi, J. (1995):** Results of Sustainable Production in Westsik's Crop Rotation Experiment. Communication of the Scientific Body of the Hungarian Academy of Sciences. Nyíregyháza, pp. 1-172.

DEVELOPMENT OF THE TECHNICAL ENVIRONMENT OF THE SITE-SPECIFIC NUTRIENT REPLACEMENT

P. Á. Mesterházi, M. Neményi, A. Kovács, K. Kacz and Zs. Stépán

University of West Hungary, Department of Agricultural and Food Sciences
Institute of Agricultural, Food and Environmental Engineering, H-9200 Mosonmagyaróvár, Vár 2.
Tel./Fax.: +36 96/ 566-641, E-mail: nemenyim@mtk.nyime.hu

Abstract

Because of its undoubted advantages, the site-specific plant production is getting more and more popular nowadays. This process can be observed both in the USA and in Europe and an increasing interest for this technology is present in Hungary as well. By means of it, it is possible to make the economic and ecologic trends meet. As a part of their research activity, the authors examined the whole site-specific cultivation cycle from yield monitoring through soil sampling to variable rate application of solid fertilizers. In the frame of these field experiments the site-specific application plan was created by means of the fertilizer advisory system of the Research Institute for Soil and Agricultural Chemistry of the Hungarian Academy of Sciences. The investigations provided the possibility for studying not only the practical usability and the accuracy of the precision farming system but also the effect of the variable rate nutrient replacement on the yield. The authors introduce their experiences in connection with the site-specific fertilizer distribution. With its research activity the Institute of Agricultural, Food and Environmental Engineering is involved in the Precision Plant Production National Research and Development Project.

Introduction

For the successful plant production – among others - the harmonic nutrient supply is essential. The optimal amount of fertilizer is required to be determined and applied. Quite similar the situation in case of site-specific nutrient replacement, but in this case the treatment carried out in the level of in-field treatment units opposite to the field level of the traditional land use. In this way, it is possible to provide the optimal or near optimal nutrient (Csizmazia, 1993) and chemical (László 1998; Mesterházi et al. 2001) amount, in each part of any field. Consequently, it is possible to make both ecological and economic trends meet (Maniak et al., 2003). In the same time, the recording of the amount of applied inputs in each field and each treatment unit is also possible. In this way, a complex database can be worked up, which may help the decision-making and together with the precision application means a big step forward, concerning to the environmental friendly agricultural production.

Materials and Methods

In the frame of the Institute's research activity beside the investigations concerning to data transfer among precision farming systems (Mesterházi et al. 2002/a and b, Neményi et al.

2002), soil draft and weed density monitoring (Neményi and Mesterházi 2002), a field level precision plant production experiment was also established next to Mosonmagyaróvár, in a 16ha field of the study farm of the University of West Hungary. This experiment was based on our previous experiences. The examination started in 2001 with yield monitoring after homogenous nutrient replacement. After that a grid soil-sampling was carried out, and based on that information the fertilizer application plan was worked out in cooperation with the Research Institute for Soil and Agricultural Chemistry of the Hungarian Academy of Sciences (RISSAC-RIA). And eventually the site-specific solid nutrient replacement was carried out. The investigations have been continued; yield and fertilizer distribution data from this field are available from two growing seasons.

With this trial our goals were the followings: to examine the capability of the Agrocom ACT – and even any kind of - precision farming system under real field circumstances, the accuracy of the solid fertilizer distribution and the effect of the site-specific nutrient replacement and the RISSAC-RIA fertilizer advisory system on the yield. During the investigation the following instruments were applied: Agrocom ACT yield monitoring system installed into Deutz Fahr M 36.80 harvester, Agrocom ACT fertilizer distributor system with Amazone ZA-M MaxTronic disc spreader.

To determine the required fertilizer amount in each management unit, the RISSAC-RIA fertilizer advisory system was employed. The basic philosophy of the model is the following:

- Efforts for economic level
- The aim is “plant nutrition” (do not accumulate store in the soil)
- To achieve and sustain moderate soil PK supply
- Slow soil PK build-up
- PK fertilisation of the rotation
- PK fertilisation only at moderate or poor soil supply levels
- Lower limit values for soil nutrient supply categories
- Lower specific crop nutrient contents
- Specific crop nutrient contents dependent of the planned yield level (because of the nutrient dilution-effect in crops)
- Mineral soil N-content is taken into consideration only in the case of the most important crops (Csathó et al., 1998).

Having a look at the enumeration above, it seems clearly, that this advisory system and the precision agriculture have an important common point: the aim is to save the environment defining the optimal nutrient amount.

Results and Discussion

The first step in our disquisition was the yield monitoring. This step was a very important starting point, which provides valuable information about the soil fertility under equal nutrient supply. (The base fertilizer amount was 300 kg 13:13:21 complex). Despite the homogenous nutrient replacement, the yield showed substantial in-field heterogeneity (Fig. 1.).

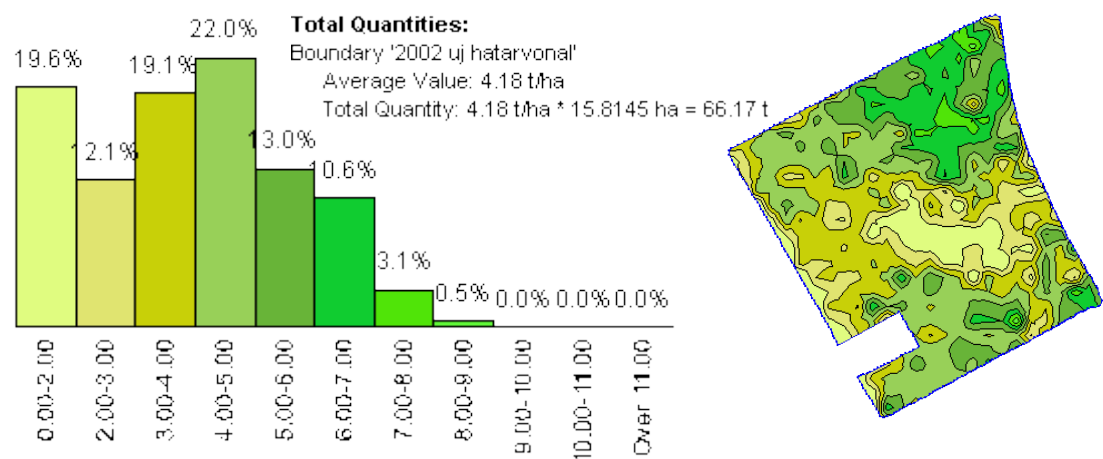


Figure 1: The yield map of maize after homogenous fertilizer distribution

After the yield monitoring, in spring of 2001, a grid soil sampling was carried out with an average grid size of 2500 square meter. This measurement provides adequate detailed information about the soil nutrient conditions. Following the soil analysis, the soil nutrient content maps were created (Fig. 2.), which also show heterogeneity.

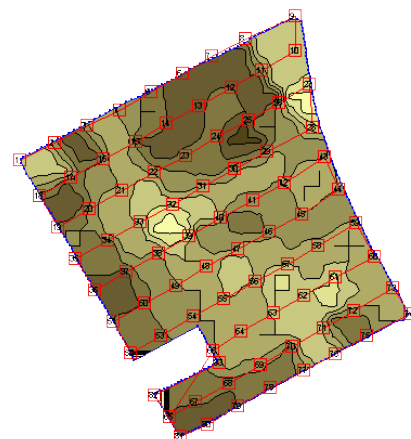
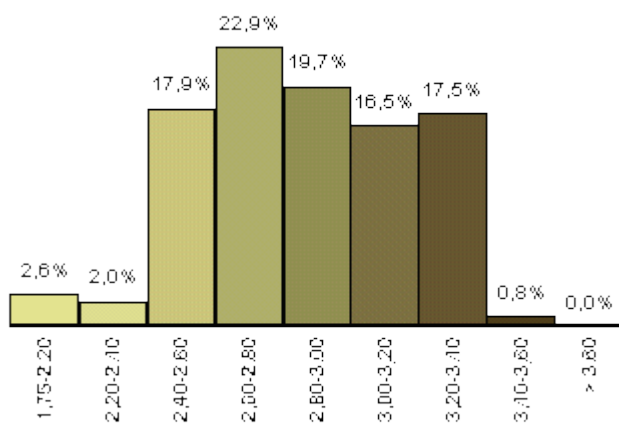
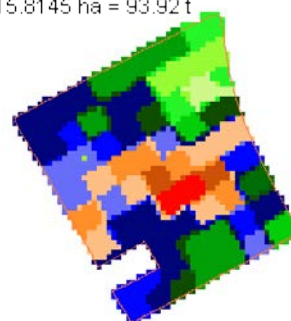
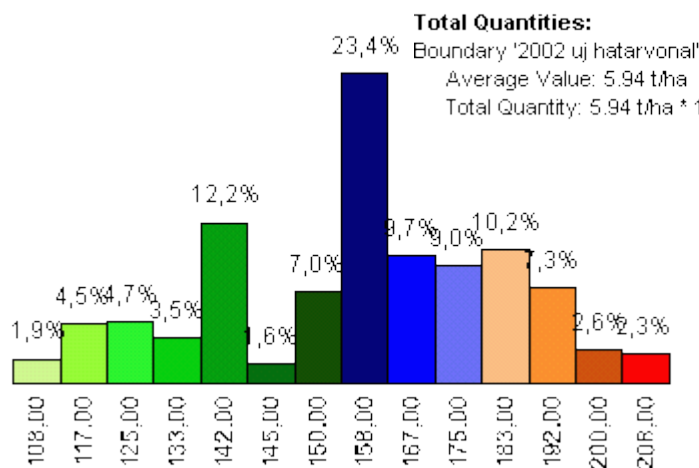


Figure 2: The humus content map of the experimental field with the sampling grid

As a next step, the optimal fertilizer amounts for maize for each treatment unit were calculated by means of the fertilizer advisory system of the RISSAC-RIA (Fig. 3.). Then the K_2O and N fertilizer distribution was carried out.

Figure 3: The K_2O fertilizer application map



The harvest of the experimental field took place in the autumn of 2002, and yield map was also generated (Fig. 4.).

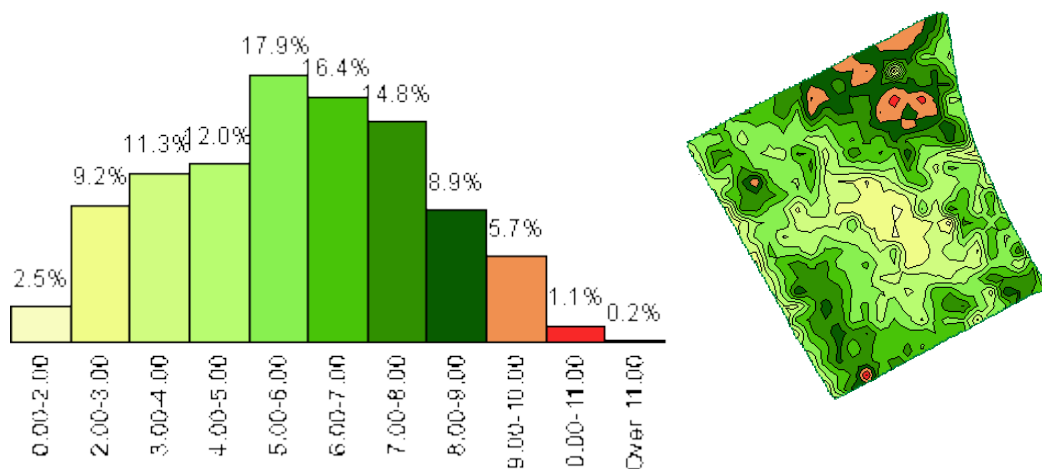


Figure 4: The yield map of maize from 2002

After the harvest, the site-specific fertilizer distribution came again, with K_2O and P_2O_5 (Fig. 5.). The N application map showed a hardly homogeneous picture, so it's precision application would have been causeless.

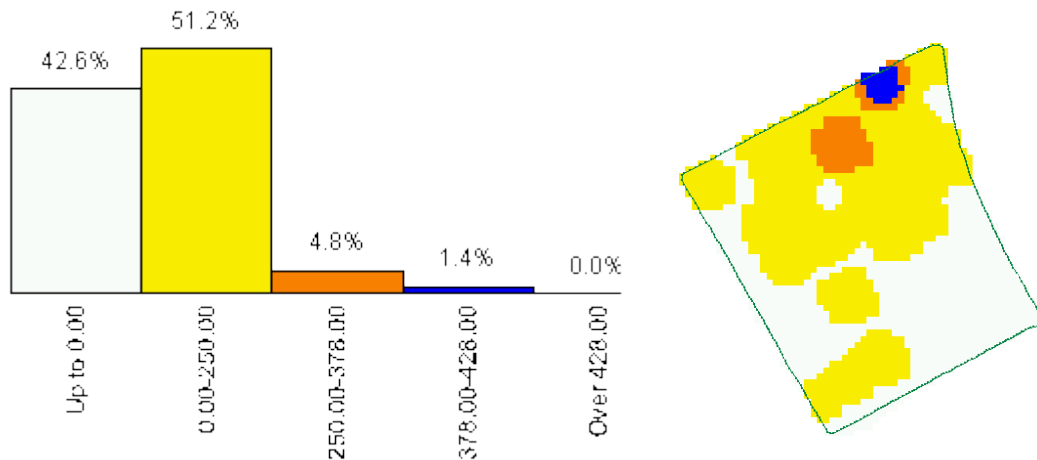


Figure 5: The P_2O_5 application plan for spring barley in 2003

In the basis of the above-mentioned field trial the authors state the followings:

- The application of the Agrocom ACT precision farming system for yield monitoring, soil sampling and nutrient replacement was successful under real field circumstances.
- However, further development of the system is required in some concerns (easy to use surface, more heavy-duty software, wider compatibility, on-line cutting width measurement and infield navigation during any kind of application). (For infield guidance the RDS Marker Guide system was employed with high accuracy).
- The yield increased after the site-specific fertilizer distribution. (The average yield grew from 4,19 t/ha to 5,94 t/ha) However, be it remembered that this period is too short for marking out trends. The statistical analysis is in process.
- The RISSAC-RIA fertilizer advisory system proved to be a reliable solution to ensure a proper yield taking into account the environmental protection, even together with the precision farming technology.
- The yield variability seems to be equalized in a certain extent (Fig. 1. and 4.).
- As Fig. 6. shows, the fertilizer plan can be realized with high accuracy by means of the applied system. (The fertilizer distributor system has the capability to record the applied amounts of any fertilizer, in this way a control map can be created).
- An unlike limitation of the above described nutrient replacement system is, that only one agent can be handled at the same time (because of the changing rate of these agents). In this way, the solution must be separate rounds.

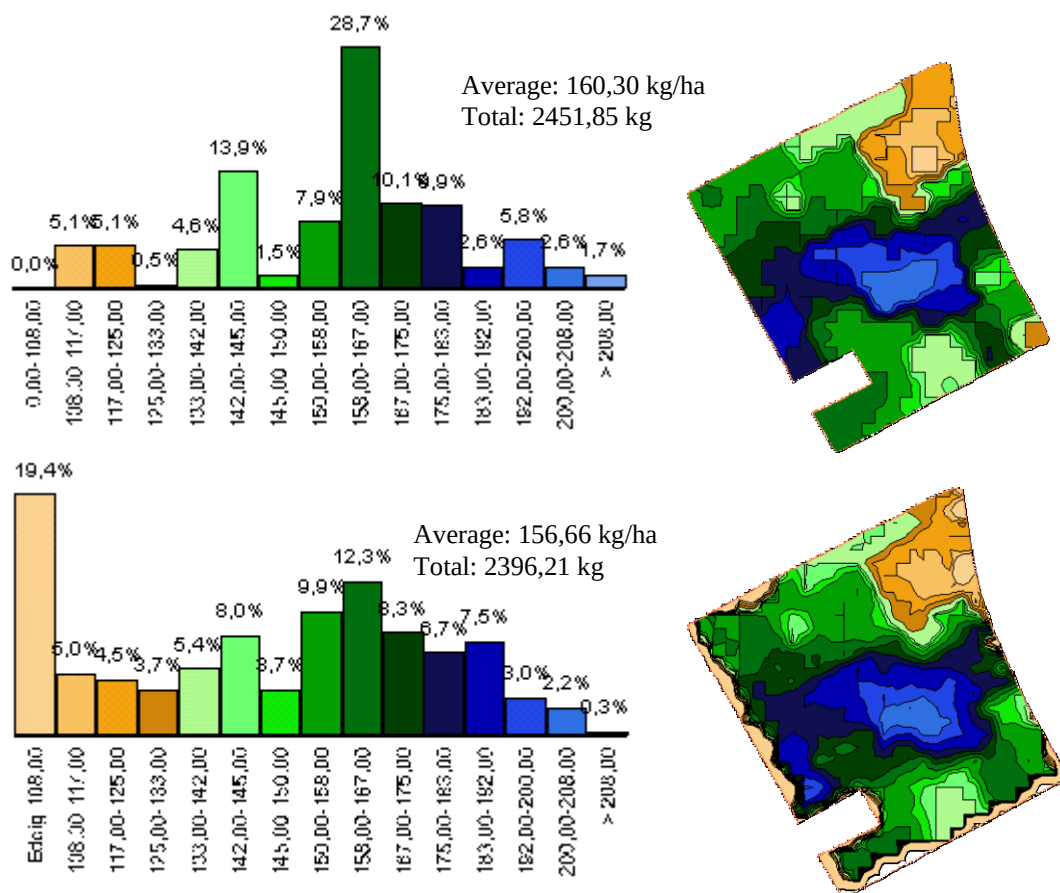


Figure 6: The interpolated map of the K₂O fertilizer plan from 2002 spring and the map of the applied amounts (Mesterházi et al., 2002/c)

Conclusions

Because of its undoubted advantages site-specific plant production is spreading far and wide. This technology is known as a tool for making both ecological and economic trends meet. Due to the rapid evolution in satellite technology, informatics and agricultural machinery, a quarry of facilities became available for the farmers and even for the researchers. However, limiting factors still exist. These are among others the demand of high input and special, all-round knowledge. Using this technology it is possible to follow precisely the balance of chemicals in each part of any field, in this was to provide the most suitable treatment – in other words to enrich high yields without destroying the environment.

References

- Csathó, P., Árendás T., Németh T. 1998. New environmentally friendly fertiliser advisory system, based on the data set of the Hungarian Long-term field trials set up between 1960 and 1995. *Communications in soil science and plant analysis*, volume 29, numbers 11-14, p. 2161-2174
- Csizmazia, Z. (1993) Technical Conditions of Equalized Fertilizer Application. *Hungarian Agricultural Research*, 1993, No. 4 P16-22.
- László, A. (1992) Automatizálás a vegyszerkijuttatásban. (Automatization in case of chemicals distribution) *Mezőgazdasági Technika (Agricultural Technique)*, 33. 4 33.
- Mesterházi, P.Á., Pecze, Zs., Neményi, M. (2001). A precíziós növényvédelmi eljárások műszaki - térinformatikai feltételrendszere (The engineering and GIS background of the precision farming technology). *Növényvédelem (Plant protection)*, 37 (6), 2001.
- Mesterházi P. Á - Neményi M. – Kacz K. – Stépán Zs. (2002/a): Data transfer among precision farming systems. *ASAE Annual International Meeting/CIGR World Congress*, 2002. 07.28-31, Chicago, Illinois, USA, cd kiadvány (021047)
- Mesterházi P. Á - Neményi M. – Kacz K. – Stépán Zs. (2002/b): Compatibility of precision farming systems. *International Conference on Agriculture Engineering*, 2001. 06.30- 07.04, Budapest. „ AgEng Full papers, posters and abstracts” cd kiadvány, (02-PA-012
- Mesterházi P.Á. – Neményi M. – Kacz K. – Stépán Zs. (2002/c): Precíziós növénytermesztési kísérletek a mosonmagyaróvári Agrárműszaki Intézetben. (Site-specific plant production experiments at the Institute of Agricultural Engineering in Mosonmagyaróvár.) *EU konform mezőgazdaság és élelmiszerbiztonság. (EU conform agriculture and food quality) Szerk. Nagy János, Debrecen 2002.*, p57-70.
- Neményi M. – Mesterházi P. (2002): Hozam- és talajellenállás térképezés és helyspecifikus tápanyag-visszapótlás a precíziós növénytermesztésben. (Yield and soil draft mapping and site-specific nutrient replacement in precision farming) *Agrárinformatika (Agrarinformatics) 2002*, 2002.09.27-28, Debreceni Egyetem, in print.
- Neményi M. - Mesterházi P.Á. - Pecze Zs. - Stépán Zs. (2002): The role of GIS és GPS in precision farming. *Computers and Electronics in Agriculture*. (in print)

SEASONAL CONCENTRATION CHANGES OF ELEMENTS AND NUTRIENTS IN THE SOIL OF A ROOT ZONE WASTEWATER TREATMENT SYSTEM

N. Németh¹ and T. Németh²

¹Institute of Environmental Management, Szent István University, Gödöllő
e-mail: nemethn@hotmail.com

²Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Budapest

Summary

Due to their unique ecological role both natural and constructed wetlands are getting into the focus of interest and research. One of the main objectives of our research work was to study the role of plant in a root zone system used for treating communal wastewater and examine its environment. We tried to acquire a more detailed picture about the role of the plant as it is important to understand how plants live in an environment where the element and nutrient concentrations are higher than in their natural habitat.

The aim of the present study was to examine of the environment of the plant that is the soil and the wastewater flowing into the reed bed. During the two-year research period we analysed the element and nutrient content of the soil and described the potential accumulations. Soil and wastewater samples were taken monthly and the following parameters were measured: Al, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Sr, Ti, V, Zn, NH₄-N, NO₃-N and total N. We compared the soil and wastewater concentration values measured in the summer and winter terms of the research period. We also investigated whether there is any connection between the concentration values measured in the wastewater and in the soil or between those of the soil and of the different parts of the plant (root, rhizome, stem, leaf).

In order to get a picture about the differences between natural and constructed habitats we compared the average concentration values of our soil and wastewater samples with those of natural reed habitats reported by other authors. It was established that in the case of some elements the rate of the difference of the concentrations measured in the wastewater (water) could be also observed in the sediment (soil). Moreover in the case of Cu and Fe there was no measurable concentration difference in the water/wastewater as far as the order of magnitude is concerned, while in the soil in the case of Cu the order of magnitude of the concentration difference was one and it was two for Fe.

Keywords: root zone system, element and nutrient accumulation, wastewater

Introduction

During the last decades a lot of useful characteristics of wetlands were recognised. They play an important role in water storage and in the regulation of run-offs (e.g. irrigation, water retention, water quality regulation, wastewater treatment); they provide mining opportunities (e.g. peat); water plants can be utilised in a lot of ways (e.g. wood, pasture, thatching), they also have outstanding functions from the point of view of wild plants and animals (e.g. nesting and hiding place, protection of the flora and fauna); they regulate the erosion processes; they are vital from the point of view of gene conservation and biodiversity; they take part in the energy and

material cycles; and by providing study paths and recreational areas they also play a role in education and recreation.

Wetlands are one of the most valuable but at the same time they are also one of the most threatened territories of our environment. They reflect the natural characteristics and condition of the environment so their conservation and protection are very important from the point of view of ecology, society and the environment (Mitsch et al, 1994). Wetlands are able to transform and eliminate pollutants, they absorb, adsorb and accumulate nutrients and elements so they are often considered to be the „kidney of the area” (Mitsch and Gosselink, 1993). These are their main features used in treating water pollution.

The so-called root zone system or subsurface flow system is indeed a constructed wetland, which has all the good characteristics of a natural system and its further advantage that the favourable natural processes can be enhanced and in this way the efficiency of the purification can be improved. In this natural wastewater treatment system the soil, the water and the plant form together an integrated system. To know the cycles of the different elements and compounds in this system is as vital as it is in the case of soil (Kádár, 1995; Németh, 1996; Kádár, 1998).

In a subsurface flow constructed wetland wetland plants are planted in a medium with suitable water conductivity (e.g. soil, sand, gravel). They are also called root zone systems. Settled or biologically treated wastewater is conducted through the reed bed in a vertical or horizontal direction, and then the purified wastewater is collected and drained. In a horizontal flow system the wastewater arrives through a pipe into the reed bed on one of the sides and after flowing through the bed horizontally the purified wastewater leaves the bed on the other side. In a vertical flow system the wastewater arrives to the bed near the surface and the even distribution of the water is provided by perforated pipes lying parallel to each other. Wastewater flows through the filter bed in a vertical direction, and the cleaned water is collected by perforated drainpipes in the bottom of the bed. The wastewater flowing through the rhizosphere is purified through microbiological degradation and different physical and chemical processes (Brix, 1997; Cooper et al., 1996).

In systems of this type the most important plants are the followings: reed (*Phragmites australis*), cattail (*Typha latifolia*), rush (*Carex acutiformis*) and bulrush (*Schoenoplectus lacustris*) (Reed et al., 1988).

Materials and Methods

The operation of the root zone wastewater treatment system was studied in the area of Szügy, where a system of this type has been in operation since 1994. The capacity of the treatment system is 100 m³/day. The purification process involves the following units: chemical pre-precipitation, Imhoff tank, reed beds (parallel with them there are two gravel beds), septic tank (not in use) and a small pond for final NH₄-N removal (Szilágyi, 1997).

The treatment beds (both the reed and the gravel ones) are isolated from the surrounding soil with waterproof foils and consist of several gravel and sand layers. All the beds receive settled wastewater. The filter beds are connected parallel with each other and the water flows through them vertically. The water is distributed and collected by perforated pipes and the purified wastewater flows into a natural stream.

During the research period (from May 2000 until April 2002) soil samples were taken monthly for 24 months. To take soil samples the two reed beds (680 m² each) were divided into 25-25 squares of 4*4 metres, from which 5-5 were selected at random. Samples were taken from 9 points of each square. Soil samples were taken with a soil sampler from the upper 40 centimetre deep layer of the soil. Sampling was done according to the Hungarian standards (MSZ 21410-1) and then the samples were transported in plastic boxes to the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences for further preparation and examination.

Mechanical pollutants (e.g. gravel, leaves, root and other plant pieces) were removed from the soil samples. Soil samples were dried at room temperature, ground, sieved and then mixed to be homogenous. Samples prepared for further analysis were stored in paper sacks in a dry place at room temperature. From each soil sample 1,00 g was measured to be digested with nitric acid and hydrogen-peroxide in a microwave equipment (MSZ 21470-50:1998). Then the element and nutrient concentrations of the samples (Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Sr, Ti, V, Zn) were analysed by using ICP-AES. The KCl soluble ammonium and nitrate-nitrogen content of the samples were determined by distillation (Bremner), while the total nitrogen content was analysed by digestion (BÜCHI 430) and distillation (BÜCHI 322/342 with online titration) (Buzás, 1988).

During the research period (from May 2000 until April 2002) wastewater samples were taken monthly for 24 months at the same time as the soil ones. Wastewater samples were taken from the following six points: raw wastewater /1/, settled wastewater /2/, water flowing out from the

gravel beds /3/, water flowing out from the reed beds /4/, water flowing into the lake /5/ and water getting into the receiver /6/. Then the concentrations of the following parameters were measured in the samples: Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Sr, Ti, V, Zn, NO₃-N, NH₄-N and total N. The sampling and the determination of the element content of the samples were done according to the Hungarian standards (MSZ 1484-3:1998) by using ICP-AES. The KCl soluble ammonium and nitrate-nitrogen content of the samples were determined by distillation (Bremner), while the total nitrogen content was analysed by digestion (BÜCHI 430) and distillation (BÜCHI 322/342 wit online titration) (Buzás, 1988).

Plant samples were collected monthly between May 2000 and April 2002 during the vegetation periods (between May and October). Plant samples were taken from the same places as the soil ones. Whole reed plants were collected. The plants were washed with tap water and then with distilled water, and their roots, rhizomes, stems and leaves were separated. The organs deriving from 9 plants were mixed before digestion with nitric acid and hydrogen peroxide in a microwave equipment. Then the following parameters were measured in the samples: total N, P, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Sr, Ti, V and Zn.

The preparation of the plant samples (drying, grinding), their digestion (with nitric acid and hydrogen-peroxide in a microwave equipment) were done according to the regulations. The element concentrations of the samples were measured by using ICP-AES, while the total nitrogen content was analysed by digestion (BÜCHI 430) and distillation (BÜCHI 322/342 wit online titration).

To evaluate the results of the examination of the soil the two reed beds (A and B), the two terms of the research period (May 200 - April 2001 and May 2001 - April 2002) and the concentration values of the soil and the wastewater measured in the summer and winter terms were compared. We also investigated whether there is any connection between the concentration values measured in the wastewater and in the soil or between those of the soil and the different parts of the plant (root, rhizome, stem, leaf). FVA 7 statistical analysis programme and MS Excel were applied to analyse the examination data, the method used were two-way ANOVA, F probe, t probe and linear regression analysis.

Results and Discussion

The aim of the present study was to examine the environment of the plant that is the soil and the wastewater flowing into the reed bed. During the period under investigation the changes of the

element and nutrient content of the soil were followed, and the potential accumulations were observed.

In order to acquire a more detailed picture about the characteristics of the contaminated environment of the reed and its function and to learn the differences between natural and constructed habitats our results of the soil and wastewater samples were compared with the data of natural reed habitats by Lake Balaton reported by other authors. In the future it will help to understand how plants live in an environment where the nutrient and element concentrations are higher than in their natural habitat. For the comparison we chose the natural reed habitats by Lake Balaton as we wanted to make a contrast between our results concerning an artificial habitat and those of a natural habitat having the same geographical and climatic conditions in Hungary.

In addition to the comparison with a natural habitat we also investigated whether there is any difference between the concentration values of the soil and the wastewater measured in the summer and winter terms and whether there is any connection between the concentration values measured in the wastewater and in the soil or between those of the soil and the different parts of the plant (root, rhizome, stem, leaf).

Table 1 shows the average monthly values of the soil samples taken from the two reed beds (the range of the concentration values of the elements and nutrients and the average values). The average values calculated from the monthly average concentration values (the average of 5-5 samplings per bed per parameter for 24 months, that is 120 samples per bed, so in total the average value of 240 samples) are presented in the table.

Table 1: The element and nutrient concentration values of the soil of the reed beds (average value of 120-120 samples)

Parameter	range of concentration values	average value	LSD _{95%}
	mg/kg		
Al	16483 - 24520	21088	100
Ba	104,3 - 161,2	128,3	1,5
Ca	3032 - 5394	3914	40
Cd	1,5 - 7,7	3,7	0,06
Co	7,1 - 10,6	8,9	1,16
Cr	23,1 - 32,0	28	0,5
Cu	4,5 - 12,1	8,5	0,2
Fe	14590 - 20650	17639	51
K	2348 - 5270	3634	21
Li	14,3 - 27,0	26	0,4
Mg	2863 - 3978	3320	60
Mn	416 - 1054	686	5
Na	137 - 388	219	3
Ni	14,4 - 21,9	18,3	0,3
P	517 - 1023	736	5
Sr	20,0 - 30,7	24,5	0,4
Ti	249 - 453	367	0,4
V	21,9 - 41,4	32,8	0,4
Zn	39,6 - 139,4	51,9	0,4
NH ₄ -N	9,4 - 36,3	18,3	0,6
NO ₃ -N	10,0 - 62,4	21,4	0,3
total N	1623 - 2181	1860	12

In the case of all the parameters under examination the difference between the two reed beds of the root zone system was statistically significant ($\alpha=0.05$). The minimum and maximum concentration values presented in the table cannot be connected to one of the reed beds in the case of each element. With the exception of P, Ti and NH₄-N the concentration values of all the other elements measured in bed A were higher than those of bed B. Moreover, in the case of Cd, Cu, Li, V, NO₃-N and total N the concentration values of the two reed beds were almost equal, there was not significant difference between them.

Assessing the results of the soil samples it could be established that the difference between the two terms of the period under investigation (May 2000 - April 2001 and May 2001 - April 2002) was statistically significant in the case of all the parameters except Mn. Considering the average of 60-60 samples in the case of one of the groups of parameters examined - Co, Cr, Cu, Fe, Ni, P, Ti, total N and NH₄-N - the concentration values of the second term were higher,

while in the case of the other group of them - Al, Ba, Ca, Cd, K, Li, Mg, Mn, Na, Sr, V, Zn and $\text{NO}_3\text{-N}$ - the concentration values of the first term were higher.

The examination provided us the possibility to describe the monthly average values. Making and assessing this grouping it could be seen that in the case of some of the parameters under investigation (Al, Ba, Ca, Co, Cr, K, Mg, Mn, Na, Sr, V, Zn and total N) lower concentration values were measured in spring and early summer (May, June) that is the time of intensive growing for plants. In the case of the same parameters the higher concentration values were measured in late autumn and winter (November, December, January, February) that is the time of decreasing metabolism for plants. The concentration values of three parameters - Ni, P and Ti - were different. In their cases the lowest values were measured in December, while the highest in September.

Some of the samples were taken during the vegetation period, while some of them during the period of dormancy. In the case of K, Li, Mn and $\text{NO}_3\text{-N}$ in both of the terms of the period examined higher concentration values were measured in the period of dormancy than in the vegetation period. Comparing the results of the soil samples it could be established that concerning the first term of the period examined (May 2000 - April 2001) in the case of Ba, Ca, Cd, Mg, Sr and V the higher concentration values were measured in the period of dormancy similarly to the four parameters mentioned above. On the contrary in the case of Cu lower concentration values were measured in the vegetation period of the first term.

The concentration values of Na gradually increased in the first term but it could not be observed in the second term.

Moreover, the concentration values of P gradually increased during the period under examination.

Comparing the average values of the two terms of the period under examination (the average of 5-5 samplings per bed per parameter for 24 months, that is 120 samples per bed, so in total 240 samples) it could be established that in the case of some of the elements and nutrients the concentration values measured in the soil increased at different rates with time during the two-year period, while in the case of other parameters the decrease of the concentration values was observed. The small rate of concentration decreases and increases could be explained by certain errors (e.g. sampling, random). In the case of the following parameters the decrease of the concentration values could be observed (the rate of the change in percentage is put in brackets): Al (1,8%), Ba (4,7%), Ca (6,1%), Cd (39,5%), K (3,6%), Li (12,9%), Mg (3,9%), Mn (1,96%),

Na (36,8%), Sr (8,5%), V (10,3%), Zn (2,5%) and $\text{NO}_3\text{-N}$ (61%). In the case of the following parameters the increase of the concentration values could be observed (the rate of the change in percentage is put in brackets): Co (2,2%), Cr (4,3%), Cu (19%), Fe (5,8%), Ni (12,1%), P (28,8%), Ti (2,7%) and total N (2,6%). The concentration of $\text{NH}_4\text{-N}$ measured in the soil did not change.

We compared our results of the soil samples with the ones measured in the sediments of some parts of the northern shore of Lake Balaton having different rate of contamination (Dinka, Kovács, Podani, 1979). The Ca, K and Na concentrations of the samples taken at Lake Balaton were analysed by flame photometry, while those of the Mg and microelements (Fe, Mn, Sr, Cu, Zn) were analysed by atomic absorption (Unicam).

Dinka and her colleagues pointed out a shoreline (mouth of the Csókakő stream, Szent: Imre and Szent László trench) which was heavily contaminated by wastewater discharges and where considerable amount of Ca, Mg, Na, $\text{NH}_4\text{-N}$, total N and PO_4 flowed into the lake. It can be seen from the data that considering such environmental and polluting conditions mainly Fe, Sr, Zn and Mn were observed in higher amounts compared to the control area. The data of the authors also derive from the sediment of unpolluted shorelines (Alsógyenesdiás, Vonyarcvashegy, Balatongyörök) where there were not wastewater discharges.

Table 2 shows the comparison of the average element and nutrient concentration values of the samples taken from the contaminated and uncontaminated shorelines of Lake Balaton and those of the wastewater flowing into the constructed reed bed. The data in the table are calculated from the concentration values of the wastewater flowing into the reed bed (monthly sampling for two years, that is 24 samples). Table 3 presents the concentration values of the sediment and the soil (the average of 5-5 samplings per bed per parameter for 24 months, that is 120 samples per bed, so in total 240 samples).

Table 2: The element and nutrient concentration values of the water/wastewater

Parameter	contaminated shore	reed bed	clean shore
	mg/l		
Ca	36,4	136,8	24,7
Mg	44,3	43,3	39,3
K	6,4	41,2	5,4
Na	26	134,2	24,5
total N	***	95,8	***
NH ₄ -N	1,1	66	0,02
NO ₃ -N	0,3	0,6	0,3
P	1	12,7	0,8
	µg/l		
Fe	860,8	540	298,6
Sr	350,2	350	306,5
Mn	136,2	80	49,8
Zn	98,5	320	64,9
Cu	12,7	60	20

Table 2: The element and nutrient concentration values of the sediment/soil

Parameter	contaminated shore	reed bed	clean shore
	mg/kg		
Ca	750	3860	290
Mg	321	3338	107
K	61	3657	31
Na	70	222	28
total N	2,7	1841	1,5
NH ₄ -N	***	17,1	***
NO ₃ -N	***	12,4	***
P	19	746	12
Fe	316,7	17739	169,8
Sr	15,2	24,5	17,2
Mn	64,1	594	63,8
Zn	49,2	50,4	11,8
Cu	6,7	10,4	4,2

It could be established that in the case of Ca, K, Na, P, NH₄-N and Zn the concentration values of the water/wastewater measured in the root zone system were higher with one order of magnitude than those of Lake Balaton, while the values of Mg and Sr were nearly equal. As far

as the NO₃-N, Fe and Cu contents of the water/wastewater were concerned there were no real difference between the natural and the constructed habitat.

It could be established that in the case of Ca, Mg, Na, P, Mn and Cu the concentration values of the sediment/soil measured in the root zone system were higher with one order of magnitude than those of Lake Balaton, while in the case of K and Fe the difference in concentration was two order of magnitude and three order of magnitude in the case of total N. As far as the Sr and Zn contents of the sediment/soil were concerned no difference of that kind could be experienced.

It was established that in the case of some elements the rate of the difference of the concentrations measured in the wastewater (water) could be also examined in the sediment (soil). Considering the difference of the order of magnitude of the concentration values measured in the water/wastewater no difference was found in the case of Cu and Fe, while there was a difference of two order of magnitude regarding the values measured in the sediment/soil.

In the case of one group of the parameters examined - Ca, K, Na, P, Sr, NH₄-N and NO₃-N - the concentration values measured (monthly samplings for each parameter for 24 months) in the summer and winter terms differed significantly ($\alpha=0.05$). While for the other group of the elements - Al, Ba, Cu, Fe, Mg, Mn, Ti, Zn and total N - this seasonal difference could not be justified statistically.

Analysing the concentration values of the parameters examined in the soil (24 months per parameter, 10 samples a month, that is 240 values per parameter) it could be concluded that excluding only three parameters - Fe, NO₃-N and total N - the difference between the values of the summer and winter terms were statistically significant ($\alpha=0.05$) in the case of all the other parameters.

As far as Ba, Ca, K, Mg and V were concerned there was statistically proven linear regression relationship between the concentration values measured in the wastewater and in the soil, that is the increase of the concentration values in the wastewater caused concentration increase in the soil as well ($\alpha=0.05$). The same relationship could not be detected in the case of the other group of the parameters under investigation (Al, Cu, Fe, Mn, Na, P, Sr, Ti, Zn, NH₄-N, NO₃-N and total N).

Analysing the concentration values of the soil measured in the vegetation period and those of the different parts of the reed (root, rhizome, stem, leaf) (10 samples per each part for 12 months, that is 120 samples per plant part) it could be established that there was statistically

proven linear regression relationship between the concentration values of Cu and Sr measured in the soil and those of all the four parts of the reed ($\alpha=0.05$). In the case of K, Na, Ti, and V the same relationship was seen between the values measured in the soil and in the root, between those of the soil and the rhizome and between those of the soil and the stem. In the case of Ca and Mg the linear regression could be observed between the values measured in the soil and in the rhizome, between those of the soil and the stem and between those of the soil and the leaf. In the case of Cd and P similar connections were detected between the values of the soil and the root and between those of the soil and the rhizome, while in the case of Cr and Mn it was statistically proven only between the values of the soil and the stem. As far as the linear regression relationship was concerned between the concentration values of the soil and the root it was statistically justified in the case of Al, Ba, Co and Fe. Regarding Fe it was also valid between the values of the soil and the stem and between those of the soil and the leaf, while in the case of Ba it was also true between the values of the soil and the stem. Considering Li the relationship mentioned above was only observed between the values of the soil and the rhizome, while in the case of Zn it was also seen between the values of the soil and the leaf. There was no linear regression relationship between the Ni and the total N content of the soil and neither of the plant parts.

It could be concluded that in the case of the major part of the parameters examined - Al, Ba, Cd, Co, Cu, Fe, K, Na, P, Sr, Ti and V - the linear regression relationship between the concentration values measured in the soil and in the root could be proven statistically ($\alpha=0.05$). In the case of similar number of parameters the same relationship could be seen between the values of the soil and the rhizome (Al, Ca, Cd, Cu, K, Li, Mg, Na, P, Sr, Ti, V and Zn), and between those of the soil and the stem (Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Sr, Ti and V) ($\alpha=0.05$). In the case of some elements (Al, Ca, Cu, Fe, Mg, Sr and Zn) the linear regression relationship was statistically proven between the values of the soil and the stem ($\alpha=0.05$).

It can be established that a natural wastewater treatment system of this kind can play its role if the necessary technical and ecological requirements are met during its operation. Our results can provide basic information for the more exact examination of the element and nutrient accumulation of the soil and for the analysis of the effect of the changes occurring during the purification processes. Our results also draw the attention to the fact that the examination of such a system requires the simultaneous monitoring of the soil, the water and the plant in order to get a more precise picture about the cycle of elements in the system. The collection, analysis and assessment of the data and results of the regular examinations can provide an opportunity to

observe short-term and long-term changes of the cycles of the elements and further help for planning and establishing the conditions of the operation.

References

- Buzás, I (Szerk.) (1988): Talaj- és agrokémiail vizsgálati módszerkönyv 2. A talaj fizikai-kémiai és kémiai vizsgálati módszerei (Methods of soil and agrochemical analyses 2. Physico-chemical and chemical analyses of the soil), Mezőgazdasági Kiadó, Budapest
- Brix, H. (1987): Treatment of wastewater in the rhizosphere of wetland plants – the root zone method. *Water Science and Technology*, 19, 107-118 pp.
- Cooper, P.F., Job, G.D., Green, M.B., Shutes, R.B.E. (1996): Reed Beds and Constructed Wetlands for Wastewater Treatment. WRC Publications, Medmenham, Marlow, UK.
- Dinka M., Kovács M., Podani J. (1979): A balatoni nád elemtartalmának vizsgálata, II. A nád elem-akkumulációja a különböző terhelésű partszakaszokon (Analysis of the element content of reed by Lake Balaton II. The element accumulation of reed on shorelines with different rate of contamination. *Bot. Közlem.* 66/4., 285-290 pp.
- Kádár I (1995): A talaj-növény-állat-ember tápláléklánc szennyeződése kémiai elemekkel Magyarországon (The contamination of the soil-plant-animal-human food chain with chemical elements in Hungary), Budapest
- Kádár I (1998): A szennyezett talajok vizsgálatáról. Kármentesítési kézikönyv 2. (Analysis of polluted soils) Környezetvédelmi Minisztérium, Budapest
- Mitsch, W.J., Gosselink, J.G. (1993): Wetlands. Second edition. Van Nostrand Reinhold, New York
- Mitsch, W.J., Mitsch, R.H., Turner, E.E. (1994): Wetlands for the old and the new worlds: ecology and management. In: Mitsch, W.J. (ed.): *Old World and New*. Elsevier Science, Amsterdam. 3-56 pp.
- Németh T (1996): Talajaink szervesanyag-tartalma és nitrogénforgalma (Organic matter content and nitrogen transport in Hungarian soils). MTA Talajtani és Agrokémiail Kutató Intézete, Budapest
- Reed, S.C.; Crites, R.W.; Middlebrooks, E.J. (1988): Natural systems for waste management and treatment, McGraw-Hill Inc., New York
- Szilágyi F. (1997): A szügyi gyökérmezős szennyvíztisztító telep üzemelési tapasztalatai (Experience of the operation of the root zone wastewater system in Szügy). Témabeszámoló kézirata. Ökotech Kft., Budapest
- MSZ 21470-1 Környezetvédelmi talajvizsgálatok. Mintavétel
- MSZ 21470-50:1998 Környezetvédelmi talajvizsgálatok. Az összes és az oldható toxikuselem-, nehézfém- és a króm(VI)tartalom meghatározása
- MSZ 1484-3:1998 Vízvizsgálat. Az oldott, a lebegőanyaghoz kötött és az összes fémtartalom meghatározása AAS- és ICP-OES-módszerrel

PRODUCTION AND EVALUATION OF TWO DIFFERENT ENRICHED ^{113}Cd LABELED-FERTILIZERS

H. Oda^{*}, A. Kawasaki and S. Wang

Department of Chemical Environment, National Institute for Agro-Environmental Sciences
3-1-3 Kannondai, Tsukuba, Ibaraki 305-8604, Japan

^{*}E-mail: odah@niaes.affrc.go.jp

Abstract

This research was conducted to elucidate the behavior of fertilizer-derived cadmium (Cd) compared with soil-derived Cd in the soil-plant system. Two kinds of enriched ^{113}Cd labeled-fertilizers were produced for legume and rice, and were evaluated for solubility. Then a feasibility study of the labeled-fertilizer for legume was conducted to determine Cd concentrations derived from both fertilizer and soil, in plant tissue and soil solution in the lysimeter experiment of raising soybean plants. The labeled-fertilizer for legume (3-10-10) and rice (10-10-10) was produced by adding a calculated amount of ammonium sulfate and potassium chloride to mono-calcium phosphate (MCP). Prior to preparing MCP, ^{113}Cd (94.8 %) nitric acid solution was added into phosphoric acid solution. The contents of ^{113}Cd in the labeled-fertilizer for legume and rice were similar at 87.8 and 88.2 mg kg⁻¹, respectively. The ratio of citric acid-soluble (excl. water-soluble) and that of water-soluble to the total ^{113}Cd concentration were 97% and 21% in the labeled-fertilizer for legume, and 99% and 44% for rice, which indicated that the ratio of water-soluble was higher in the labeled-fertilizer for rice. To estimate soil burden of fertilizer-derived Cd, 400 g of the ^{113}Cd labeled-fertilizer for legume was applied into unpolluted upland soil (Andosols) of a lysimeter (2mX2mX2m), where the soybean (*Glycine max* var. Enrei.) plants were cultivated. The result indicated that the total amount of labeled-Cd of the soybean uptake was only 0.13% in each part of the harvested plants, and that the remainder of that was burdened into the soil.

Introduction

The soil pollution control law for arable land was enacted in Japan, in 1970 and Cd, Cu, As, and other compounds were designated as harmful elements. For identifying Cd polluted areas, the threshold concentrations defined by law is Cd 1mg kg⁻¹ in brown rice taken from rice plants in the field. However, recently, at the 33rd session of the codex committee on food additives and contaminants¹⁾ a safety criterion of 0.2 mg kg⁻¹ has been proposed for Cd concentration in rice, soybean, peanuts and wheat grain. It is, therefore, a matter of urgency to more precisely elucidate the input-output balance of Cd, such as that derived from phosphate fertilizers²⁾ and sewage sludge in arable soil. It is also necessarily to clarify the mechanisms by which Cd is absorbed and translocated by soybean and other upland crops. It is, therefore, essential to elucidate the behavior and balance of fertilizer-derived Cd in the soil-crop system, using method that satisfies the following 3 conditions; (1) friendly to nature and the agro-environments, (2) traceable for more than 6 months, and (3) measurable under the nanogram per

gram range. Stable isotope (SI) tracers have many advantages over their radio-isotope (RI) counterparts that satisfy the above 3 conditions. Suzuki et al.³⁾ quantitatively traced cadmium, as low as a nanogram per liter in rice, using ^{113}Cd tracer – high-performance liquid chromatography / inductively coupled plasma –mass spectrometry (HPLC/ICP-MS). However, there are only a few reports⁴⁾ of field studies using Cd SI. Furthermore, there are no reports on producing Cd SI-labeled fertilizer and its use. The purpose of this study is to produce two types of ^{113}Cd -labeled fertilizers, to evaluate their chemical properties, to obtain the Cd absorption percentage of a labeled-fertilizer by soybean plants, and to simultaneously monitor the changes of Cd concentration in soil solutions derived from fertilizer and soil.

Materials and Methods

Preparation of nitric acid solution containing enriched ^{113}Cd : Enriched ^{113}Cd (metal, ^{113}Cd 94.8±0.3, ^{114}Cd 3.03 content %) ⁵⁾ imported from JV ISOFLEX, Russia, was used as a tracer for the fertilizers. About 2.8 g of ^{113}Cd enriched metal was dissolved in 250 mL of 0.5M- HNO_3 solution.

Production of the two ^{113}Cd labeled-fertilizers: Mono-calcium phosphate (MCP) labeled with enriched ^{113}Cd (94.8%) was prepared using a kneading machine in which the homogenized liquid made from a South-African phosphoric acid solution and the nitric acid solution containing enriched ^{113}Cd reacted to lime. The enriched ^{113}Cd labeled-fertilizer for rice (10-10-10) and legume (3-10-10) was prepared by adding a calculated amount of ammonium sulfate and potassium chloride to the MCP. The detailed procedure for the production of the two labeled-fertilizers is shown in Figure 1.

Determination of total Cd in the fertilizers: Digested 0.5g of the fertilizer with aqua regia, dissolved the digested mixture with 5mL nitric acid, and then diluted exactly to 50mL with water.

Determination of citric acid-soluble Cd: A 0.4g of the labeled-fertilizer was taken into a 100mL centrifuging tube, and then leached out with 60mL 2% citric acid solution warmed to 30 °C. The supernatant obtained by centrifuging the processed fertilizer described above was used as the sample solution.

Determination of water-soluble Cd: Four grams of the labeled-fertilizer was taken into a 100mL centrifuging tube, and then leached out with 40mL of water at 20°C. The supernatant obtained by centrifuging the processed fertilizer described above was used as the sample solution.

Determination of ^{113}Cd and ^{114}Cd intensities in the sample solutions: After diluting each sample solution accordingly, ^{113}Cd and ^{114}Cd values were determined by ICP-MS analysis adopting Te as an internal standard,.

Application of ^{113}Cd labeled-fertilizer for the lysimeter experiment of raising soybean plants: The labeled-fertilizer for legume (400 g) was applied into the 2m x 2m-sized field lysimeter packed with unpolluted upland soil (Light-colored Andosols), in which soybean (*Glycine max* var. Enrei.) was cultivated. Each part of soybean was cultivated for 159 days after seeding. The soil water taken from the topsoil at the depth of 15cm was used as samples for analysis. Fertilizer-derived and the soil-derived Cd concentrations in the samples were calculated after measurement by acid digestion -ICP-MS⁶⁾.

Results and Discussion

Production of two kinds of ^{113}Cd labeled-fertilizers: Two kinds of ^{113}Cd labeled-fertilizers were produced by the procedure shown in Figure 1. Each product volume of the labeled-fertilizer for legume (3-10-10) with a granular diameter from 1.6-4.0 mm, that for rice (10-10-10) with a granular diameter from 1.6-4.0 mm, and that for legume (3-10-10) with a granular diameter under 1.6 mm were 8.53 kg, 9.49 kg and 3.8 kg respectively. The product volume of the labeled-fertilizer for legume and that for rice was enough to cover the experiment space of ca. 85 m² and ca. 95 m², respectively. The composition of N, P₂O₅, K₂O, and pH in the 3 products are shown in Figure 1.

Evaluating chemical solubility of the fertilizers: The concentrations of total-, citric acid soluble- and water soluble-Cd in labeled-fertilizer are shown in Figure 2. Each labeled-fertilizer for legume and rice contained 87.8 and 88.2 mg kg⁻¹ DW of total ^{113}Cd concentration respectively. The ratios of citric acid-soluble ^{113}Cd and water-soluble ^{113}Cd to the total ^{113}Cd concentration in the fertilizer for legume were 97% and 21%, and those in the fertilizer for rice were 99% and 44% respectively. This indicates the fertilizer for rice had the higher ratio of available form (water and citric acid-soluble form). It seems that the difference of the pH in the two kinds of fertilizers influenced the proportion of soluble form of Cd. The total Cd concentrations in unlabeled fertilizers for legume and rice, which were made by the same procedure as the labeled-fertilizer without mixing of ^{113}Cd tracer, were 0.18 and 0.14 mg kg⁻¹DW respectively. The ratios of citric acid-soluble and water-soluble Cd to the total Cd concentration in unlabeled fertilizer for legume were 83% and 21%, and those in the unlabeled fertilizer for rice were 90%

and 35% respectively. These results show that the proportions of the available form of Cd in the labeled fertilizers are almost the same as in the case of unlabeled fertilizers.

Cd absorption percentage of a labeled- fertilizer by soybean plants: Both fertilizer-derived and soil-derived Cd concentrations of each part were high in order of root>stem>leaf $\approx$ petiole. About 11 % of the whole Cd absorbed by soybean plants was derived from the fertilizer, which was no more than 0.13% of the whole amount of fertilizer-derived Cd (Table 1). Contrary to this, the absorption rate of N and P₂O₅ was 54-70% ⁷⁾ and around 10% ⁸⁾, and the value for Cd corresponded to approximately one hundredth for N or P₂O₅. The remainder of the fertilizer-derived Cd was burdened into soil.

Monitoring Cd concentration in soil solutions derived from fertilizer and soil: The concentration of fertilizer-derived Cd in the soil water taken from the topsoil varied between 0.01 and 0.07ng mL⁻¹, and that of soil-derived Cd varied between 0.06 and 0.22 ng mL⁻¹. The former values were constantly lower than the latter, and increased until one month after the fertilizer application followed by a decrease to the original value after the application. Almost the same fluctuation was observed with the latter.

Using ¹¹³Cd-labeled fertilizer, ICP-MS can be performed simultaneously on both labeled- and unlabeled-Cd in soil solutions. This enables the efficient and separate determination of Cd concentrations, under nanogram per gram range, of both fertilizer-derived and soil-derived Cd. This method also enables us to monitor if available Cd is easily absorbed by crops, as well as other Cd in the soil throughout the cultivation period. The Cd trace-ability using this method is better than the Cd RI-tracer method, for example using e.g. ¹⁰⁹Cd and ^{115m}Cd ⁹⁾. Additionally, the field application by RI-tracer is unfriendly to nature and agro-environments compared to SI-tracer ¹⁰⁾.

Conclusion

The ¹¹³Cd labeled-fertilizer for legume and rice were produced and contained about 88 mg kg⁻¹ of ¹¹³Cd. The proportions of the available form of Cd in the labeled-fertilizers are almost the same as those of unlabeled fertilizers. The labeled fertilizer for legume was applied to the lysimeter experiment of raising soybean plant. Results indicated the feasibility of determining Cd concentrations derived from both fertilizer and soil in plant tissue and soil solution with satisfactory sensitivity. The total amount of labeled-Cd of the soybean uptake was only 0.13% in whole parts of the harvested plants.

Acknowledgements

To produce two kinds of ^{113}Cd labeled-fertilizers, we greatly appreciated the fund from Japan Phosphatic & Compound Fertilizers Manufacturers' Association (JAPCA) and the help from the staff of Niigata Plant, Co-Op Chemical Co., Ltd. This research was a part of a project entitled, "Evaluation of trace heavy metals loaded in arable soil", funded by a grant from the Ministry of Environment Agency of Japan.

References

- 1) Report of the 33rd session of the codex committee on food additives and contaminants, Hague, Netherlands 12-16 March 2001, p. 285 (2001)
- 2) V. Kauwenbergh: Cadmium and other potential hazards, Fertilizer International No. 380, January/February 2001, British Sulphur Publishing Inc., UK (2001)
- 3) K. T. Suzuki, C. Sasakura and M. Ohmichi: Binding of endogenous and exogenous cadmium to glutelin in rice grains as studied by HPLC/ICP-MS with use of stable isotope, *J. Trace Elements Med. Biol.* **11**, 71-76 (1997).
- 4) H. Oda and A. Kawasaki: Application of a ^{113}Cd tracer technique to cadmium absorption by soybean in an on-site experiment, *NIAES Annual Report 2001/2002*, p.39-40 (2003)
- 5) Quality Certificate of cadmium-113, Certificate #I-0910/1, JSC "JV ISOFLEX", Moscow, Russia (2000)
- 6) H. Oda and A. Kawasaki: Application of ^{113}Cd and ^{203}Tl -tracer to the soil-pot experiment of soybean (*Glycine max*) plant, *Proc. Intl. Sym. on Bio-Trace Elements 2002 (BITREL2002)* (2003) [in press]
- 7) A. Nishimune: Evaluation of the soil nitrogen supply in upland field crops in Tokachi, Hokkaido, *Res. Bull. Hokkaido Natl. Agric. Exp. Stn.*, **140**, 33-91 (1984) [in Japanese with English summary].
- 8) The value of obtained from the results of the Long-term N-P-K application experiment in 1996, Plant Nutrition Lab., Dept. of Soil & Fertilizer, Natl. Agr. Res. Center.
- 9) M. Chino: The distribution of heavy metals in rice plants influenced by the time and the path of supply, *J. Sci. Soil and Manure, Jpn.* **44**, 204-210 (1973) [in Japanese].
- 10) Subcommittee for Investigation of Field Experiments Using Radiotracers, Physical Science and Engineering Committee, Japan Radioisotope Association: Problems in promoting field and factory experiments of radiotracers, *Radioisotopes*, **39**, 272-280 (1990) [in Japanese].

Preparation for phosphoric acid with ¹¹³Cd

Dissolve 2.8 g of ¹¹³Cd-metal into 250 mL of 0.5M-HNO₃.

Mix 5,513g of South-African phosphate (P₂O₅: 53.33%) with ¹¹³Cd solution (phosphoric acid with ¹¹³Cd)

Production of MCP (mono-calcium phosphate)

Mix 2,462g of calcium carbonate and phosphoric acid with ¹¹³Cd in 20L-kneader, then added anti-foaming agent (silicone oil) when foaming.

Scrape out the reaction product to a vat and dry it at 75°C

Weight of dried reaction product: 5,611g

H₂O: 0.80%
T-P₂O₅: 50.16% W-P₂O₅: 43.77%
T-CaO: 16.40% W-CaO: 11.29%

Granulation

Granulate the mixture of labeled-MCP, (NH₄)₂SO₄ and KCl in the granulator (750 mmφ×200 h×24 rpm, Capacity: 5-7 kg per batch)

Feeding of the first batch: Granulate 5 kg of new material using water spray and steam, and then make it semidry, with flame of a burner, enough to be sieved.

Feeding of the second and after: Granulate the ground oversized product and the undersized product of the last batch, after adding 4 kg of new material.

Sieving (Manual) ON size: φ1.6-4.0 mm

	Result of each product		
	3-10-10	10-10-10	3-10-10 under
Volume	8.53 kg	9.49 kg	3.8 kg
A-N	3.27 %	10.00 %	3.39 %
S-P ₂ O ₅	10.72 %	10.60 %	10.83 %
W-P ₂ O ₅	7.61 %	9.34 %	7.55 %
W-K ₂ O	10.05 %	10.20 %	10.60 %
PH	5.97	5.77	5.96

Figure 1: Production procedure and composition of ¹¹³Cd-labeled fertilizers

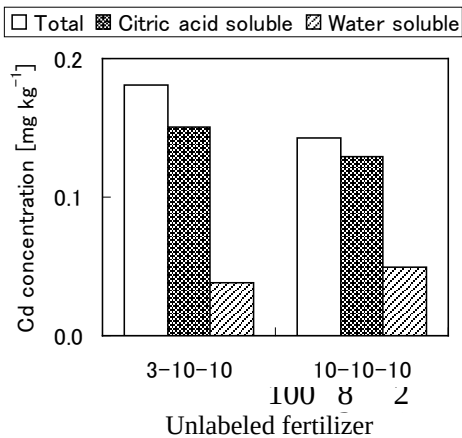
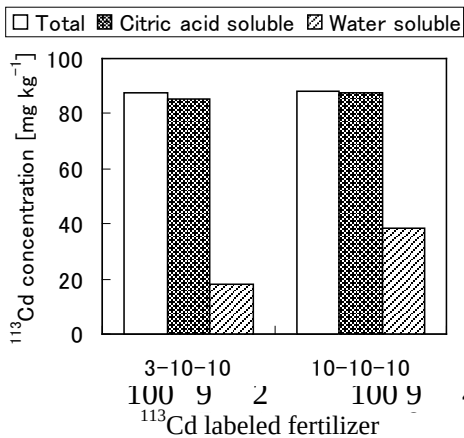


Figure 2: Result of evaluation analysis of solubility (Ratio of existing Cd in each form in the prepared labeled fertilizers)

Table 1: Amount of Cd uptake and ratio of fertilizer-derived Cd in each part of the harvested soybean plants

Part	Cd uptake (mg/10a)		Ratio of fertilizer- derived Cd to total Cd uptake (%) $b/(a+b)$	Labeled fertilizer-derived Cd absorbed by soybean
	a: Soil-deriv.	b:Fertilizer-deriv.		
Leaf	2.5	0.2	6.3	Cd in labeled fertilizer (mg/10a) 8,780 ^c
Seed	33.4	3.9	10.4	
Pod	9.2	0.9	8.6	Cd absorbed by soybean from labeled fertilizer (mg/10a) 11.2 ^d
Stem	37.1	4.1	10.0	
Root	8.2	2.2	20.9	Ratio of uptake by soybean (%) $d/c \times 100 = 0.13$
Total	90.4	11.2 ^d	11.0	

SOIL-PLANT RELATIONSHIP UNDER THE INFLUENCE OF ORGANIC AND CHEMICAL FERTILIZATION IN CONVENTIONAL AND BIOLOGICAL VITICULTURE

A. Șerdinescu and L. Pîrcălabu

Research and Development Institute for Viticulture and Enology
2040-Valea Calugareasca, Prahova District, Romania , E-mail: icvv.vie.vin@xnet.ro

Keywords: mineral nutrition, nutrient leaching, lysimeter, grapevine, cultural system

Introduction

The actual preoccupations concerning the optimisation of the viticultural ecosystem are meant not only to improve the production, its quality and the profit, but also to establish a reasonable use of the ecological resources and to preserve the habitat against pollution. In this context the alternative techniques of culture, and mainly the utilisation of the biological culture methods, help to avoid the inconvenient aspects of a prolonged monoculture, tending to establish a new balance at the level of the component parts of the ecosystem (Cooke, 1988; Fregoni, 1989; Bartolucci, 1992; Condei et al., 2002). The optimisation of the fertilisation solutions in order to achieve an agrochemical optimum that should condition the character of sustainability of all the agrotechnical measures imply a new estimation of the soil-plant relationships under the influence of the combined chemical and organic fertilisation and of the differentiated systems concerning soil maintenance which characterise the conventional or biological systems of grapevine culture (; Condei et al., 1987; Bätz, 1990 ;Sicher and Dorigoni, 1991).

Starting from these concerns, the purpose of the present work is to establish the amplitude of the changes induced by the differentiated systems of soil fertilisation and maintenance in soil-plant relationship, and to establish their impact upon grape yield and its quality.

Material and Method

The research works were carried out under lysimeter conditions in order to estimate as more precisely as possible both the changes induced in soil and plant chemism, and the nutrient losses brought about by practicing differentiated systems of grapevine culture. Four systems of grapevine culture were taken into study:

1. *Ecological culture system*, characterised by:
 - organic and mineral fertilisation with biopost (3 t/ha) and phosphorites (150 kg/ha)
 - soil maintenance by means of perennial weeds on the interval between the rows and mulch on the vine row
2. *Biological culture system*, characterised by:
 - organic culture fertilisation (40 t/ha – manure)
 - soil maintenance by using mulch
3. *Biodynamic culture system*, characterised by:
 - organic and mineral fertilisation with biopost (3 t/ha) and phosphorites (150 kg/ha)
 - soil maintenance by using green fertilisers on the interval between the rows and perennial weeds on the vine row
4. *Conventional culture system*, characterised by:
 - chemical fertilisation with N,P,K (100/50/125 kg active substance/ha)
 - soil maintenance as black furrow

Each culture system was placed in a lysimeter having a capacity of 8 m³ (4x2x1) filled with a reddish-brown soil and planted with 4 vines belonging to Cabernet Sauvignon/Kober 5 BB variety.

The soil explored by the roots was of 2780 kg/vine according to the planting distances of 2.0 x 1.0m. The reddish-brown soil presented the following characteristics: appearing density 1.32 g/cm³, humus 0.74-2.57%; pH 7.5-7.7; P_{AL} 64-72 ppm; K_{AL} 152-176 ppm.

The changes induced by the combined chemical and organic fertilisation in the soil and plant chemism on the background of different soil maintenance systems were achieved by chemical analyses of soil and plant carried out during 4 vegetative phenological stages (flowering, berry setting, veraison, grape maturation).

Both during the growing period (April-September) and during the dormant period, in order to monitor the nutrient losses by leaching, the amounts of drained water were collected and analysed for their content in: NO₃, NH₄, PO₄³⁻K, Ca and Mg. For maintaining an optimum level of soil humidity (50% of IUA), the lysimeters were applied drip-irrigation, any time it was necessary, during the growing season.

The impact on the plants brought about by the modifications induced in the soil chemism was estimated by the grape yield and its quality (sugar, acidity, anthocyanins). The grape yield obtained in each culture system was used for producing wines in a micro scale winery and the quality of those wines was assessed.

Results and Discussion

The application of chemical, organic or of combined organic and mineral fertilisation on the background of different systems of soil maintenance (black furrow, mulch, perennial weeds, green fertilisers) induced a different mobility of the nutrients in the soil-plant system (Table 1).

Table 1: Nutrient mobility in the soil-plant system under the influence of differentiated grapevine culture systems (average of the vegetative phenological stages)

Culture system	Mineral forms in soil (ppm)			Total forms in leaves (%)		
	NO ₃ +NH ₄	P _{AL}	K _{AL}	N	P	K
Ecological	5.1	72.5	182.0	2.11	0.30	0.89
Biological	6.3	71.0	184.0	2.18	0.31	0.91
Biodynamic	6.6	69.5	187.0	2.00	0.29	0.94
Conventional	12.3	79.5	203.0	2.33	0.33	1.05

Considering the rendered data we may notice that nutrient mobility in the soil-plant system was higher in case of nitrogen and potassium, grapevine response to phosphorous fertilisation being less evident.

Grapevine nutrition estimated by the overall nutrition registered higher values in case of the conventional and biological culture systems of grapevine (Table 2).

Table 2: Mineral nutrition of grapevine stems under the influence of differentiated grapevine culture systems (average of the vegetative phenological stages)

Culture system	N %	P %	K %	Overall nutrition (N+P+K) %	Nutrient balance-sheet N:P:K %
Ecological	2.11	0.30	0.89	3.30	63.9:9.1:27.0
Biological	2.18	0.31	0.91	3.40	64.1:9.1:26.8
Biodynamic	2.00	0.29	0.94	3.23	61.9:9.0:29.1
Conventional	2.33	0.33	1.05	3.71	62.8:8.9:28.3

Nitrogen content in the overall nutrition registered higher values in case of the ecological and biological systems of culture, whereas potassium content was higher in case of the biodynamic and conventional culture systems.

The differentiated culture systems that supposed different inputs of nutrients (according to the fertilisation prescription) and a differentiated permeability of the water in accordance with the maintenance soil system induced differentiated nutrient losses by leaching (Table 3). Nutrient losses were calculated in kg/ha.

Table 3: Nutrient losses by leaching according to the grapevine culture systems

a) during the growing season (April-September)

Culture system	Water inputs (rainfalls + irrigation) m ³ /ha	Water outputs m ³ /ha	Nutrient losses (kg/ha)					
			N-NH ₄	N-NO ₃	PO ₄ ³⁻	K	Ca	Mg
Ecological	6360	1753	1.72	46.62	2.07	4.38	295.12	58.53
Biological	6300	2417	1.26	202.30	2.30	6.36	685.84	125.95
Biodynamic	6300	1623	1.13	56.88	2.46	4.77	382.63	97.65
Conventional	6300	1989	0.76	132.40	2.17	3.36	543.54	92.81

b) during the dormant period (October-March)

Culture system	Water inputs (rainfalls) m ³ /ha	Water outputs m ³ /ha	Nutrient losses (kg/ha)					
			N-NH ₄	N-NO ₃	PO ₄ ³⁻	K	Ca	Mg
Ecological	2800	333	0.30	8.99	0.40	0.84	52.02	10.49
Biological	2800	648	0.27	53.35	0.57	1.65	180.01	32.31
Biodynamic	2800	407	0.27	11.58	0.50	0.97	84.13	19.77
Conventional	2800	573	0.24	46.17	0.84	1.19	181.70	30.83

From the rendered data it's noticeable that the greater losses of nutrients by leaching were registered during the growing season of the grapevine when the outputs represented almost 78.5% for nitrogen, 79.6% for phosphorous, 80.2% for potassium, 79.3% for calcium and 80.1% for magnesium, from the whole amount leached during a year.

Whether in case of phosphorous and potassium losses there were not registered great differences between the culture systems (although the inputs had been different from one system to another), in case of nitrogen, the biologic and conventional culture systems which profited by higher rates of organic or chemical nitrogen fertilisation registered the greater losses through leaching.

The quantitative grape yield and its quality differed from one system to another (Table 4).

Table 4: Grape yield and its quality according to different grapevine culture systems

Culture system	Number of grapes/vine	Yield kg/vine	Grape weight	Weight of 100 berries g	Sugars g/l	Acidity g/l	Anthocyanins mg/kg
Ecological	26	1.53	58.8	100	183.6	5.05	1329
Biological	33	1.90	57.6	130	172.1	6.14	937
Biodynamic	31	1.69	54.5	107	191.7	6.14	1583
Conventional	33	2.23	67.6	118	181.5	5.85	1275

Greater yields were obtained in case of the biological and conventional culture system, which benefited from a higher uptake of nutrients and implicitly by a higher nutritional level, while the quality of the yield expressed by the sugar and anthocyanin content was superior in case of the ecologic and biodynamic culture system. The same thing is proved by the quality of the wines obtained (Table 5)

Table 5: Physico-chemical characteristics of the wines

Culture system	Alcohol % vol.	Total acidity g/l H ₂ SO ₄	Extract g/l	Ash g/l	Total polyphenols g/l	Colour intensity g/l	Tint
Ecological	12.0	3.0	30.78	3.10	2.15	7.83	0.772
Biological	11.5	2.8	27.93	2.80	1.75	5.61	0.750
Biodynamic	13.0	3.4	28.90	2.83	2.31	11.80	0.581
Conventional	12.4	2.6	27.66	2.78	2.03	9.31	0.739

When analysing the physico-chemical characteristics of the wines obtained, it becomes quite evident that the biodynamic culture system followed by the conventional one induced the higher quality of the wines, expressed by higher alcoholic strength and colour intensity, and a greater content in total polyphenols.

Conclusions

The differentiated systems of soil fertilisation and maintenance which are characteristic for the conventional or biological viticulture induce differentiated soil-plant relationships reflected in the mineral nutrition level and its quality, and also in the grape yield and wine quality.

The utilisation of combined organic and mineral fertilisation and the soil maintenance systems based on perennial weeds or green fertilisers, having the role of storing the nutrients, decrease nutrient losses through leaching.

Grape yield and wine quality are correlated with the level of the mineral nutrition and of the nutritive balance.

References

- BÄTZ H., 1990 - Concimazione del vigneto e tutela dell'ambiente, *Vignevini*, **3**, 39-42
- BARTOLUCCI R., 1992-Philosophical considerations in converting to organic vineyard production, *American Journal of Enology and Viticulture*, (43), **3**, 294-295
- CONDEI et al., 1987-Abordarea ecologică a sistemului integrat de întreținere și fertilizare a solului în plantațiile viticole, *Buletin ICVV*, **4**, 3-11
- CONDEI et al., 2002-Cercetarea nutriției minerale cu azot, fosfor și potasiu a unor soiuri vinifera, în condiții de lizimetrie, *Proc. "Fertilizarea echilibrată a principalelor culturi în România"* Brașov, 259-267
- FREGONI M., 1989-La viticoltura biologica:basi scientifiche e prospettive, *Vignevini*, **12**, 7-10
- SICHER L., DORIGONIA, 1991- Influenza delle tecniche di gestione del suolo sull'attività-produttiva della vite e sui parametri qualitative del mosto, *CR. IV Simp. Int. di Fiziol. della vite*, S. Michele all'Adige/Torino, 99-102

SPATIAL AND TEMPORAL TRENDS OF ENVIRONMENTAL INDICATORS RELATING TO NITROGEN AND PHOSPHOROUS IN SPAIN

J. Soler-Rovira and J. M. Arroyo-Sanz

Departamento de Producción Vegetal: Fitotecnia, Escuela Universitaria de Ingeniería Técnica Agrícola,
Universidad Politécnica de Madrid, Spain.

Abstract

Temporal trends of some selected indicators have been studied: livestock production and intensive crop production is increasing over long and short-term. Sixteen indicators (twelve descriptive ones and four eco-efficiency indicators) have been selected to explain the variability between provinces using principal component analyses. Some regions show high values of livestock density and N and P loads.

Introduction

During last decades European agriculture has changed in the direction of concentration, intensification and specialisation (EEA, 2001). This pattern of development can be seen in Spanish agriculture. Since 1950, agriculture has reduced its contribution to the Gross Domestic Product and has lost workers (Abad and Naredo, 1997). The loss of work is substituted by investment in mechanisation and external inputs (fertilisers, feeds, fuel, etc.). The use of fertilisers increases since 1940, with a parallel formation of a national industry of fertilisers that enable to produce the inner consumption. All livestock production sub-sectors showed a specialisation (division between meat, milk and eggs production), intensification (yield per animal and farm size) and spatial concentration, near to big market centres (Soria and Rodríguez-Zúñiga, 1989). The utilisation of feeds from the outside of the farm and/or the country (maize and soybean) increased and farmers got integrated into the feed industry. The use of land has also changed. The historical irrigated land (ca. 10^6 ha) has been multiplied by a factor of three since 1940 with new irrigation schemes by public promotion (mainly in the inner river basins) and by private initiative (with wells and groundwater use) (MAPA, 2003). These driving forces have carried environmental pressures, as nutrient loads to the water and the atmosphere, with the concurrent deterioration in the quality of the environment.

Environmental indicators

Environmental indicators provide information about phenomena that are regarded typical for and/or critical to environmental quality (EEA, 1999). Indicators are studied within the framework DPSIR (Driving forces, Pressures, State, Impact and Response). Social and economic activities (e.g. agriculture and livestock production) are driving forces that cause

pressure (e.g. manure produced and nutrient surpluses and loads) on the environment and, as a consequence, the state (quality) of the environment changes (e.g. water pollution and eutrophication). This leads to impacts on human health and ecosystems that may elicit a response from society and policy makers. Eco-efficiency improves with less pressure coming from more driving forces. Indicators can be classified as: descriptive, performance and efficiency indicators. Descriptive indicators are those based in the DPSIR-framework. Performance indicators compare actual conditions with specific set of reference conditions (desired situation or target). For nitrogen, there is a target value of 170-210 kgN/ha as limit value for the rate of N in animal manure applied to land in designated vulnerable zones. Efficiency indicators relate environmental pressures to human activities, in terms of emissions and waste generated per unit of desired output.

Materials and Methods

Several statistical sources have been used, as Ministry of Agriculture, Fisheries and Food (MAPA, 1994, 1996 and 2001a) that include data for land use, crops, livestock, inputs and economy. The National Institute of Statistics (INE) makes the Agricultural Census (INE, 2003) and, among others, provide data about environment (INE, 2002b) and economics (INE, 2002a). Asociación Nacional de Fabricantes de Fertilizantes (ANFFE, 2001) provide fertiliser production and use data. OECD provides data about nitrogen balance (OECD, 2001).

Two sets of indicators have been studied. One set for the whole country is shown in Table 2. These 56 indicators can be classified as descriptive indicators of livestock production, agricultural production, emissions and nitrogen balance. Another group of indicators is about eco-efficiency, that has been calculated in relation to agricultural production value (constant prices of 1990) and agricultural works units. These indicators have been studied over two time series (Table 2), to test their sensitivity to changes over time. The time series starts in 1985 (one year before the incorporation of Spain to the EU) and 1992 (CAP reform). The trend has been studied by regression analyses of indicators over time, and its determination coefficient at a 90% error level. The second set of indicators has been chosen for the spatial scale of province. Three groups have been calculated: Livestock production, crop production and eco-efficiency (see Table 1). The 41 variables of the 50 provinces of Spain for livestock production have been studied by principal component analyses (PCA), and eight indicators has been selected as the ones with the higher correlation with the two principal axes (62.3% of variance absorption). From the PCA have been selected seven indicators (69.9 % of variance absorption by the two first axes) for crop production and four indicators for eco-efficiency indicators (88.8 % of

variance absorption). This preliminary set of 19 (8+7+4) indicators for each provinces have been studied by PCA, using STATITCF software.

Table 1: Set of indicators calculated for the study of spatial trends.

<u>Livestock production (41 indicators)</u> - Cattle, sheep+goats, pigs, poultry and total species livestock units and density per UAA. - Nitrogen and phosphorous excreted using excretion factors of Codes of Good Agricultural Practices (Soler-Rovira <i>et al.</i>, 2001). Organic N and P per utilised agricultural area. - Cattle, sheep, pigs and poultry LU's per farm (with land, landless and total).
<u>Crop production (18 indicators)</u> - Irrigated land area and per UAA. Horticultural crops area. - Irrigated field crops, fruit trees, horticultural crops, fruits plus horticultural, and protected crops area as percentage of irrigated land. - Mineral N and P use total, per UAA and per fertilised area (UAA minus fallow). - Use of total (organic+mineral) N and P per UAA and per fertilised area.
<u>Eco-efficiency (12 indicators)</u> - Mineral, organic and total N and P (per UAA) per agricultural working unit. - Mineral, organic and total N and P (per UAA) per agricultural gross added value at market prices.

Results and discussion

Temporal trends

An overview of the trend of indicators is presented in Table 2. The total number of cattle and pig heads have had a significant upward trend in a short and long-term. An intensification process has taken place for all species, because the number of holdings has decreased between 1989 and 1999 and the number of heads per holding has increased (Table 3). An upward trend in the short and long-term is shown by the number of slaughtered cattle, pigs and poultry and also beef, pork and chicken meat production. The animals are fattened in intensive rearing farms, with purchased feeds, due to the lack of good climatic conditions for grass production (Massot, 1996). Dairy cows has been replaced by meat production cows, because the application of the milk quota in 1992, but an intensification is shown by the increasing yield of milk per cow and per farm (MAPA, 2001b). The number of lying hens and egg production show a downward trend in the long-term, but in the last years the trend is zero, due to the decrease in egg consumption (Buxadé, 2000). The eggs yield per hen has increased in the long-term, but it has reached a maximum. The value of feeds used as inputs in livestock system has increased in the short term (constant prices), so feed inputs account for 45.6% of final livestock production value. The integration of farmers into feed industry is very characteristic (Soria and Rodríguez-Zúñiga, 1989). The increase in livestock number has implied an upward significant trend of manure produce in a short and long-term. Nitrogen inputs in manure in Spanish

agriculture has also increased in the long-term. For EU-15 a decreasing trend is reported. In the short-term the trend is zero for total amount of input, as it is reported for the EU (De Clercq *et al.*, 2001).

Table 2: Temporal trend of the indicators. (+) indicates a significant upward trend, (-) indicates a significant downward trend and (0) indicates that a trend is not significant at a 90% error level.

Indicator	Long-term	Time series	Short-term (from 1992)	Variation (%) in the long-term
Livestock heads number ^a	+	1985-2000	+	See Table 3
Dairy cows	-	1985-1998	-	-31.5
Milk production	0	1985-1998	0	-3.3
Milk yield per cow	+	1985-1998	+	+41.2
Slaughtered animals and meat ^b	+	1985-2000	+	(^b)
Sheep heads number, slaughtered animals and meat	+	1985-1999	0	+47.0, +33.5, +15.0
Lying hens number and egg production	-	1985-1998	0	-15.2, -12.2
Eggs yield per hen	+	1985-1998	0	+3.5
Feeds value (constant prices)	no data	1992-1996	+	+11.7
Manure produced	+	1985-1998	+	+29.5
Irrigated land	+	1985-1998	+	+11.9
Protected crops area	no data	1992-1998	+	+30.8
N mineral from fertilisers total and per ha	0	1987-2000	+	+24.0, +21.7
P mineral from fertilisers total	0	1987-2000	+	+10.0
P mineral from fertilisers per ha	+	1987-1998	+	+38.6
Maize, sugarbeet, tomato and melon yield	+	1985-2000	+	+41.3, +71.8, +48.5, +91.6
Orange tree yield	+	1985-1999	0	+22.1
Gaseous emissions of NH ₃ , N ₂ O, NO _x	no data	1995-1998	0	+11.2, +16.0, +4.3
N surplus total and per ha	0	1985-1997	+	+20.8, +26.5
N inputs total and per ha	0	1985-1997	+	+9.4, +14.6
N inputs in manure total	+	1985-1997	0	+21.2
N inputs in manure per ha	+	1985-1997	+	+26.9
N outputs total and per ha	0	1985-1997	0	-3.4, +1.1
N efficiency (Noutputs/Ninputs)	0	1985-1997	0	-11.7
N discharge (Nsurplus/Noutputs)	0	1985-1997	0	+25.0
N or P mineral per Plant Production Value	no data	1992-2000	0	+15.0, +3.3
Manure per Livestock Production Value	no data	1992-1999	0	-7.0
N surplus per Plant or Agricultural Prod. Value	no data	1992-1998	0	+2.5, +1.6
N,P mineral or N surplus per Agric. Work Unit	no data	1992-1997	+	+18.5, +25.3, +7.0

(^a) The indicator has the same trend for cattle (total, < 12 months, > 12 months) and pigs (total, 20-40 kg live weight, fattened, reproductive females).

(^b) Slaughtered cattle (+34%), beef meat (+58%), slaughtered pigs (+87%), pork meat (+110%), slaughtered poultry (+27%) and chicken meat (+21%).

Table 3: Percentage of variation (1989-1999) of number of heads, farms and animals per farm.

Livestock	Heads	Farms	Heads/Farm
Cattle	32.5	-40.1	113.3
Sheep	19.4	-17.0	44.5
Poultry	54.0	-36.9	144.5
Pigs	84.7	-42.0	215.6

Irrigated land area has increased significantly, although during the decades of 1980-90 public investments in irrigation schemes have decreased (MAPA, 2003). Crop yields show an increasing trend in both time series, due to the more intensive use of inputs, the use of new cultivars, the improvement of irrigation and crop protection and the increase of horticultural crops in greenhouses and plastic tunnels (Caballero *et al.*, 1992). Mineral fertiliser utilisation (N and P) does not show an increasing trend in the long-term (only as P per ha). However, the trend in the short-term is increasing, because during 1992-93 the drought and the uncertainty about the CAP reform forced farmers to reduce fertilisation (Sumpsi, 1996; Ruano *et al.*, 1998). A downward trend is reported to EU, but in the short term shows an increasing trend (De Clercq *et al.*, 2001). N inputs (total and per ha) of the OECD's nitrogen balance shows the same pattern as N mineral. Nitrogen gaseous emissions from agricultural sources show a slightly upward trend, but it is non-significant. Ammonia emissions from agriculture account for 95% of total ammonia emissions, nitrous oxide (N₂O) for 9,4% and NO_x for 0,01%. Nitrogen surplus (total and per ha) is stable in the long-term, but shows an increasing trend in the last years. This pattern is similar to N mineral use, with a high reduction of both inputs and outputs during the dry years of 1992 to 1993, and the afterwards upward trend until 1997. Variation of N surplus is explained by variation of N inputs ($r^2=0,63$). In most of the European countries the long-term trend shows that the surplus is decreasing, as in EU-15 as a whole, but in last years it is stable (De Clercq *et al.*, 2001). The trend of the ratio of N outputs and inputs (N efficiency) and N surplus and outputs (discharge index) is zero.

The eco-efficiency of production value (in constant prices of 1990) has a trend of zero in the short-term, because the use of fertilisers, surplus and manure increase as does the value of the Plant production, so the ratio is stable. The eco-efficiency of work is decreasing because the number of work units are stable in time and N mineral, P mineral and N surplus increase, so does the ratio.

Spatial trends

The results of the PCA for the selected 19 indicators is shown in Table 4. The first axis is highly correlated with eight indicators that describe the livestock production (total species (LUt), pigs (LU_p) and poultry (LU_{po}) livestock density) and total and organic N (N_t and N_o) and P (P_t and P_o) per UAA. The second axis is correlated with five indicators that describe crop production (irrigated land (ILA), horticultural crops area (HCA) and mineral N (N_m) and P (P_m) use in agriculture) and one indicator about cattle livestock density (LU_c). The third axis is negatively correlated with eco-efficiency indicators (total N and P per unit of agricultural work (AWU)

and gross added value at market prices (GAV)). These 16 indicators will explain with good agreement the differences between provinces, relating to nutrient management. The Figure 1 shows the distribution of the 50 observations (provinces) in the plane generated with the projection of the two first axes. The provinces situated in the right part of the plane show higher values of indicators positively correlated with the first axis (Table 4). Provinces of Galicia region (in the Northwest of Spain) show high values of these indicators. In Pontevedra it is exceeded the target value of 170 kgN/ha, and also in La Coruña, Orense and Pontevedra province is exceeded the target value of 22 kgP/ha dictated in Sweden (Steineck *et al.*, 2001). In relation to the second axis this region is situated in the lower part of the plane because the high cattle livestock density and also high proportion of irrigated horticultural crops (in this wet zone of Spain horticultural crops occupy a great proportion of irrigated land). This is true for the other provinces of the wet North (Asturias, Cantabria, Guipúzcoa and Vizcaya), as in the wet North and Northwest regions it is located the main proportion of dairy production (MAPA, 2001b). In regard of first axis they are located in an intermediate zone.

Cataluña region (Barcelona, Gerona, Lérida and Tarragona, located in the Northeast) shows also high values of indicators: total livestock density, pig and poultry livestock densities and the subsequent production of organic N and P. Barcelona, Gerona and Lérida exceed the target value of 22kgP/ha. This indicates that, although at country scale Spain has low values of P loads, there are six provinces that exceed 22 kgP/ha, because the spatial concentration of livestock production (Massot, 1996). In relation to the second axis Tarragona is located in the upper part of the plane because the high value in this province of the proportion of irrigated land and the high use of mineral fertilisers. Barcelona has a high proportion of irrigated horticultural crops. Canarias islands are also located in the right part of the plane because the high value of total N and P, mainly as mineral N and P. Valencia Region (in the East of Spain) is located in the right part of the plane, mostly Castellón province, due to the relative high pig and poultry livestock density, and Valencia because the high value of mineral N and P use (the position in the upper part of the plane can be explained by the high proportion of irrigated land in this province). Another interesting points in the plane are represented by: La Rioja (with a high value of mineral P use), Murcia (high values of irrigated land, horticultural crops and mineral N use), Almería (high proportion of irrigated horticultural crops). In the left part of the plane are located some provinces (in the West, Centre and South) with low values of indicators: Cáceres (Extremadura), Ciudad Real (Castilla-La Mancha), Jaén (Andalucía) and Toledo (Castilla-La Mancha).

The third axis defines the eco-efficiency of N and P. The points are located in the upper part of the plane (not shown) have a higher eco-efficiency, and the opposite is true for those in the lower part. Gerona, Álava, Soria and Segovia show the worst eco-efficiency.

Table 4: Indicators correlated with each axis of the PCA (r: correlation coefficient).

Axis 1 (42.1% of variance)		Axis 2 (21.9% of variance)		Axis 3 (13.6% of variance)	
Indicator	r	Indicator	r	Indicator	r
Pt/UAA	+0.94	LUc/UAA	-0.78	Nt/UAA/AWU	-0.67
Nt/UAA	+0.93	ILA/UAA	+0.70	Pt/UAA/AWU	-0.65
Po/UAA	+0.86	HCA/ILA	-0.68	Nt/UAA/GAV	-0.54
LUt/UAA	+0.82	Nm/UAA	+0.66	Pt/UAA/GAV	-0.52
No/UAA	+0.82	Pm/UAA	+0.63		
LUpo/UAA	+0.77				
LUp/UAA	+0.72				

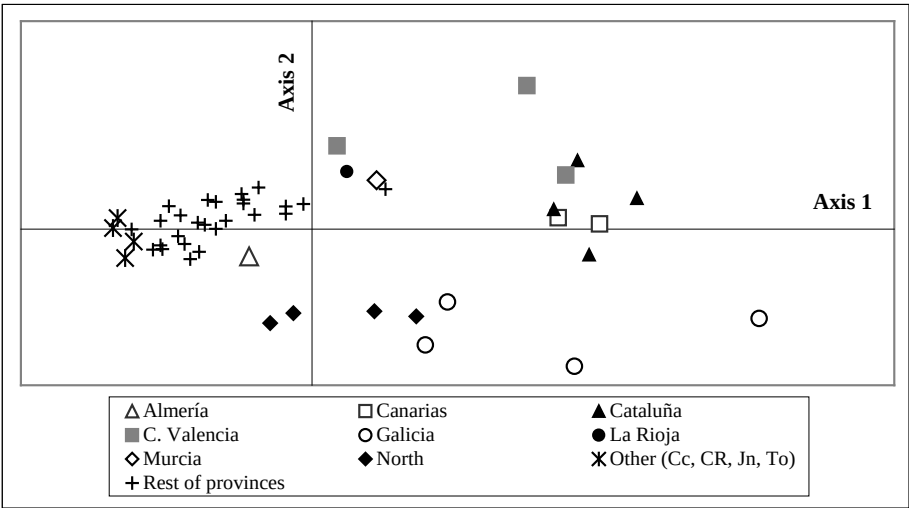


Figure 1: Representation of Spanish provinces on the plane generated by the two first principal axes.

Conclusions

There is a significant upward trend in indicator related to livestock production (mainly meat production), concentrated feed use and manure production. Also an increasing trend is obtained for intensity of crop production indicators: irrigated land, protected crops area and crop yields. There is a no clear trend for fertilisers’ use, gaseous emissions and nitrogen surplus. Eco-efficiency indicators show and stable trend for value indicators and a reduction of the eco-efficiency of agricultural work. Sixteen indicators have been selected (twelve descriptive ones and four eco-efficiency indicators) (see Table 4). These indicators explain the situation

(livestock production, crop production and eco-efficiency) of certain provinces (Galicia, Cataluña, Valencia and Canarias Regions). In one province (Pontevedra) the target value of 170 kgN/ha is exceeded. In six provinces is exceeded the target value of 22 kgP/ha. The relative low values of N and P use and production at a national level can be very high at a province level, due to the inequity of livestock distribution and fertiliser use. This work on nutrient management should be completed with future works about identification and selection of other indicators relating to state of the environment, impact and response, and their relation with those selected in this work. This analysis should be also expanded to other spatial scales: districts, municipalities and farms. Thus, the study of the complex relationships between agriculture and environment should be completed.

References

- Abad, C., Naredo, J.M. (1997). Sobre la Modernización de la Agricultura Española (1940-1995). In: Gómez-Benito, C., González, J.J. (eds). *Agricultura y Sociedad en la España Contemporánea*. CIS, Madrid, pp: 249-316.
- ANFFE (2001). *Desarrollo del Mercado de los Fertilizantes en España*. ANFFE.
- Buxadé, C. (2000). La Importancia de Avicultura de Puesta en España. In: Buxadé, C. (ed). *La Gallina Ponedora*. Mundi-Prensa, Madrid, pp: 71-124.
- Caballero, P., De Miguel, M.D., Julia, J.F. (1992). *Costes y Precios en Hortofruticultura*. Mundi-Prensa, Madrid, 761 pp.
- De Clercq, P., Gertsis, A.C., Hofman, G., Jarvis, S.C., Neeteson, J.J., Sinabell, F. (2001). Discussion and Conclusions. In: De Clercq, P., Gertsis, A.C., Hofman, G., Jarvis, S.C., Neeteson, J.J., Sinabell, F. (eds). *Nutrient Management Legislation in European Countries*. Department of Soil Management and Soil Care, Wageningen Pers, The Netherlands, pp: 307-324.
- EEA (1999). *Environmental Indicators: Typology and Overview*. European Environment Agency, Denmark, 19 pp.
- EEA (2001). *Environmental Signals 2001*. European Environment Agency, Denmark, 113 pp.
- INE(2002a). Base 1995. Serie Contable 1995-2000. Tablas de Origen y de Destino 1997. INE.
- INE (2002b). *Estadísticas de Medio Ambiente. Cuentas Medioambientales*. INE, Madrid, 139 pp.
- INE (2003). *Censo Agrario 1999*. At <http://www.ine.es>.
- MAPA (1994). *Anuario de Estadística Agraria 1992*. MAPA, Madrid, 679 pp.
- MAPA (1996). *Anuario de Estadística Agraria 1994*. MAPA, Madrid, 710 pp.
- MAPA (2001a). *Anuario de Estadística Agroalimentaria 2000*. MAPA, Madrid, 699 pp.
- MAPA (2001b). *Evolución y Perspectivas del Sector Lácteo*. Secretaría General de Agricultura, Dirección General de Ganadería, 30 pp.
- MAPA (2003). *Plan Nacional de Regadíos*. MAPA. At <http://www.mapya.es>
- Massot, A. (1996). Carne y Huevos. In: Sumpsi, J.M., Barceló, L.V. (eds). *La Ronda Uruguay y el Sector Agroalimentario Español*. MAPA, Madrid, pp: 367-486.
- OECD (2001). *Nitrogen balance database*. At www.oecd.org/agr/env/indicators.htm.
- Ruano, S., López, L.A., Soler-Rovira, J., Cadahía, C. (1998). Situación Actual de la Fertilización. In: Cadahía, C. (ed). *Fertirrigación*. Mundi-Prensa, Madrid, pp:25-62.
- Soler-Rovira, J., Soler-Rovira, P., Soler-Soler, J. (2001). Environmental Pressures and National Environmental Legislation with respect to Nutrient Management: España. In: De Clercq, P., Gertsis, A.C., Hofman, G., Jarvis, S.C., Neeteson, J.J., Sinabell, F. (eds). *Nutrient Management Legislation in European Countries*. Department of Soil Management and Soil Care, Wageningen Pers, The Netherlands, pp: 114-137.
- Soria, R., Rodríguez-Zúñiga, M. (1989). El Sector Ganadero. In: San Juan, C. (ed). *La Modernización de la Agricultura Española (1956-1986)*. MAPA, Madrid, pp: 313-335.
- Steineck, S., Jakobsson, C., Akerhielm, H., Carlson, G. (2001). Environmental Pressures and National Environmental Legislation with respect to Nutrient Management: Sweden. In: De Clercq, P., Gertsis, A.C., Hofman, G., Jarvis, S.C., Neeteson, J.J., Sinabell, F. (eds). *Nutrient Management Legislation in European Countries*. Department of Soil Management and Soil Care, Wageningen Pers, The Netherlands, pp: 250-265.
- Sumpsi, J.M. (1996). Fertilizantes. In: Sumpsi, J.M., Barceló, L.V. (eds). *La Ronda Uruguay y el Sector Agroalimentario Español*. MAPA, Madrid, pp: 594-629.

DEVELOPMENT OF ENVIRONMENTAL FARM GATE NUTRIENT BALANCES IN MIXED FARMS

P. Urfi, K. Sárdi, P. Polgár, Zs. Bacsí and T. Somogyi

University of Veszprém, Georgikon Faculty of Agriculture, Keszthely, Hungary

Introduction

The farm level application of environmental balances has been extensively used in the last 15 years (*Kanning, 2001*). Several varieties of these balances are known, but all of them focus on the quantification of matter and energy exchange taking place between the farm and its environment. The balances may be built for the whole farm, for specific production processes, or products (*Henseler et al., 1995, Kósi, 1997, Letmathe, 1998*). The whole-farm level balance compares the inputs of matter and energy to the outputs of these two for the whole farm as a „black box”. However, when applying process balances - as *Michaelis (1999)* uses the expression – the „black box” approach of the transformation processes taking place in the farm is abandoned, contrasting the incoming matter and energy amounts to those leaving the farm.

The most widely used version of farm nutrient balances, the “farm gate balance”, is a typical farm balance based on the “black box” principle. Differently from traditional soil nutrient balances which compare amounts of nutrients entering and leaving the soil, the concept of farm level nutrient balance focuses on nutrients getting into the farming unit (farm, enterprise) within purchased inputs and those leaving it in sold products (or in other ways) (*Isermann, 1993, Halberg et al., 1995, Breembroek et al., 1996, Doluschitz & Pape, 1998, Oenema, 1999*). Nutrient surpluses computed as the difference between the two are usually considered by the concept of „farm gate balance” as nutrient accumulation or loss. For this difference, a limit value can be defined for each nutrient, which can be taken as environmentally tolerable, that is, not requiring any change in the practice, nor leading to sanctions.

The „farm gate balance” will provide reliable information for the environmental assessment of the farm business when no considerable changes take place either in the purchased stock or in the home produced one. A significant proportion of the nutrient accumulation or extraction reflected by the „black box” approach, however, is really contained in the changes of the unsold stocks of the business, therefore causing uncertainty in the interpretation of the farm balance. Therefore, a more refined approach was applied in our case studies, which is really a combination of the farm gate balance and the process balance. Beside the “farm gate balance” (external balance), an internal nutrient balance was also calculated in which nutrient inputs used in the production process were compared to nutrient amounts taken up with the annual yields

(outputs). In the case studies of mixed farms, farm nutrient balances were divided into two separate balances of the crop enterprise and the animal enterprise, and internal nutrient flows between crop production and animal husbandry were also surveyed.

Material and Method

The objective of our study was to set up farm nutrient balances for nitrogen and phosphorus nutrients relying on data originating from farms having rather different production structures. The six farms selected from Western Hungary providing the data can be grouped into the following four types:

- I. farms specialised on arable crop production (three farms, 250 to 300 ha of land each),
- II. turkey fattening enterprise without arable farmland (one farm),
- III. combination of dairy and crop production enterprise (one farm, approx. 1300 ha of land),
- IV. combination of pig fattening and crop production enterprises (one farm, approx. 2000 ha of land).

The data collection was mainly based on the records kept within the traditional accounting system, therefore, the nutrient flows were followed by the „logic” of accounting. Following this way of thinking the external nutrient exchange is the nutrient flow created by the purchase of material and animal stocks, or the sale of them, while the internal nutrient exchange means the nutrient flows between the materials present in the inventories and the production processes. Thus the quantitative data of the inventory changes (such as purchases, sales, utilisation, yields of animal or crop production) were collected from the analytic inventory records for all stock items containing the nutrients studied in the research. Preliminary research helped us to identify stock items containing the studied nutrients but in extremely low amounts. These stock items were not taken into account in the further analysis. For this reason herbicides and pesticides were not included in the present study. For the case of the mixed farms dealing with animal husbandry and crop production the inventories of purchased materials were divided into inventories for these two enterprises. This division is naturally not present in the accounting records but it was necessary to facilitate the analysis of external nutrient connections of the animal and crop enterprises.

The respective nutrient contents of the various materials (e.g. crop yields, fodders, fertilisers, manures, livestock, animal produces, etc.) are attached to the quantities of these materials given

by the analytic records according to the form of the change, relying on the studies by *Kakuk & Schmidt (1988 a and b)*, *Füleký (1999)*, *Kádár et al. (1981)*, *Kádár (1992)*, *Horn (1976)*, *Sarkadi (1979)* and research results by *Katalin Sárdi*. Then the following values were computed:

- The **external nutrient balance (ENB)** is the difference of nutrients entering the farm with purchased material (P) and leaving it with sold stocks (S, including perished animals):
 $ENB = P - S$.
- The **internal nutrient balance (INB)** is the difference of nutrients leaving the farm with the yields or outputs (Y), and nutrients utilised (U) by or placed into the production processes ($INB = Y - U$).
- The **stock change (SC)** is the difference of nutrients of closing balance and opening balance of the inventories, and is the same as the sum of external and internal nutrient balances ($SC = ENB + INB$).

The balances of the main farming enterprises can be defined in a similar way to those of the „whole farm balances”. For example:

- The *external nutrient balance of the crop production enterprise* (ENBC) is the difference of nutrients entering the farm with purchased material to be used for crop production, and leaving it with the yields of the crop enterprise.
- The *internal nutrient balance of the crop enterprise* (INBC) is the difference of nutrients leaving the farm with the yields of crop production (YC), and nutrients utilised (UC) by or taken into the crop production processes ($INBC = YC - UC$).

In the following analysis all the data presented refers to the year 2001. The farms analysed are denoted by the following numbers:

- I. one of the three crop production farms (very similar results were obtained by all the three crop production farms, so it is sufficient to present only one of them here);
- II. the turkey fattening farm;
- III. mixed dairy and crop production farm;
- IV. mixed pig and crop production farm.

In the presentation of results the following notations are also used:

C: crop production

A: animal husbandry

Results and Discussion

The nitrogen balances for the four above enterprises are shown in *Table 1*. Each of the farms I. and II. are rather small sized, with specialised businesses. They purchased their inputs (fertilisers, fodders) directly before using them and they sold all of their produces by the end of the year. The opening and closing inventories were empty and inventory management was not taken into consideration. They used up all the purchased materials and they sold all the produced amounts. Thus the internal and the external nutrient balances were equal and the stock changes were zero for these farms. Nutrient linkages between crop enterprises and animal enterprises were negligible for them as farm I deals entirely with crops and farm II with animal husbandry.

Therefore, in the case of farm I, the external nutrient balance of the crop enterprise is equal to the external nutrient balance, thus the internal nutrient balance of the „whole farm”. The balance is positive, and due to the intensive replacement of nutrients resulted in a nitrogen input of nearly 28 tons more in the farm – and in the crop production processes – than the amount extracted by the production process and out of the farm. A similarly high level of positive nutrient balance can be found in the case of farm II where the external nutrient balance of the animal enterprise is equal to the external and the internal nutrient balance of the whole farm. The large amount (35 tons) of nutrient accumulation deserves some consideration here, because the farm does not have any land, so this quantity of nitrogen is to be considered entirely as loss.

Farms III and IV are both mixed farms with crop and animal enterprises, so the nutrient linkages between these two enterprises are meaningful for both of them. Each of them carries out extensive inventory management activities, so the external and the internal nutrient balances are different. Both of the farms purchase large quantities of nitrogen fertilisers, while the replacement of phosphorus is neglectable for both of them. In the case of farm III, the role of animal husbandry in the utilisation of nutrients is much larger than in the case of farm IV.

Table 1: Nitrogen balances for the studied farms (kg N)

Item	ENB		INB		Total		
	C	A	C	A	ENB	INB	SC
Farm I.							
Crop products	-17206		-17206		-17206	-17206	0
Seed	68		68		68	68	0
Fertiliser	44698		44698		44698	44698	0
Total	27560		27560		27560	27560	0
Farm II.							
Animals, animal products		-11035		-11035	11035	11035	0
Manure		-10080		-10080	-10080	-10080	0
Fodder, straw		56415		56415	56415	56415	0
Total		35300		35300	35300	35300	0
Farm III.							
Animals, animal products		-19704	0	-19272	-19704	-19272	-432
Manure		-1049	2811	-4936	-1049	-2125	1076
Fodder, straw		34636	-225148	247503	34636	22355	12281
Cash crops	-91897		-107820	0	-91897	-107820	15923
Seed	1430		1438	0	1430	1438	-8
Fertiliser	185456		185456	0	185456	185456	0
Total	94989	13883	-143263	223295	108872	80032	28840
Farm IV.							
Animals, animal products		-3758	0	-3859	-3758	-3859	101
Manure		0	12	-131	0	-119	119
Fodder, straw		8208	-12077	20460	8208	8383	-175
Cash crops	-174956		-185195	0	-174956	-185195	10238
Seed	1689		1713	0	1689	1713	-24
Fertiliser	158737		168865	0	158737	168865	-10128
Total	-14530	4450	-26682	16470	-10080	-10212	132

The „whole farm” external nutrient balance for farm III (that is, the „farm gate balance”) is positive, with 109 tons more nitrogen entering the farm than leaving it. The external balance for the animal enterprise and that of the crop enterprise are also positive, mainly because of the nitrogen fertilisers and fodders purchased. Although the external balance is 109 tons, the internal nutrient accumulation is much less, because, as it is shown by the internal nutrient balance, 80 tons more nitrogen is utilised in the production processes than the amount leaving them with the yields. The difference of the external and the internal balances is found in the increased inventory levels (mainly in the fodder and the cash crops). It is remarkable, that both the crop enterprise and the animal enterprise influenced the internal nutrient balance significantly, but in a different direction. The crop enterprise extracted 143 tons more nitrogen from the production process than the amount placed into it. Just the contrary, the animal enterprise utilised only 10 percent of the nitrogen placed into the production process, leaving a substantial positive internal nutrient balance (223 tons).

In the case of farm III. 225 tons of nitrogen was moved from crop production into animal husbandry with fodder and straw, where it is utilised much less efficiently than in the crop enterprise. Animal husbandry transferred only 3 tons of nitrogen back to crop production with manure. This means that ruthless exploitation of the natural resources is typical in crop production, hardly more than half of the extracted nitrogen is replaced, while the internal nutrient balance shows substantial nutrient accumulation due to the high levels and low efficiencies of nutrient utilisation in animal husbandry.

For farm IV both the external and the internal nutrient balances are negative for nitrogen. In the crop enterprise, the external and the internal balances are also negative, while both the external and the internal balances of the animal enterprise are positive. However, while in the case of farm III, 68 % of the nitrogen content of crop yields was used by the animal enterprise, the same value is only 7 % for farm IV. This means that the majority of the nitrogen content of crop yields does not enter the rather wasteful animal production processes, but leaves the farm in the form of cash crops. This is the main explanation for the negative external and internal nutrient balances in spite of the fact that for this farm the proportion of nitrogen replacement in the crop enterprise is higher (86%) than for farm III.

Table 2 describes the phosphorus balances for the four farms. In the case of farms I and II, the phosphorus balances are similar to the nitrogen balances discussed above. Positive balances are due to the intensive replacement of phosphorus in farm I, and to the lower efficiency of utilisation in animal husbandry in farm II.

While assessing the phosphorus balances of farm III, similarities and differences to the nitrogen balances may be identified. In the case of phosphorus, not only the internal balance of crop production is negative, but the external balance, too. This result reflects the typical, biased nitrogen-oriented practice of nutrient management practices used in Hungary in the last decade, The extraction of phosphorus in crop production significantly decreased the positive external balance of animal husbandry and completely absorbed its positive internal balance. The impact of this biased practice of nutrient management is more obviously demonstrated in the phosphorus balance of farm IV. The reason for this is that the crop yields are transferred to the animal enterprise to a less extent, and because practically no phosphorus replacement took place in the crop enterprise. As a result of this approximately 80 % of the phosphorus extracted from the soil leaves the farm with the sold products.

Table 2: Phosphorus balances in the studies farms (kg P)

Item	ENB		INB		Total		
	C	A	C	A	ENB	INB	SC
Farm I.							
Crop products	-2821		-2821		-2821	-2821	0
Seed	13		13		13	13	0
Fertiliser	5087		5087		5087	5087	0
Total	2279		2279		2279	2279	0
Farm II.							
Animals, animal products		-3481		-3480	-3481	-3481	0
Manure		-8280		-8280	-8280	-8280	0
Fodder, straw		13891		13891	13891	13891	0
Total		2130		2130	2130	2130	0
Farm III.							
Animals, animal products		-2898	0	-2876	-2898	-2876	-22
Manure		-187	502	-881	-187	-379	192
Fodder, straw		11348	-37657	47645	11348	9988	1360
Cash crops	-14569		-16632	0	-14569	-16632	2063
Seed	207		208	0	207	208	-1
Fertiliser	7553		7553	0	7553	7553	0
Total	-6809	8263	-46026	43888	1454	-2138	3592
Farm IV.							
Animals, animal products		-251	0	-257	-251	-257	6
Manure		0	3	-37	0	-34	34
Fodder, straw		1709	-2347	4093	1709	1746	-37
Cash crops	-27596		-29076	0	-27596	-29076	1480
Seed	306		313	0	306	313	-7
Fertiliser	0		0	0	0	0	0
Total	-27290	1458	-31107	3799	-25832	-27308	1476

As a summary to the above analysis it may be stated that the differences of the results are well explained by the different production structures, and the different efficiencies of nutrient utilisation of animal and crop production. The research has also lead to two important methodological conclusions. The first is that the concept of “farm gate balance” in itself is not sufficient for the environmental assessment of nutrient management in Hungary, because there are many large mixed farms which have extensive inventory management activities. Secondly, although the internal nutrient balance is more suitable from this respect, more attention is to be paid to minimize the miscalculations due to “hidden stock changes” (inaccuracy of assessing organic manure, mass increases of breeding animal stocks not accounted for in the records, etc.).

Acknowledgment

The authors gratefully acknowledge the support of the National Scientific Research Fund provided for the project No. **OTKA 034370**.

References

- Breembroek, J. A., Koole, B., Poppe, K. J., Wossink, G. A. A. (1996): Environmental Farm Accounting: The Case of the Dutch Nutrients Accounting System. *Agricultural Systems*. 51. 1. 29-40.
- Doluschitz, R., Pape, J. (1998): Hoftorbilanzen als Grundlage des Agrar-Öko-Audits. In: Spindler, E. A. (Hrsg.), *Agrar-Öko-Audit*. Springer, Berlin – Heidelberg. 385-399.
- Fülek Gy. szerk. (1999): Tápanyag-gazdálkodás. Mezőgazda Kiadó, Budapest.
- Halberg, N., Kristensen, E. S., Kristensen, I. S. (1995): Nitrogen turnover on organic and conventional mixed farms. *Journal of Agriculture and Environmental Ethics*. 8. 30-51.
- Henseler, G., Bader, H. P., Oehler, D., Scheidegger, R., Baccini, P. (1995): Methode und Anwendung der betrieblichen Stoffbuchhaltung. Hochschulverlag AG an der ETH Zürich.
- Horn A. szerk. (1976): Állattenyésztés. Első kötet. Mezőgazdasági Kiadó, Budapest.
- Isermann, K. (1993): Nährstoffbilanzen und aktuelle Nährstoffversorgung der Böden. *Berichte über Landwirtschaft*. 207. Sonderheft. 15-54.
- Kádár I. – Lásztity B. – Simon L. (1981): Az üzemi talaj- és növényvizsgálati eredmények értelmezése és felhasználása mezőföldi csernozjom talajon. *Agrokémia és Talajtan*. 30. 1-2. 65-76.
- Kádár I. (1992): A növénytáplálás alapelvei és módszerei. MTA Talajtani és Agrokémiai Kutatóintézete, Budapest.
- Kakuk T. – Schmidt J. (1988a): Takarmányozástan. Mezőgazdasági Kiadó, Budapest.
- Kakuk T. – Schmidt J. szerk. (1988b): Takarmányozási táblázatok. Mezőgazdasági Kiadó, Budapest.
- Kanning, H. (2001): 7.3. Umweltbilanzmethoden. In: Scholles, F. (Hrsg.): *Gesellschaftswissenschaftliche Grundlagen*. Universität Hannover. www.ilrs1.laum.uni-hannover.de/ilr/lehre/Ptm/Ptm2.htm
- Kósi K. (1997): 2. A vállalati környezeti menedzsment rendszer. In: Kósi K. et al.: *Auditálás, menedzsment rendszerek*. Közgazdasági és Jogi Könyvkiadó, Budapest. 24-40.
- Letmathe, P. (1998): Umweltbezogene Kostenrechnung. Vahlen, München.
- Michaelis, P. (1999): Betriebliches Umweltmanagement. Verlag Neue Wirtschafts-Briefe, Herne/Berlin.
- Oenema, O. (1999): Nitrogen cycling and losses in agricultural systems; identification of sustainability indicators. In: Proceedings of the conference „Nitrogen cycle and balance in polish agriculture”. Institute for Land Reclamation and Grassland Farming, Falenty. 25-43.
- Sarkadi J. (1975): A műtrágyaigény becslésének módszerei. Mezőgazdasági Kiadó, Budapest.

IMPACT OF ACID AND LIMED SOILS OF DIFFERENT FERTILITY TO THE PHOTOSYNTHESIS

R. Veitienė¹ and Z. Kregždys²

¹Klaipėda University, Lithuania, E mail: rimaveit@yahoo.com

²Lithuanian Institute of Agriculture, Veizaiciai branch, Lithuania, E- mail: zilvinas@veizaiciai.lzi.lt

Introduction

Acidification of soils is one of the reasons of decreasing of soil fertility. Liming usually improved the agrochemical conditions of acid soils. Another side of liming – the leaching down of nutritious matter and acidification process is more intensive in comparison with non-limed soil (Ozeraitienė, 2001). In Lithuanian Institute of Agriculture Veizaiciai branch was established that pH of limed soils decreased in average 0.1 units every year (Knasys, 1985, Veitienė, 2001). By the acidification process the efficiency of mineral fertilizers in mostly cases decreased, the amount of aggressive elements such as aluminum, manganese, zinc increased until toxic level for mostly plants. The ratio of nutritious matter by the liming of soil and during acidification process of soil was disbalanced. Optimization of roots nutrition of plants is a main condition of plant developing and productivity.

By the long time liming and fertilizing with mineral and organic material the content of main nutritious matter decreased. It was established that content of potassium increased about two times, but content of phosphorus as well as of microelements in mostly cases decreased or not changed. Balanced fertilisation is the only way to bridge the gap between nutrient supply of the soil and crop uptake, in order to sustain productivity in modern farms without deteriorating of soil health.

The main physiological processes of plants (intensity of photosynthesis, amount of chlorophyll, accumulation of organic matter) are strongly connected by the conditions of mineral nutrition of plants.

As noted Lu Q, Lu C and etc, basic reason of photosynthesis intensity is content of chlorophyll in the leaves (Lu Q, Lu C etc., 2002). Synthesis of chlorophyll in mostly cases depends from content of nitrogen as well as from copper, zinc, iron, manganese. It is very important which forms of nutritious matter are in the substance for plants. Many authors noted that ammonium (NH_4^+) toxicity is an issue of global ecological and economical importance and changing ionic balance, relationships with carbon biochemistry and bioenergetics of primary NH_4^+ transport (Britto D.T., Kronzucker H.J., 2002). Nitrogen ensuring highest content of chlorophyll in the leaves and it influenced intensity of photosynthesis (Toth V.R., Meszros et al., 2002). From

another hand – rich using of nitrogen fertilizers increasing of soil acidity and decreasing of available calcium. By the suitable content of calcium chlorophyll fluorescence parameters were less affected than in the calcium deficient group (Schmitz-Eiberg M., Haefs R. at all, 2002). Decreasing of available calcium and phosphorus as well as increasing of content of potassium and destroying of ratio of mostly nutritive elements by the soil acidification have a negative effect to the yield and mostly physiological processes of plants (Veitene, 2001).

The main aim of researches was: 1) to establishing impact of ratio of the main biogenic elements to the intensity of photosynthesis by the liming and acidification of soils, 2) to establishing the effect of additional macro- and micro-fertilizers to the intensity of photosynthesis.

Materials and Methods

The vegetative trial was in the acid and limed soil fertilized with different NPK and manure doses arranged. The soil was taken from field trial where necessary soil reaction was reached by liming with different doses of lime and fertility of soil was different due to using of different doses of NPK fertilizers and manure in long time period. The soil reaction and fertilizing properties are: non-limed soil ($\text{pH} < 4.7$), limed soil ($\text{pH} 4.7\text{-}5.2$ and $\text{pH} > 6.7$). NPK fertilization properties are: non-fertilized (0 NPK), fertilized with 2 and 3 doses of NPK*. It was arranged in non-fertilized and fertilized of 40 t ha^{-1} of manure every 5 years.

Vegetation trial was carried out according of this scheme: 0.5% of Fe Cl_2 , 0.05% of MnSO_4 , 0.02% of H_3BO_3 , 0.02% of CuSO_4 , 0.02% of ZnSO_4 , 0.03% of $(\text{NH}_4)_2\text{MoO}_4$, 1.0% of KCl , 1.0% of CaCl_2 , 0.5% of MgSO_4 , 3% of NH_4NO_3 , 0.05% of NaH_2PO_4 , 0.0006% of NaHSeO_3 .

Mineral solutions for rapes (*Brasica napus*) was in beginning of burgeon used. After two weeks the intensity of photosynthesis (content of $\text{CO}_2 \text{ mg/cm}^2/\text{h}$) as well as area of leaves was established. The exudation of CO_2 was with Ba(OH)_2 established. The yield of rapes seeds after harvesting from every pot was established. Soil samples for chemical analyses were taken from the every pot after harvesting. Soil pH was estimated by electrometer with glass electrode; hydrolytic soil acidity according to Kappen; exchangeable soil acidity and mobile aluminium according to Sokolov; amount of bases according to Kappen-Hilcovic; mobile potassium and phosphorus according to AL.; total nitrogen by Kjeldal method.

The agrochemical characteristic of soil in the field trial was following: pH – 4.56 – 6.88, mobile aluminum – 0 – 13.5 mg kg^{-1} , exchangeable soil acidity – 0 – 1.9 m-ekv. kg^{-1} , hydrolytic soil acidity – 7.9 – 41.6 m-ekv. kg^{-1} . Acidity of soil and other indices connected

*1 dose of N P K was: N45-70, P30-60, K45 kg ha⁻¹

by soil reaction depended from used doses of lime, mineral fertilizers as well as from using of manure(table 1).

Table 1: Agrochemical soil characteristic

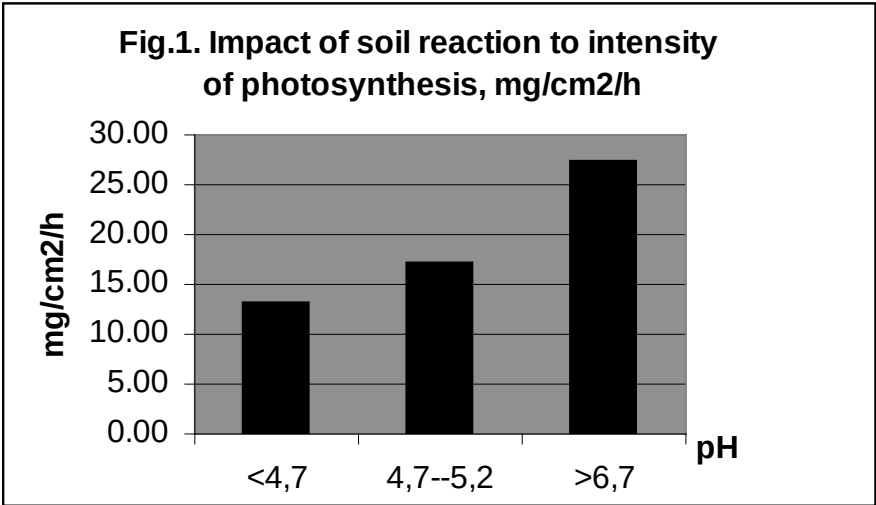
Liming t ha ⁻¹	Mineral fertilizing	Organic fertilizing, t ha ⁻¹	pH _{KCl}	Mobile aluminum mg kg ⁻¹	Exchangeable soil acidity m-ekv.kg ⁻¹	Hydrolytic soil acidity m-ekv.kg ⁻¹
0	0	0	5.31	0	0.4	22.5
0	0	40	5.73	0	0.2	17.6
0	2NPK	0	5.49	2.9	0.5	22.5
0	2NPK	40	5.54	1.9	0.4	22.5
0	3NPK	0	4.73	9.6	1.4	39.0
0	3NPK	40	4.52	10.6	1.5	41.6
4.4	0	0	4.69	10.6	1.6	34.7
4.4	0	40	5.39	1.9	0.5	23.4
4.4	2NPK	0	4.56	13.5	1.9	39.0
4.4	2NPK	40	5.05	1.9	0.5	29.5
4.4	3NPK	0	5.05	3.9	0.7	32.9
4.4	3NPK	40	5.05	2.9	0.6	32.9
44	0	0	6.63	0	0	7.8
44	0	40	6.79	0	0	7.9
44	2NPK	0	6.93	0	0	9.6
44	2NPK	40	6.58	0	0	9.6
44	3NPK	0	6.64	0	0.2	10.5
44	3NPK	40	6.80	0	0	8.8

Results and Discussions

Intensity of photosynthesis depended from intensity of liming (Fig.1). In un-limed soil the intensity of photosynthesis was about two times less than in soil, limed with 44 t/ha of lime. There need to note that soil reaction play minor reason for intensity of photosynthesis. As can see from data in table 1, by intensive liming content of aluminum decreased from 1.9 – 13.5 to 0 in comparison with un-limed and not intensive limed soil. It was established that correlation between soil reaction and intensity of photosynthesis are 0.66 in un-limed soil, 0.31 in not intensive limed soil and -0.33 in intensive limed soil. Correlation between content of aluminum and intensity of photosynthesis was 0.42, 0.64 and 0.81 accordingly.

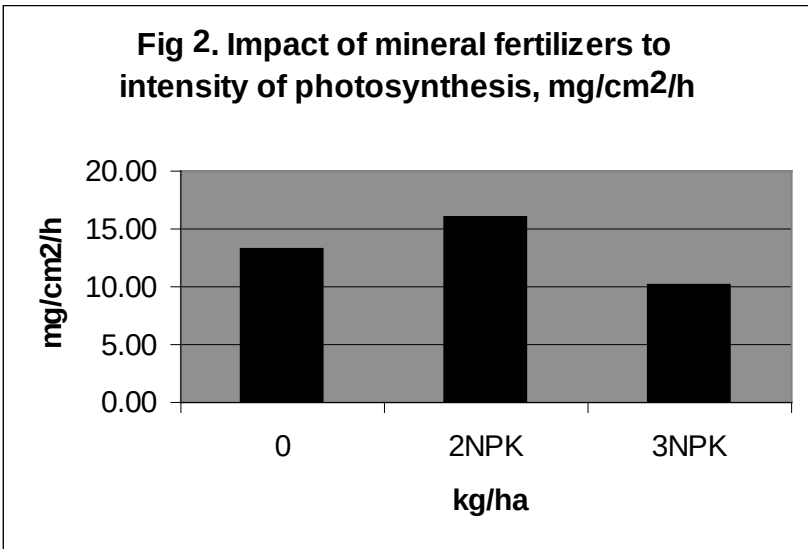
Amount of mineral fertilizers influenced the intensity of photosynthesis in lower level in comparison with soil reaction (Fig.2.). Highest amount of NPK fertilizers the intensity of photosynthesis of rape(*Brasica napus*) decreased about 30% in non fertilized soil and about

60% in fertilized with lowest ratio of NPK. The reason of decreasing of intensity of photosynthesis is increasing of content of aluminum by big norms of NPK (table 1). The



using of 3 norms of NPK the content of aluminum decreased from 0 to 10 mg/kg in un-limed soil approximately. Liming neutralized the negative influence of mineral fertilizers for acidification and content of aluminum in the soil.

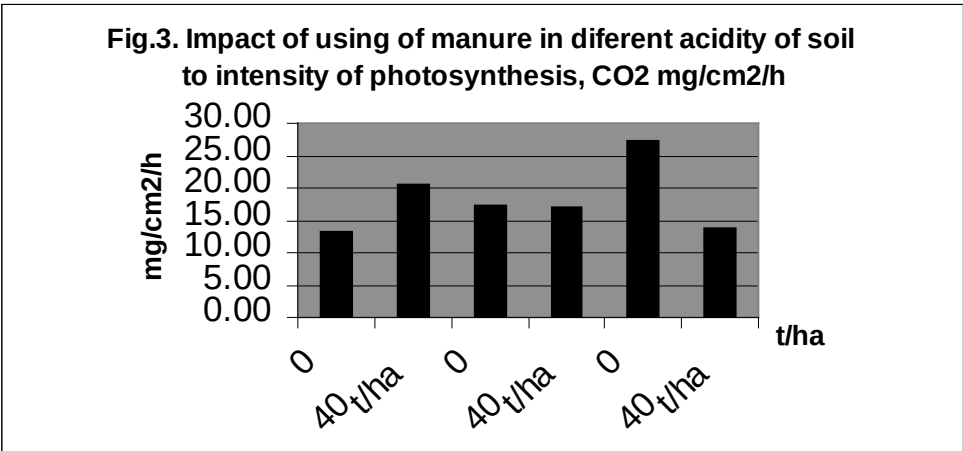
By this situation is very important to arrange properly the main mineral fertilizers taking into account of variety of cultivated plants and chemical soil properties especially into aluminum content in the soil.



By the fertilizing of rape (*Brasica napus*) in addition with KCl, the correlation between intensity of photosynthesis and content of aluminum was 0.84 in non limed soil and 0.41 in non intensive limed soil. The correlation between such indices in intensive limed soil was not established. It mean that in acid non limed soils for intensity of photosynthesis fertilizers of KCl is more important especially by the high level of aluminum content.

Using of NaH_2PO_4 by the increasing of aluminum content in the un-limed soil increased intensity of photosynthesis about 3 - 4 times in comparison with limed soil where effectiveness of such kind of fertilizers was not so high. Correlation between aluminum content and intensity of photosynthesis in non limed soil by the using of additional NaH_2PO_4 was established. In intensive limed soil intensity of photosynthesis was about 2.3 times higher than in non limed soil because mostly mineral elements including phosphorus after intensive liming are not available for plants and additional fertilizing is effective.

Effectiveness of manure for intensity of photosynthesis is higher in non limed soil (Fig.3.) One of the reason of it – decreasing of content of aluminum and soil reaction as well. Intensity of photosynthesis in non limed soil after manuring was 53% higher. In not intensive limed soil manuring the intensity of photosynthesis not effected and using of manure in intensive limed soil the intensity of photosynthesis decreased about 2 times. Reason of this is low availability of mineral elements by the double effect of lime and manure on the soil acidity.



Conclusions

1. Soil reaction is secondary index for intensity of photosynthesis of rapes (*Brasica napus*). Main reason of decreasing of intensity of photosynthesis is content of aluminum.
2. Increasing of soil alkalinity decreasing of availability of mostly mineral elements, therefore using of mineral fertilizers in response to fertility and acidity of soil is primary condition for rape (*Brasica napus*).
3. By the cultivating of rape (*Brasica napus*) in not intensive limed soils (pH 4.5 – 5.0) additional using of KCl increased intensity of photosynthesis about 2 times in comparison with non limed soil (pH 4.5 – 5.7). Using of KCl in intensive limed soil was not effective.
4. The additional fertilizing with phosphorus fertilizers (NaH_2PO_4) was more effective in limed soil and intensity of photosynthesis was about 2.3 times higher in intensive limed soil and about 1.9 time higher in non intensive limed soil in comparison with un-limed soil.

References

- Lu Q, Lu C. at all.(2002) Photosynthesis and chlorophyll a fluorescence during flag leaf senesce field-grown wheat plants. Journal of Plant Physiology. No. 11, vol. 159, pp.1173-1182.
- Britto D.T., Kronzucker H.J. (2002) NH_4^+ toxicity in higher plants: a critical review. Journal of Plant Physiology. No. 6, vol. 159, pp.567-584.
- Ožeraitienė D. Duration of primary liming action on agroecosystem// Natural and anthropogenic causes and effects of soil acidification. Lublin, 2001, P.100.
- Veitienė R. Dirvožemio rūgštėjimo įtaka cheminių elementų kiekiui ir sėjomainos augalų produktyvumui// Žemdirbystė. Mokslo darbai. T.74.Akademija, 2001, P. 13-24.
- Veitienė R. Snižėjimo plodurudija počvy v uslovijach okislenija//Aktualnyje problemy plodurudija počv v sovremenyh uslovijach. Minsk, 2001, P. 78-80 (rusų k.).
- Knasys, V. (1985) *Dirvozemių kalkinimas*. Vilnius, 262 pp.
- Schmitz-Eiberg M., Haefs R. at all. (2002). Calcium deficiency – influence on the antioxidative defense system in tomato plants. Journal of Plant Physiology. No. 7, vol. 159, pp.733-742.
- Toth V.R., Meszros I. at all (2002). Effects of the available nitrogen on the photosynthetic activity and xanthophylls cycle pool of maize in field. Journal of Plant Physiology. No. 6, vol. 159, pp.627-634.

EFFECT OF A LONG-TERM FERTILIZATION EXPERIMENT ON HEAVY METAL UPTAKE BY RYEGRASS AND LETTUCE

Zs. Kiss¹, É. Lehoczky¹, T. Németh² and Gy. Baczó²

¹University of Veszprém, Georgikon Faculty of Agriculture
H-8361 Keszthely, Deák F. u. 16., Hungary, kzs@georgikon.hu

²Research Institute for Soil Science and Agricultural Chemistry
H-1022 Budapest, Herman O. u. 5., Hungary

Introduction

A great variety of soil-climatic and geochemical conditions are typical for the region under research that determines considerable differentiation of naturally-evolutional soils on the element-content. The biogeochemical cycling of heavy metals have received worldwide attention in recent years. The soil–plant system is an open system subject to inputs, such as contaminants, fertilizers and pesticides. Plant species and varieties differ widely in their ability to absorb, accumulate and tolerate different heavy metals.

Heavy metals are known to be essential and toxic elements for plants, animals and human. It is well known from literature that there are significant differences in the element uptake of ryegrass and lettuce. Lehoczky et al. (2000) studied the Cd uptake by different plants (ryegrass, lettuce, white mustard). Comparing the three plants in respect of Cd concentrations the order found was as follows: ryegrass < white mustard < lettuce.

The Cd and Pb are adsorbed by soils and are able to accumulate (Lehoczky et al., 2002a). The National Long-Term Fertilization Trials (NLFT) in 1967 made possible to follow the change of the heavy metal content of soils and at the same time the heavy metal input of plants. The maximum permissible quantity of the Cd and Pb content in the soils and in the different fertilizers there are shown Table 1 and Table 2.

Table 1: Hungarian maximum permissible quantity of the Cd and Pb content in the soils (KÖM-EÜM-FVM-KHVM 10/2000. VI.2. Order, 2000)

Cd	Pb
mg·kg ⁻¹ dry matter	
1	100

In Hungary P fertilizer production is based on Kola phosphates that have low Cd contents 0.2-0.7 mg·kg⁻¹ (Karpova, 1990). The phosphate fertilizers are not a major Cd source (Kádár, 1995).

Table 2: Hungarian maximum permissible quantities of the Cd and Pb content in different fertilizers (FVM 8/2001. I.26. Order, 2001)

Fertilizers	Heavy metal	
	Cd	Pb
	mg·kg ⁻¹ dry matter	
Nitrogen	2	100
Phosphor P₂O₅<20% d.m.^a	3	100
Potassium	3	100
Remarks: ^a dry matter		

The heavy metal content of the parts of plant is different. Most of the Cd content was found in the vegetative parts of plant than generative parts (Fodor, 2000). The highest Cd concentrations were measured in the leaves of plant. In contrast with Cd, Pb concentration was lower in the stem and leaves than in the roots (Lehoczky et al., 2002). Fodor (2000) observed that Pb is less mobile than Cd.

Our aim was to compare the heavy metal uptake of ryegrass and lettuce in relation to heavy metal content of experimental soils and different fertilization treatments in Long-Term Fertilization Trials in Keszthely.

Material and Method

The pot experiment was carried out under green house conditions using soils of National Long-Term Fertilization Trials (NLFT) in Keszthely in 2001. The National Long-Term Fertilization Trials were set up in 1967 but winter wheat-maize-maize-winter wheat rotation has been growing since 1989. The experiment soil samples have been given expanding dose of P fertilizer (Table 3). The soil used was Ramann-type brown forest soil (Eutric cambisol). Soils samples were taken in October 2000 in the 34th years of the experiment. For experiment we collected soil samples from the 0-20 cm deep surface layer by mechanic soil drill.

The experiment was carried out in four replicates. We filled the pots with 1 kg of air-dry soil (Chaminade, 1960).

The test plants were ryegrass (*Lolium perenne* L. cv. Gulács) and lettuce (*Lactuca sativa* L. cv. Balatonzöld). One thousand ryegrass seeds and tow hundred lettuce seeds were sown in the pots. Ryegrass and lettuce were grown for four weeks and the plants were cut above the soil. Fresh and dry biomass weight of ryegrass and lettuce were determined and Cd and Pb content of plant samples were measured after microwave digestion with cc.HNO₃+H₂O₂ by ICP-AES.

The cc.HNO₃+H₂O₂ and LE (0.5M ammonium-acetate + 0.5M acetic acid + 0.02M EDTA) soluble Cd and Pb content of the National Long-Term Fertilization Trial soils was determined by ICP-AES. The most important physical and chemical properties of the experimental soil: pH_{KCl}: 6.3; clay(%): 24; H(%): 1.9-2.2. Mathematical and statistical analysis of the experimental data was done by ANOVA of SPSS for Windows statistical program.

Table 3: The experiments include 6 fertilizer treatments, kg·ha⁻¹·év⁻¹

Code	Treatment	N ^a	N ^s	P ₂ O ₅	K ₂ O
1	000	0	0	0	0
2	301	75	75	0	100
3	311	75	75	50	100
4	321	75	75	100	100
5	331	75	75	150	100
6	441	100	100	200	100
Remarks: ^a autumn; ^s spring;					

Results and Discussion

The Cd and Pb concentration of the experimental soils in all treatments was only a fraction of the maximum permissible quantity valid in Hungary.

The cc.HNO₃+H₂O₂ soluble Cd content of soil samples ranged between 0.19 and 0.22 mg·kg⁻¹ soil (Table 4). The highest cc.HNO₃+H₂O₂ soluble Cd content of soils was determined in the No. 2 and 4 treatment (301; 321) and the lowest in the No. 1 treatments (000). The higher difference of 1.15 fold were observed with cc.HNO₃+H₂O₂ soluble Cd content of soil samples.

The available (LE) Cd content of the soil was 0.08-0.10 mg·kg⁻¹ soil (table 4). The LE soluble Cd content of the soil varied between 0.8 fold. The highest Cd content difference of the experimental soil was in No. 3 and No. 6 treatments (311; 441). The available Cd content was 41.8-55.8% of the cc.HNO₃+H₂O₂ soluble Cd content of the soils. Positive linear correlation wasn't found between the cc.HNO₃+H₂O₂ and LE soluble Cd content of the experimental soils.

The Cd content of ryegrass was 0.15-0.26 mg·kg⁻¹ dry matter (table 4). The highest difference between fertilization treatments was 1.73 fold. The Cd content of ryegrass was 80-128% of the cc.HNO₃+H₂O₂ and 148-240% of the LE soluble Cd content of soils. The cadmium accumulation could be observed in ryegrass in No. 6 treatments (441).

The Cd content of lettuce was 0.8-1.17 mg·kg⁻¹ dry matter (Table 4). There were 1.46 fold differences in the Cd content of lettuce. The Cd concentration of lettuce was 372-538% of the cc.HNO₃+H₂O₂ soluble Cd content of soils. The Cd content of lettuce 8.1-11 fold bigger than the LE soluble Cd content of the soils. No significant correlation was found between cc.HNO₃+H₂O₂ and LE soluble Cd content of soil and Cd content of lettuce. Cadmium accumulation was found in the lettuce in all fertilizer treatments.

We compared Cd content of ryegrass with Cd content of lettuce. We found that Cd content of lettuce was higher than Cd content of ryegrass. There were 3.9-5.8 fold differences. This difference is shown the transfer coefficients too (Alloway, 1995) (Table 5).

The cc.HNO₃+H₂O₂ soluble Pb contents of the experimental soils were higher than the cc.HNO₃+H₂O₂ soluble Cd contents of the soils (20.70-21.82 mg·kg⁻¹ soil) (Table 4). We found only 1.05 fold difference in the cc.HNO₃+H₂O₂ soluble Pb contents of the soil samples. We wasn't found significant correlation between cc.HNO₃+H₂O₂ soluble Pb content of the soils and the fertilizers treatments. The highest cc.HNO₃+H₂O₂ soluble Pb content of soils was measured in the No. 3 treatment (311) and the lowest in the No. 4 treatments (321).

The LE soluble Pb content of the soils was 7.29-8.92 mg·kg⁻¹ soil (Table 4). The available Pb content of the soils was 31-41% of the cc.HNO₃+H₂O₂ soluble Pb content of the experimental soils. The highest difference of LE soluble Pb content of soil was 1.2 fold in fertilizers treatment. The lowest available Pb content of the soils was in No. 6 treatments (441) and the highest Pb content was in the No. 3 treatment (311).

The ryegrass' Pb content was 0.88-1.147 mg·kg⁻¹ dry matter (Table 4). Positive linear correlation wasn't found between the cc.HNO₃+H₂O₂ and LE soluble Pb content of the soils and Pb content of the ryegrass. The Pb content of ryegrass was 4-8% of the cc.HNO₃+H₂O₂ and it 11-21% of the LE soluble Pb content of the soils. The lowest Pb content of ryegrass was in the No. 6 treatment (441) and the highest Pb content of the ryegrass was in the No. 2 treatment (301).

Pb content of the lettuce was 0.55-1.85 mg·kg⁻¹ dry matter (Table 4). The difference of the treatment was high (3.3 fold). Pb content of lettuce was 2-8% of the cc.HNO₃+H₂O₂ soluble and

6-20% of the available (LE) Pb content of the soils. We couldn't found Pb accumulation in the lettuce. The Pb content of ryegrass higher than Pb content of the lettuce but in the No. 3 and No. 6 treatments (311; 441) the Pb content of the lettuce was higher than in the ryegrass (Table 4) and it is shown the transfer coefficients (Table 5).

Fresh and dry weights of the test plants were determined. The fresh weight of the lettuce (15.49-30.18 g·pot⁻¹) was higher than fresh weight of ryegrass (9.18-15.81 g·pot⁻¹) (Figure 1). The differences between the fertilizer treatments were 1.6-2.0 fold. The smallest fresh weight of the test plants was in the No. 1 treatment (000) and the biggest weight of ryegrass and lettuce was in the No. 6 treatment (441). The smallest dry weight of ryegrass was in No. 1 treatment (000) and the biggest dry weight was in the No. 6 treatment (441) also than fresh weight of ryegrass (Figure 2). The smallest dry weight of lettuce was also in No. 1 treatment (000) and the biggest dry weight was in the No. 5 treatment (331) (Figure 2). The dry weight of the ryegrass 11-14% of the fresh weight of the ryegrass and the dry weight of lettuce was 6-7% of the fresh weight of lettuce.

Table 4: Cd and Pb content of experimental soils and test plant

Code	Cd mg·kg ⁻¹ soil		Pb mg·kg ⁻¹ soil		Cd mg·kg ⁻¹ dry matter		Pb mg·kg ⁻¹ dry matter	
	cc.HNO ₃	LE	cc.HNO ₃	LE	ryegrass	lettuce	ryegrass	lettuce
1	0.19	0.10	20.75	8.35	0.15	0.84	0.94	0.55
2	0.22	0.10	21.33	8.06	0.20	1.17	1.74	1.41
3	0.21	0.11	21.83	8.92	0.18	0.87	1.49	1.85
4	0.22	0.09	20.70	7.41	0.20	0.80	1.40	1.03
5	0.21	0.09	21.78	8.89	0.21	0.83	1.61	1.30
6	0.20	0.11	21.60	7.29	0.26	1.17	0.88	1.24
LSD _{5%}	0.03	0.02	5.23	3.43	0.06	0.62	0.93	0.79

Table 5: Transfer coefficients of the cadmium and the lead

	Transfer coefficient	
	Cd	Pb
ryegrass	0.80-0.99	0.04-0.08
lettuce	3.72-5.80	0.02-0.08

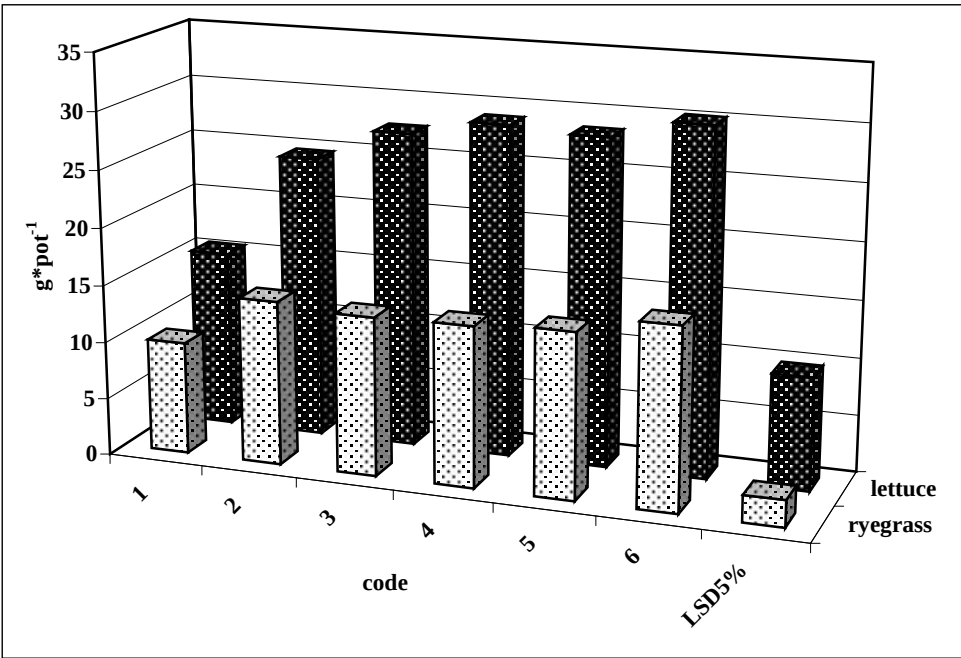


Figure 1: The fresh biomass production of ryegrass and lettuce

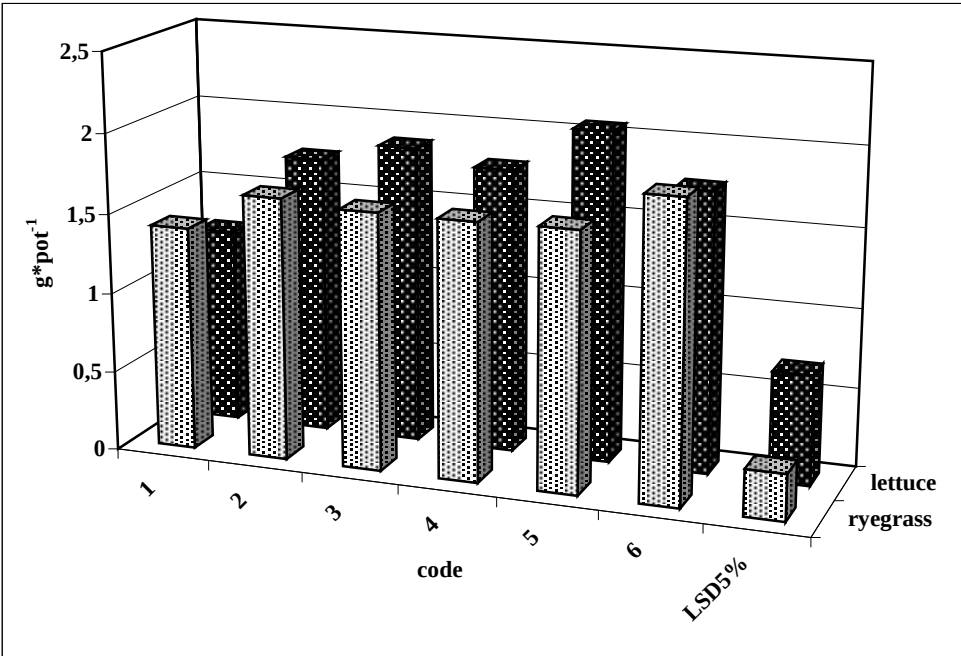


Figure 2: The dry biomass production of ryegrass and lettuce

Conclusions

The concentration of the examined Cd and Pb in the soils was only a fraction of the valid Hungarian maximum permissible quantity. Significant correlation wasn't found between different fertilizer treatments and amount of Cd and Pb content in the experimental soils and in the different test plants (ryegrass and lettuce). The lettuce can be higher accumulation of heavy metal than the ryegrass. The different soluble ($\text{cc.HNO}_3 + \text{H}_2\text{O}_2$ and LE) Cd and Pb content in the soils was different and characteristic for each element: the Cd was more mobile than Pb in the soil-plant-fertilizer system.

Acknowledgements

The authors wish to express their sincere thanks to T037925 Hungarian Scientific Research Foundation (OTKA). From the authors, Zsanett Kiss thanks her supervisors Dr. Éva Lehoczky and Prof. Tamás Németh for their help in her research work.

References

- Alloway, B.J.. Heavy Metals in Soils. Blackie Academic and Professional: London, England. 1995.
- Chaminade, R. Experimentation en Petits Vases de Vegetation Types d'Essais pour Tester l'Efficacite des Engrais Humiques. Ann. Agron. II 121-131. 1960.
- Fodor, L. Nehézfémek Akkumulációja a Talaj-Növény Rendszerben. PhD. Dissertation, Keszthely, Hungary, 2000.
- Karpova, E.A. Ju.A. Potatueva, Kadmiy v Pocsvah, Rasztenijah, Udobrenijah. Him. Szelszk. Hozj. 2, 44-47. 1990.
- Kádár, I. A Talaj- Növény- Állat- Ember Tápláléklánc Szennyeződése Kémiai Elemekkel Magyarországon. Környezetvédelmi és Területfejlesztési Minisztérium MTA Talajtani és Agrokémiai Kutató Intézet, Budapest, Hungary, 1995.
- Lehoczky, É., P. Marth. I. Szabados, M. Palkovics, and P. Lukács, Influence of Soil Factors on the Accumulation of Cadmium by Lettuce. Communications in Soil Science and Plant Analysis, 31. 2425-2431p. 2000.
- Lehoczky, É., T. Németh, Zs. Kiss, and T. Szalai Cadmium and Lead Uptake by Ryegrass, Lettuce and White Mustard Plants On Different Soils. Agrokémia és talajtan, Hungarian Contributions to the 17th International Congress of Soil Science. Vol.51. 201-210. 2002.
- 10/2000. (VI.2.) KöM-EüM-FVM-KHVM e.r.: A felszín alatti víz és a földtani közeg minőségi védelméhez szükséges határértékekről. Magyar Közlöny, Budapest, Hungary 3156-3168.
- 8/2001. (I.26.) FVM r.: A terméshozam növelő anyagok engedélyezéséről, tárolásáról, forgalmazásáról és felhasználásáról. Magyar Közlöny, Budapest, Hungary. 458-523.

REACTIVE PHOSPHATE ROCKS – RPRS AND PARTIALLY ACIDULATED PHOSPHATE ROCKS – PAPRS AS A POTENTIAL SOURCE OF PHOSPHORUS IN AGRICULTURE OF CENTRAL AND EASTERN EUROPE

W. Grzebisz*, J. Potarzycki and R. Gaj

Department of Agricultural Chemistry, Agricultural University
Woksa polskiego str. 71 F, 60-685 Poznań, Poland, witegr@au.poznan.pl

Abstract

Partially acidulated phosphate rocks (PAPRs) are manufactured by acidulation of PRs with less than the stoichiometric amounts of, usually, phosphoric or sulphuric acids. Products of similar composition to PAPRS are also prepared by cogranulating superphosphate with PRs. In Europe some kinds of these types are used for a long time, for instance the Novaphos or Cederan in Germany and currently Lubofos in Poland. However there are lack of data on the agronomic effectiveness of PAPR fertilizers. In spite of this fact, the most potential areas of PAPR and phosphate rocks use could be suggested: pastures, perennial crops, legumes.

The objective of the presented review paper is to discuss the features of these alternative phosphate fertilizers for the use in Europe.

Keywords: partially acidulated phosphate rocks, phosphate rock, relative agronomic efficiency (RAE)

Introduction

In the last decade of the XX century in all of the European countries in transition, including Poland consumption of fertilizers decreased significantly (Fotyma, Gosek, 2000). The main reason for this situation are severe financial constraints, which in turn force farmers to intensive use of soil's nutrient reserves. As a logical consequence of these practices the considerable yields year to year variability takes place. Hence, rapid increases in the cost of phosphate fertilizers forces farmers to the search for cheaper P fertilizers.

The objective of this review paper is to discuss the potential agronomic value of alternative phosphate fertilizers such as phosphate rocks and partially acidulated phosphate rocks for annual crops and pastures in temperate climates.

Phosphorus fertilizers

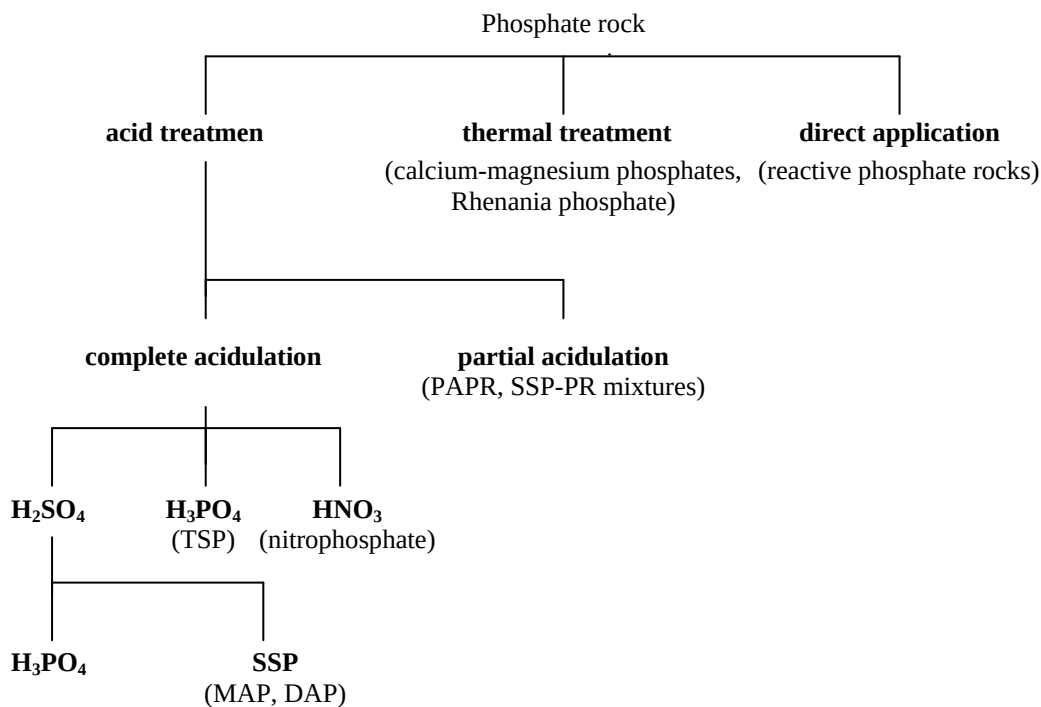


Figure 1: Schematic diagram of phosphate fertilizers production (Bolan et al., 1993)

The original source of phosphorus fertilizers is phosphate rock, which occur as igneous, sedimentary, metamorphic and guano depositions. Chemical composition of phosphate rocks is highly variable. The mineral deposits contain calcium phosphate (mineral known as apatite), aluminum phosphate (crandallite), iron and aluminum phosphates (millisite), etc.. The most important source of phosphorus fertilizers production are sedimentary depositions containing mainly carbonate apatites. They deliver around 80% of the World production of phosphates (Bolan et al., 1993). As is shown in the Fig.1. the final product (P fertilizer) of phosphate rock manufacturing depends on its technological treatment.

Phosphate rocks as P fertilizers

The direct use of ground phosphate rock in agriculture is highly variable, but not very low. In 1997 its amounted to 15% of P total use (IFA Data Bank). All types of phosphate rocks could be used for direct crop fertilization, but in practice apatites are preferred (Bolan et al., 1993). The main disadvantages of phosphate rock as a source of P for crops is its low water solubility

(Khasawneh et al., 1980; Hagin et al., 1990). Therefore some characteristics of factors affecting phosphate rocks agronomic efficiency are required to incorporate RPRs into a phosphorus fertilizer program. The four groups of factors should be taken into account:

a. Reactivity of phosphate rock

Direct use of apatites depends on their *reactivity*, which is related to carbonate content in minerals. Substitution of a divalent planar carbonate group for a trivalent tetrahedral phosphate group is the decisive for a crystal stability. It was found that the higher relationship of hydroxide or carbonate moles per mole of phosphate increases rate of apatite dissolution (Bolan et al., 1993). Chemical reactivity of RPRs is measured by means of selected extractants such as 2% citric acid, 2% formic acid (Braithwaite et al., 1990). On the basis of citric soluble P Syers et al. (1986) classified the main phosphate rocks into two groups, i.e. *reactive* and *non-reactive*. The first group of depositions is characterized by more than 30% of citric soluble P.

b. Soil factors

Dissolution of RPRs is enhanced by soil conditions such as :

- low pH (Bolan and Hedley, 1990; Kanabo and Gilkes, 1987; Wright et al., 1992). The dissolution of an apatite mineral follows the reaction:
$$\text{Ca}_{10}(\text{PO}_4)_6\text{F}_2 + 12\text{H}^+ \leftrightarrow 10 \text{Ca}^{2+} + 6\text{H}_2\text{PO}_4^- + 2\text{F}^- \quad [1]$$
- low concentration of P and Ca in soil solution (MacKay and Syers, 1986);
- high soil P and Ca capacity (Chien and Hammond, 1989);
- moisture regime (rainfall amounts and distribution) ()

c. Plant factors

The expected benefit from the use of fertilizer phosphorus is not only yield increase but also stabilization of crop production. Both goals can only be achieved when during critical stages of plant growth phosphorus supply is adequate. Among plant characteristics some of them should be taken into account (Bekele et al., 1983):

- P requirement (amount and rate of P uptake);
- plant characteristics (root system morphology, root cation exchange capacity, pattern of nutrients uptake);
- pH changes in the rhizosphere.

d. RPRs residual effect

Annual recovery of phosphorus from P fertilizers is generally low, mostly below 30%. Even lower efficiency is attributed to phosphate rocks, as reported in several papers (Bolland et al.,

1997; Hagin and Harrison, 1993; Sinclair et al., 1993). However, it is also reported that phosphate rock applied at the appropriate quantities :

- may increase the organic matter content,
- may improve the physical structure of the soil,
- may provide essential amounts of macronutrients (P, Ca) and some micronutrients;
- may decrease water pollution caused by leaching and run-off of soluble phosphates,
- may stimulate the living complex of microbes and worms,
- -are non-toxic to plants, soil microbes and humans.

Practical use of RPR fertilizers

The areas of RPRs use as a source of P to the main crops as reported in several papers are mostly limited to certain, mainly tropic regions of the World. In temperate regions RPRs may appear to be well suited for

- pastures, which require a sustained moderate supply of P (Bolan et al., 1990; Sinclair et al., 1993; Perrott and Metherell, 1997).
- legumes are known to be efficient users of RPRs, apparently because of their affinity for Ca and the acidifying effect of N₂ fixation on the rhizosphere. However, the amount of fixed N₂ can be highly influenced by P source;
- oil-seed rape, which exerts specific effect on RPRs solubilization (Hoffland et al., 1989);

This type of P fertilizers seems to be an excellent P source for ecological farming.

PAPR fertilizers

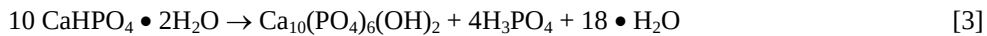
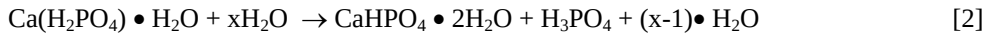
Chemical characteristics

The term partially acidulated phosphate rocks - PAPR describes two, but very similar in chemical composition products, i.e. P fertilizers produced under two distinct technological treatments (Bolan et al., 1993; Rajan and Marwaha, 1993):

1. Partial acidulation, i.e. less than the stoichiometric amount of acid required for complete dissolution of phosphate rock with H₂SO₄ or H₃PO₄.
2. Physical mixture of SSP (single superphosphate) and RPR (reactive phosphate rock).
The last product is also known as LONGLIFE type of P fertilizers.

The chemical composition and patterns of P release are both affected by the degree of phosphoric rock acidulation and acids used in the PAPR manufacture. In practice, the degree of

PR acidulation ranges from 20% to 50%. The first component of the PAPR fertilizer, i.e. MCP (monocalcium phosphate) added to the soil undergoes transformation into moderately soluble dicalcium phosphate dihydrate (DCPD) and further to much less soluble P compounds. For neutral and noncalcareous soils two step reactions take place:



Both reactions differ in the rate. The first one is fast but the second slow. Phosphoric acid, the product of MCP hydrolysis reacts with PR causing its further dissolution. The rate of the second reaction is also governed by plant P uptake, which in turn increases phosphate compounds dissolution. Therefore for a long period P originating from the PAPR stays in the form of DCPD being easily available to plants (Golden et al., 1991a and b; Hagin and Harrison, 1993) (Fig. 2 – adopted from Smith et al. 1990).

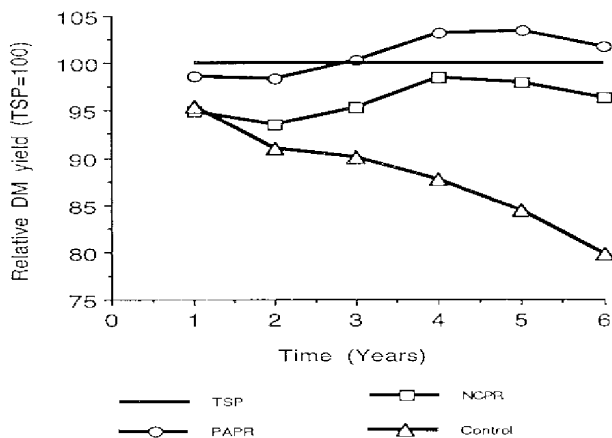


Fig. 2. Pasture dry matter (DM) yield on applying phosphoric PAPR 30% relative to that of TSP. Data points for the unground North Carolina PR (NCPR) and control are also given for comparison. Source Smith *et al.* [61].

Factors effecting PAPR fertilizers use

Theoretically the value of PAPR fertilizers is defined as its ability to maintain a soil solution P above the critical level for plant growth (0,2 ppm). In practice the relative agronomic efficiency (RAE) of PAPR fertilizers is assessed by means of the following equation:

Yield of P the tested PAPR fertilizer – yield of the control plot (-P)

$$RAE = \frac{\text{Yield of the P reference fertilizer}^1 - \text{yield of the control plot (-P)}}{\text{Yield of the P reference fertilizer}^1} \times 100 \%$$

¹ SSP or TSP

Assessing the agronomic effectiveness of PAPR fertilizers the following factors should be taken into account:

1. The presence of fast (MCP) and slow (RPR residues) release P forms (Hagin and Harrison, 1993).
2. The rate of solubility of the RPRs residues (Hagin et al., 1990).
3. Soil properties, mainly related to pH; soil P fixing capacity (Chien and Hammond, 1989; Hagin et al., 1990).
4. Crop properties, related to roots morphology, rhizosphere acidification; cation-anion uptake pattern (Hagin and Harrison 1993).
5. Weather conditions related to rainfall amounts (Lewis et al., 1997).

Strategy of phosphorus fertilizers use including RPRs or PAPRs

In the tropic, subtropic and Mediterranean climates the use of partially acidulated phosphate rocks is broadly investigated (Bollan et al., 1993; Bolland et al., 1997; Lewis et al., 1997). In Europe some kinds of these types are used for a long time, for instance the Novaphos, Cederan in Germany (Rajan and Marwaha, 1993). However current data on the agronomic effectiveness of PAPR fertilizers in Europe are scarce.

Table 1: Sugar beets response to phosphorus fertilizers, mean of 2001/02

Phosphorus Fertilizers	Localization					
	Bodzewo		Nagradowice		Ziemięcín	
	Yield ¹ , t/ha	sugar, %	yield, t/ha	sugar, %	Yield, t/ha	sugar, %
Control	49,94	16,89	56,04	17,97	60,73	17,56
SSP ²	55,95	17,11	67,09	17,24	72,60	16,78
PAPR ²	59,33	18,00	65,82	17,28	76,52	17,04

¹ yield of taproots; 36 kg P/ha

The problem of optimal use of phosphorus fertilizers on a farm is highly dependent on total management rules. Therefore, a farmer should take into account, three main rules with respect to P management:

- annual crops need easily available phosphorus in order to develop good, fast growing root system and vigorous vegetative growth; this rule is fulfilled by pre-sowing P fertilization; this group of crops may respond to PAPRs fertilizers.
- winter crops (oil seed rape, winter cereals) and permanent crops require an easily available phosphorus in order to increase rate of their regrowth; this rule is fulfilled by nitric phosphates applied overhead;
- high yielding crops respond much more to soil available phosphorus than to its current application. Therefore, it is necessary to build-up P fertility in order to grow those crops in rotation. The PAPRs fertilizer group seems to be highly suitable to solve this problem (Table 1);

At the same time too high content of soil available phosphorus or fertilizer rates may create serious environmental problems. PAPRs fertilizers due to their chemical composition are less susceptible to leaching and also run-off. However, the PAPR fertilizers use is mostly limited by the lack of long term field experiments allowing to evaluate the residual RPRs or PAPRs effects.

References

- Bekele T., Cino B.J., Ehlert P.A.I., van der Maas A.A., van Diest A., 1983: An evaluation of plant-borne factors promoting the solubilization of alkaline rock phosphates. *Plant and Soil* 75, 361-378.
- Bolan NS, Hedley M.J., 1990: Dissolution pH phosphate rocks in soils. 2. Effect of pH on the dissolution and plant availability of phosphate rock in soil with pH dependent charge. *Fertilizer Research* 24, 125-134.
- Bolan NS, Hedley M.J., Loganathan P., 1993: Preparation, forms and properties of controlled-release phosphate fertilizers. *Fertilizer Research* 35, 13-24.
- Bolland M.D.A., Lewis D.C., Gilkes R.J., Hamilton L.J., 1997: Review of Australian phosphate rock research. *Australian Journal of Experimental Agriculture*. 37 (8) 845-859.
- Braithwaite A.C., Eaton A.C., Groom P.S., 1990: Factors affecting the solubility of phosphate rock residues in 2% citric acid and 2% formic acid. *Fertilizer Research* 23, 37-42.
- Chien S.H., Hammond L.L., 1989: Agronomic effectiveness of partially acidulated phosphate rock as influenced by soil phosphorus-fixing capacity. *Plant and Soil*, 120, 159-164.
- Fotyma, Gosek, 2000: Changes in potassium fertilizers utilization and their consequences for soil fertility and plant production in Poland. *Fertilizers and Fertilization* 1:9 -52
- Golden D.C., White R.E., Tillman R.W., Stewart R.B., 1991: Partially acidulated reactive phosphate rock (PAPR) fertilizer and its reactions in soil. I. Initial movement of dissolved ions and solubility of the phosphate rock residue. *Fertilizer Research* 28: 281-293 (a).
- Golden D.C., Stewart R.B., Tillman R.W., White R.E., 1991: Partially acidulated reactive phosphate rock (PAPR) fertilizer and its reactions in soil. II. mineralogy and morphology of the reaction products. *Fertilizer Research* 28: 295-304 (b).
- Hagin J., Rajan S.S.S., Boyes M.K., Upsdel M., 1990: Partially acidulated phosphate rocks: phosphorus release characteristics. *Fertilizer Research* 22: 109-117.
- Hagin, J. and Harrison R., 1993: Phosphate rocks and partially acidulated phosphate rocks as controlled release P fertilizers. *Fertilizer Research* 35, 25-31.

- Hoffland E., Findenegg G.R., Nelemans J.A. 1989: Solubilization of rock phosphate by rape. *Plant and Soil* 113, 161-165.
- Kanabo I.A.K., Gilkes R.J., 1987: The role of soil pH in the dissolution of phosphate rock fertilizers. *Fertilizer Research* 12: 165-174.
- Lewis D.C., sale P.W.G., Johnson D., 1997: Agronomic effectiveness of a partially acidulated reactive phosphate rock fertilizer. *Australian Journal of Experimental Agriculture* 37, (8), 985-993.
- Mackay A.D., Syers J.K., 1986: Effect of phosphate, calcium and pH on the dissolution of a phosphate rock in soil. *Fertilizer Research* 10, 175-184.
- Perrot K.W., Metherell A.K., 1997: Incorporation of reactive phosphate rock into a phosphorus fertilization decision support model for grazed pasture. *Proceedings of the Dahlia Greidinger International Symposium on fertilization and the Environment*, Haifa, 1997, 133-146.
- Rajan S.S.S., Marwaha B.C., 1993: Use of partially acidulated phosphate rocks as phosphate fertilizer. *Fertilizer Research* 35, 47-59.
- Sinclair A.G., Johnstone P.D., Smith L.C., O'Connor M.B., Nguyen L., 1993: Agronomy, modeling and economics of reactive phosphate rocks as slow-release phosphate fertilizer for grassland. *Fertilizer research* 36, 229-238.
- Smith L.C., Johnstone P.D., Sinclair A.G., Shannon P.W., O'Connor M.B., Percival N., Roberts Smith R.G., Mansel G., Morton J.D., Nguyen L., Dayson C.B. and Risk W.H. 1990: Final Report on the MAF "National Series" forms of phosphate fertilizers trials. Part I: Description of the trials and annual herbage dry matter production. Ministry of Agriculture and Fisheries, New Zealand, 1-88
- Wright R.J., Baligar V.C., Belesky D.P., 1992: Dissolution of North Carolina phosphate rock in soils of the Appalachian Region. *Soil Science*, 153, 1, 25-36.

THE EFFECT OF FERTILIZATION ON THE YIELD OF MAIZE (*ZEA MAYS* L.) IN LONG TIME EXPERIMENTS

J. Nagy

University of Debrecen, Department of Land Use and Rural Development
HAS-UD Land Use and Rural Development Research Team

Abstract

The effects of fertilization in the irrigated and non-irrigated treatments were investigated at six fertilization levels in four replications every year, using the 4-year yield data of Pannonia. For the evaluation of the fertilization effect we used regression analysis and fitted a quadratic function. The linear and quadratic values of fertilization were the independent variables and the yield was the dependent one. In every case we investigated the significance of the equation and its parameters, too.

On the basis of the analysis results with several years' yield data it can be concluded that in non-irrigated treatments the approximation with a quadratic function shows a weak or moderately strong correlation between fertilization and yields. Due to the changeable water supply the effect of fertilization is also extensively changing year by year. Under such circumstances the optimum fertilizer dosage can only be calculated with decreased reliability.

With irrigation the differences in the yearly fertilizer responses of Pannónia SC have become smaller and the fluctuation of yields have decreased. The R-values show a strong correlation and its reliability is proved by the significance tests. The accuracy of approximation is good. Considering the value of the standardised regression coefficients, the linear, yield increasing influence is of greater importance. The linear part is dominating the line of the quadratic curve. Under irrigated conditions the optimum fertilizer dosage can be calculated much more precisely and with much greater reliability.

When growing Pannónia SC or a similar genotype without irrigation the suggested fertilizer dosage is 30-40 kg N/ha less, that is 100-110 kg/ha, so that to meet economical criteria. In irrigated stands, which means a higher level of yields, the economical fertilizer dosage is also greater (140 kg N/ha) than without irrigation because of the positive irrigation × fertilization interaction.

Keywords: maize, fertilization, irrigation

Introduction

Hungarian and foreign publications alike do agree on the factors which influence the effects of artificial fertilizers: the weather, soil characteristics, water supply, the uniformity of the crop and the nutrient response of the cultivated plant or variety. Since the weather regulates the heat and moisture supply of the growing area, it has an effect on the material transformations in the soil, on the growth and nutrient uptake of plants and, therefore, on the utilisation of fertilizers, too (Krámer 1963, Szász 1988, Kovács 1982, Láng *et al.* 1983, Szlovák 1986, Jolánkai 1993, Nagy 1988, Nagy *et al.* 1997, Ángyán *et al.*, Hall *et al.* 1994). According to the majority of experiments, in moderately dry years the fertilizer effect is average or good. In case of drought

maize suffers from serious water shortage resulting in considerable yield decrease (*Györfy et al.* 1965, *Debreczeni and Debreczeniné* 1983, *Ruzsányi* 1992, *Pakurár* 1997.). The amount of precipitation and the water reserve in the soil can change both the fertilizer requirement and the fertilizer effect. Towards the optimum water supply the fertilizer effect is increasing and then, reaching the point of adverse water surplus, it is decreasing again (*Bocz* 1976, *Ruzsányi* 1992). In the priority of the several factors that influence the yield increase of maize hybrids *Bocz* (1976) puts the nutrients first place and the variety second. According to him the magnitude of yields is primarily determined by the Nitrogen, whereas the necessary N dosage is affected by the endowments of the growing area, by the water supply and by the requirements of the hybrids. Foreign researchers such as *Kudzin et al.* (1976) have also called attention to the fact that the requirements of different maize hybrids should be considered when determining the dosage of fertilizers. In their experiments the differences in fertilizer effect on various hybrids varied between 4.6-27.4 %. *Balko and Russel* (1980) suggest that comparisons between hybrids should be made at such fertilizer rations that ensure the highest yields. On the other hand, *Nagy* (1995) claims that hybrids can be effectively compared in multi-stage fertilizer trials where the yields on non-fertilised plots will properly show the natural nutrient extracting ability of hybrids. According to *Menyhért* (1985) and *Menyhért et al.* (1980) there is also strong correlation between nutrient supply and crop density.

Irvine (1963) and *Mejendorf* (1971) wrote that the method and dosage of fertilization should not be decided upon on the basis of maximum achievable yields but solely on the basis of profitability. According to *Debreczeni* (1980) the upper limit of fertilization must be determined by the optimum level of efficiency deriving from extra yields.

Materials and Methods

In the fertilizer treatments there was a constant ratio of 1 N:0.75P₂O₅:0.88K₂O. The basic total dosage was 158 kg/ha, containing 60 kg/ha N, and we used 1-2-3-4-5-fold amounts of the basic dosage with a non-fertilised control. Since all treatments used the same NPK ratio, in the evaluation the dosages are referred to simply by the N content. By means of irrigation such an amount of water was applied that was near the calculated water requirement of the plants: 170, 60, 170 and 100 mm in 1990, 1991, 1992 and 1993, respectively. The irrigation equipment was a NADIR dropping system with 75 mm hole distances. The trial was set up in strip arrangement with four replications. There were 6 random fertilizer treatments in each replication, using a constant 70 thousand population density under irrigated and non-irrigated circumstances. The size of each replication was 1260 m² and the size of each fertilization plot was 210 m². Soil

characteristics. The soil of the Experimental Farm is calcareous chernozem with a lowland loess basic layer. It has average N and P supply and high K supply (humus content = 2.8-3.0 %, total N=0.14-0.18%, AL-P₂O₅=130-200 mg/kg, AL-K₂O=240-280mg/kg). The depth of the humus layer is 70-90 cm. The pH value (KCl) is 6.2, the "Arany"-type liquid limit is 43. Microelement deficiency cannot be detected. The ground water level is between 6-8 m. The minimum water holding capacity (WHC_{min}) of the soil is 27-29 volume %. The water storage capacity of the soil is 275 mm in the 0-100 cm profile and 265 mm in the 100-200 mm profile. The disponible WHC is 157 mm and 150 mm in the 0-100 and 100-200 mm profile, respectively.

Weather conditions. In 1990 the precipitation was less than the 50-year average, by 180 mm in the vegetation period and by 100 mm in the winter half year. In 1991 the precipitation in the vegetation period corresponded to the 50-year average (340 mm) and exceeded it in the winter half year. In 1992 the vegetation period was dry, the rainfall was 188 mm less than the 50-year average. Also the precipitation of the winter half year was below every record, only 92 mm, as opposed to the 50-year average of 243 mm. 1993 was a more favourable year for maize with 200 mm rainfall in the vegetation period. This was 50 mm more than in 1992, although still falling short of the 50-year average by 140 mm. In the winter half year, from the harvest of the previous crop until sowing, precipitation was about three and a half times more.

In order to ensure reliability in the evaluation we applied up-to-date experiment design methods in the planning of our research programme and used an improved version of the previously theoretically proved method by *Box and Wilson* (1951). In the evaluation of experimental data we applied correlation and regression analysis (Sváb 1981, *John* 1971, *Winer* 1971). Multiple linear regression was used in the regression analysis. When fitting the regression line the deviations' total sum of squares was minimised. In judging the reliability of fitting the following factors were considered: the multiple R-value, the result of the F-probe and the average value of the residual MQ (*Huzsvai* 1994). The parameters of the equation were tested by using the t-probe. Evaluation was done on a 486 DX computer using the 1988 version of the BMDP Statistical Software.

Results and Discussion

The effects of fertilization in the irrigated and non-irrigated treatments were investigated at six fertilization levels in four replications every year, using the 4-year yield data of Pannónia SC (see **Tabl. 1**). For the evaluation of the fertilization effect we used regression analysis and fitted a quadratic function.

The linear and quadratic values of fertilization were the independent variables and the yield was the dependent one. In every case we investigated the significance of the equation and its parameters, too. With the help of the first derivative of the quadratic equation we specified the maximum of the function as well as the corresponding fertilizer dosage. Using the first derivative again, we specified the fertilizer dosage and the corresponding yield for the pre-set tangent of the function (10 kg extra yield / 1 kg Nitrogen fertilizer per hectare).

Table 1: The effect of fertilization on the yield of Pannónia SC, tons/ha

Fertilizer active agent,	Without irrigation				
kg/ha	1990	1991	1992	1993	Average
Control	5,387	10,630	5,498	6,802	7,079
1	7,296	13,510	6,328	9,847	9,245
2	8,001	13,715	6,209	10,221	9,537
3	7,807	13,219	6,653	10,582	9,565
4	7,489	12,894	5,539	9,721	8,911
5	7,438	13,031	5,548	9,392	8,852
Average	7,236	12,833	5,963	9,428	8,865
	irrigated				
Control	10,348	10,739	6,588	7,562	8,809
1	11,462	13,612	10,774	11,243	11,773
2	13,142	14,708	11,008	12,745	12,901
3	13,594	13,338	10,881	12,450	12,566
4	13,074	13,290	10,125	12,461	12,238
5	12,593	13,064	9,979	11,460	11,774
Average	12,369	13,125	9,893	11,320	11,677
L.S.D. _{.5%} Fertilization	0,32	0,99	0,82	0,46	0,35
Irrigation	0,19	0,57	0,47	0,26	0,20

1= 60 kg N+45 kg P₂O₅+53 kg K₂O; 2= 120 kg N+90 kg P₂O₅+106 kg K₂O; 3= 180 kg N+135 kg P₂O₅+159 kg K₂O; 4= 240 kg N+180 kg P₂O₅+212 kg K₂O; 5= 300 kg N+225 kg P₂O₅+265 kg K₂O;

The statistical evaluation of the non-irrigated treatments of Pannónia SC can be found in **Tabl.**

2. The multiple R-value (0.27) is rather small and the error of the estimation is high: 2.779 tons/ha. The small R-value does not mean that the quadratic function is inappropriate for

the description of the correlation since its validity is proved by the F-probe at 3 % significance level. Based on the t-probe the linear and the quadratic terms are significant at 1 % and 2 % level, respectively, and their importance is roughly equal.

Table 2.: Statistical results of Pannónia SC, without irrigation

Source of variance	SQ	FG	MQ	F-value	Significance level *
Regression	56,5519	2	28,2760	3,660	≈ 0,03
Remainder	718,4927	93	7,7257		
Independent variable	Regression Coefficient	Error of Coefficient	Standard regression coefficient	t-value	Significance level **
Fertilizer	0,0259	0,0099	0,94	2,63	≈ 0,001

* = in case of one-tailed test

** = in case of two-tailed symmetric test

The statistical evaluation of the irrigated treatments can be seen in **Tabl. 3**. The multiple R-value (0.66) is higher than in the non-irrigated treatments. The accuracy of approximation has improved (1.495 tons/ha) and the F-probe indicates that the reliability of the quadratic function fitting is also better. Considering the significant linear and quadratic members of the equation, the linear one is of greater importance.

Table 3: Statistical results of Pannónia SC, with irrigation

Source of variance	SQ	FG	MQ	F-value	Significance level *
Regression	158,0902	2	79,0451	35,357	≈ 0,00
Remainder	207,9113	93	2,2356		
Independent variable	Regression Coefficient	Error of Coefficient	Standard regression coefficient	t-value	Significance level **
Fertilizer	0,0417	0,0053	2,19	7,86	≈ 0,00

* = in case of one-tailed test

** = in case of two-tailed symmetric test

On the basis of the analysis results with several years' yield data it can be concluded that in non-irrigated treatments the approximation with a quadratic function shows a weak or moderately strong correlation between fertilization and yields. The error of estimation is quite big, the reason of which lies with the great variations of the yearly harvest, that is, the fluctuation of yields that happens without irrigation. Due to the changeable water supply the effect of fertilization is also extensively changing year by year. Under such circumstances the optimum fertilizer dosage can only be calculated with decreased reliability. Because of the drought characteristic of the years the effects of the linear, yield increasing, and quadratic, depressing, influences are roughly equal.

With irrigation the differences in the yearly fertilizer responses of the Pannónia SC have become smaller and the fluctuation of yields have decreased. The R-values show a strong correlation and its reliability is proved by the significance tests. The accuracy of approximation is good. Considering the value of the standardised regression coefficients, the linear, yield increasing influence is of greater importance. The linear part is dominating the line of the quadratic curve. Under irrigated conditions the optimum fertilizer dosage can be calculated much more precisely and with much greater reliability.

The maximum yields of Pannónia SC and the corresponding fertilizer ratios are presented in **Tabl. 4**. The experimental results show that the maximum yield can only be achieved with high fertilizer dosage. With irrigation the maximum yield is achieved at a higher level and, due to the improved efficiency of fertilizers, the need for nutrients hardly increases.

Besides determining the fertilizer dosage for the maximum yield of Pannónia SC we also calculated the fertilizer ratio that corresponds to 10 kg grain yield so that to determine the economical dosage. The results are shown in **Tabl. 5**.

Table 4: Fertilizer dosage for the maximum yield of Pannónia SC

	N kg/ha $X_{\max}$	Yield, t/ha $Y_{\max}$	Growth t/ha	Average fertilizer efficiency, kg/kg
Without irrigation	175	9,682	2,267	13
Irrigated	183	12,992	3,817	21

Table 5: Marginal efficiency of fertilization in Pannónia SC

	Marginal efficiency 10 kg/kg fertilizer	Yield t/ha	Growth t/ha	Average fertilizer efficiency, kg/kg
Without irrigation	108	9,344	1,930	18
Irrigated	139	12,772	3,597	26

When growing Pannónia SC or a similar genotype without irrigation the suggested fertilizer dosage is 30-40 kg N/ha less, that is 100-110 kg/ha, so that to meet economical criteria. In irrigated stands, which means a higher level of yields, the economical fertilizer dosage is also greater (140 kg N/ha) than without irrigation because of the positive irrigation × fertilization interaction.

Acknowledgements

This research was supported by the Hungarian National Research Fund (OTKA T031989).

References

- Ángyán, J., Menyhért, Z., Radics L., Seres J., Jeney, Cs., Tánczos, F., Pécsi, M. 1982. Ecologic classification of data from maize production using factor and cluster analysis. *Növénytermelés* 31: 141-153.
- Balko, L.G., Russel, W.A. 1980. Effects of rates of nitrogen fertilizer on maize inbred lines and hybrid progeny. I. Prediction of yield response. *Maydica, Bergamo*, 25:2, 65-79.
- Bocz, E. 1976. Fertilization guide. *Mezőgazdasági Kiadó, Budapest*.
- Box, G.E.P., Wilson, K.B. 1951. On the Experimental Attainment of Optimum Conditions. *Journal of the Royal Statistical Society*, 13:1.
- Debreczeni, B. 1980. Artificial fertilization. *Acta Agronomica*, 29:117-225.
- Debreczeni, B., Debreczeni, B.-né 1983. The connection between nutrients and water supply. *Mezőgazdasági Kiadó, Budapest*.
- Györffy, B., Izsó, I., Bölöni, I. 1965. Maize production. *Mezőgazdasági Kiadó, Budapest*.
- Hall, D.O., Scurlock, J.M.O., Bolhar-Nordenkamp, H.R., Leegood, R.C., Long, S.P. 1994. Photosynthesis and Production in a Changing Environment, Chapman & Hall, London.
- Huzsvai, L. 1994. Comparison of biometric methods of crop production and soil cultivation experiments. D. Univ. Theses, Debrecen.
- Irvine, F.R. 1963. Soils and crops. Oxford University Press, London.
- John, P.W.M. 1971. Statistical Design and Analysis of Experiments. New York, McGraw-Hill.
- Jolánkai, M. 1993. Certain decisive factors of wheat production. D. Sc. Theses, Martonvásár.
- Kovács, G. J. 1982. The critical eco-physical relationship between the water and nutrient dynamics of maize. *Növénytermelés*, 31:4, 355-365.
- Kramer, P.I. 1963. Water stress and plant growth. *Agron J. Madison*, 55: 31-35.
- Kudzin, JU., Csernaszkaja, N., Csuh, T. 1976. Ocenka gibridov po ih otzürsivoszti na udobrenija. *Kukuruza, Moszkva*, 3:20.
- Láng, I., Csete, L., Harnos, Zs. 1983. The agro-ecological potential of the Hungarian agriculture at the turn of the millennium. *Mezőgazdasági Kiadó, Budapest*.
- Mejendorf, A.L. 1971. Prosztjesij metod opredelenija ekonomicseszki optimalnük norm vneszenija udobrenij. In: *Voproszű ekonomiki himizacii szelszkogo hozjajsztva v zarubeznüh sztrana. Nauki, Moszkva*, 265-279.
- Menyhért, Z. 1985. Maize production handbook (ed. Menyhért, Z.). *Mezőgazdasági Kiadó, Budapest*.
- Menyhért, Z., Ángyán, J., Radics L. 1980. Relationship between leaf area index (LAI), light conditions and yield in maize stands of different sowing time and vegetation period. *Növénytermelés*, 29:4, 357-369.
- Nagy, J. 1988. Performance of maize hybrids as effected by fertilization and irrigation I. *Növénytermelés*, 37:4, 327-336.
- Nagy, J. 1995. Evaluation of fertilization effect on the yield of maize (*Zea mays* L.) in different years. *Növénytermelés*, 44:5-6. 493-506.
- Nagy, J., Rátónyi, T., Pakurár, M., Szabó, Gy., Bodán, I., Megyes A., Dobos, A. 1997. The effects of fertilization on the yield of maize Soil, Pland and Environment Relationship Debrecen Agricutural University, 105-114.
- Nagy, J., Rátónyi, T., Pakurár, M., Szabó, Gy., Bogdán, I., Megyes, A., Dobos, A. 1997. Interrelations of soil cultivation systems and fertilization. *Land Use and Soil Management Debrecen Agricultural University*, 194-207.
- Pakurár, M. 1997. Evaluation of fertilization effect on the leaf area and yield of maize. *Soil, Pland and Environment Relationship Debrecen Agricutural University*, 291-295.
- Ruzsányi, L. 1992. The relationship between major crop production factors and the water supply. D. Sc. Theses, Debrecen.

- Sváb, J. 1981. Biometric methods in research. Mezőgazdasági Kiadó, Budapest.
- Szász, G. 1988. Agrometeorology. Mezőgazdasági Kiadó, Budapest.
- Szlovák, S. 1986. The effect of nitrogen doses and different water supply upon nitrogen utilization of maize. Act. Agron. Hungarica, 35: 239-255.
- Winer, B.J. 1971. Statistical Principles in Experimental Design. New York, McGraw-Hill.

EXAMINING THE EFFECT OF FERTILIZER ON THE YIELD OF MAIZE (ZEA MAYS) IN DIFFERENT YEARS

T. Rátonyi, D. Sulyok and L. Huzsvai

Department of Land Use and Rural Development, Center for Agricultural Sciences
University of Debrecen, Hungary

Summary

The effect of fertilization on the yield of maize was examined on chernoem soil with lime deposits at the experimental station at Látókép of the Center for Agricultural Sciences, University of Debrecen. The yields of maize were evaluated, by using quadratic regression function, in three years – between 2000 and 2002 – in non-irrigated and irrigated treatments. After calculating the regression equations, by derivation of the functions, we have determined the amount of fertilizers needed for maximum yield.

In the non-irrigated treatments, maximum yield and the active substance amount of fertilizer was as it follows: in 2000, yield of 9,133 t/ha with the application of 384 kg/ha mixed active substance, while in 2002 a yield of 6,289 t/ha with the application 236 kg/ha NPK active substance was achieved. In 2001, due to the favourable precipitation, a yield of 9,864 t/ha was achieved with the application of 245 kg/ha fertilizer. In the case of maximum yield, compared to the unfertilized control, the yield increase was 2,5 – 5 t/ha. The average increase for 1 kg of NPK fertilizer was 13-19 kg.

We have also determined the necessary fertilizer dosage for maximum yield in irrigated treatments. In 2000, 10,003 t/ha with a dosage of 423 kg/ha, in 2001, 11,542 t/ha with a dosage of 277 kg/ha and in 2002, 8,596 t/ha of maximum yield could be achieved with a fertilizer treatment of 277 kg/ha in the examined three years. The yield increase, in irrigated treatments, varied between 3,9 – 5,9 t/ha so it was greater than in the case of non-irrigated experimental plots. The yield increase for 1 kg fertilizer varied between 12 – 21 kg.

Introduction and bibliographical overview

We can often come across contradictory knowledge regarding the nutrient supply and fertilization of maize. According to Balás (1888): „maize tolerates the greatest possible fertilization and we do not have to be afraid that heavy fertilization will cause any harm”.

Cserhádi's opinion is very similar: „the more manure we apply, the greater maize yield will be”. In the beginning of maize fertilization experiments – since 1955 – the basic theory was that

maize responds less favourably to greater dosage of fertilizer than other eared plants. According to Grábner (1965): „if we apply manure under maize plants, then fertilization is unnecessary”.

Győrffy (1966) stated that maize planted on soil with high cultivation value does not really react to the directly applied manure with extra yield but rather to the nutrient supply level of the soil. Other authors have also stressed that it is more proper to plan fertilization in the framework of the whole crop rotation (Surányi 1957, Bauer 1959, Dezső and Martin 1965).

Between 1956 and 1960, in the fertilizer experiment of Sarkadi and Bánó, carried out on chernozem meadow soil, the first three years did not while the last two years did result in a significant yield difference between the control yields of the fertilized and unfertilized treatments. It also came to light that in droughty years, fertilization can result yield depression. However, on soils with poor nutrient supply the smaller dosage of fertilization resulted in more reliable yields that were less vulnerable to weather.

The long-term fertilizer experiments carried out by Győrffy (1979) characterise the increase of fertilizer optimum quite well with the progress of time. In the case of hybrids cultivated in the 1960's, the applied nitrogen was 80-120 kg and in this range the yield curve palled out. In the 1970's the nitrogen optimum increased to 100-160 kg/ha.

The water supply of a specific area plays an important role in the utilization of fertilizers' active agent especially in the case of nitrogen (Bocz 1976). Both the Hungarian and foreign authors agree that the effect of fertilizers is greatly influenced by weather. Weather influences the heat and moisture supply and has an indirect effect on clay transformation in soils, plant growth, nutrient uptake, quantity of yield and thus on the utilization of manure. (Hank and Frank 1951, Szász 1988, Kovács 1982, Jolánkai 1982, nagy 1988, Ángyán 1991, Kádár 1992, Varga-Haszoics and Mikéné-Hegedűs 1993, Hall et al. 1994).

In the majority of the experiments medium or good fertilizer effect can be detected in years of high precipitation. In case of severe drought – in the first half of the vegetative season – the plant develops well, but in the second half of the vegetative season – due to the great leaf surface index and the increased water demand - a severe water deficiency occurs, which will result in a significant yield depression (Debreczeni and Debreczeniné 1983, ruzsányi 1992, Berzsényi 1993).

The amount of precipitation, and the moisture resources of the soil significantly modifies fertilizer requisites and and fertilizer effect. In case of optimum water supply, fertilizer effect increases but when it reaches the level of harmful water surplus, the effect of fertilizers

decreases (Harmati 1987). The influence of soil characteristics depends on the soil fertility, thickness of cultivation layer and water balance (Sarkadi 1975, Búzás 1987, Németh and Búzás 1991, Ruzsányi 1992). Optimum nitrogen supply contributes significantly to number of grains per maize cobs, less significantly to the increase of kernel weight (Bocz and Nagy 1981). In case of nitrogen deficiency, the accumulation of dry matter and the dynamics of dry matter accumulation is slower (Debreczeniné and Szlovák 1985, Hanway and Russel 1969, Berzsenyi 1993). Good nutrient supply promotes the fast, early increase of leaf surface index of maize and because of this the optimum LAI value can be maintained longer which is favourable for endurance of biomass and the flow of assimilates into the grain yield (Anderson et al. 1985, Berzsenyi 1993). In case of drought, this favourable characteristic does come with economic benefit because maize is deprived of water in the early phase of the vegetative season which reaches its peak in the reproductive season and thus the yield decreases.

The method and degree of fertilization should be determined not on the basis of the different maximum yield but rather on the basis of profitability (Irvine 1963, Mejendorf 1971). The upper limit of fertilizer use has to be determined on the level economic optimum arising from extra yield (Debreczeni 1980).

Materials and Method

The Center for Agricultural Sciences of Debrecen University in cooperation with KITE of Nádudvar, a three factorial (fertilizer, irrigation and genotype) experiment was started. The experiment is carried out on chernozem soil with lime deposits, where we examine the productivity, natural nutrient utilizing ability, fertilizer requirement and utilization of ten maize hybrids annually.

The fertilizer treatments: 1 N: 0,75 P₂O₅ : 0,88 K₂O constant ratio NPK dosage experiment, where the basic dosage is 79 kg/ha – from which N 30 kg/ha – and we applied 1,2,3,4,5 times the dosage along with unfertilized control. The identical NPK ratio dosages were simply marked with the amount of nitrogen, during the evaluation. We have applied the amount of irrigation close to the water demand of the irrigated plant.

We have used the De 377 hybrid into research. The experiment is setup in lanes with four repetitions. Within one repetition, we have used the same plant density with six fertilizer treatments and ten hybrids in random order, in irrigated and non-irrigated versions. The size of the repetition is 1260 m², the fertilized parcels were 210 m². The total number of parcels were 6 treatments x 10 hybrid = 60 x 4 repetitions = 240 x 2 (irrigation) = 480.

Soil characteristics: The soil of the experimental station is lowland calcareous chernozem formed on loess. The nitrogen- and phosphorous supply of the soil is medium. Its potassium content is high (humus content 2,8 – 3 %, total N 0,14 – 0,18 %, Al-P₂O₅ 130-200 mg/kg, AL-K₂O 240 – 280 mg/kg). The thickness of humus layer is 70-90 cm. The pH (KCl) value is 6,2, soil plasticity (K_A) is 43. Microelement deficiency cannot be detected. The groundwater level is between 6-8 meters. The VK_{min} value of soil is 27-29 tf %. The 0-100 cm soil profile can store 275 mm, while the 100-200 cm stores 265 mm of moisture. The available VK at 0-100 cm is 157 mm, at 100-200 cm is 150 mm.

Weather characteristics: In the examined period the precipitation for maize was unfavourable. All three years were dry. In 2001 and 2002 spring drought, while in 2000 a severe drought was experienced.

Data, obtained during the experiment, was evaluated with correlation- and regression analysis (Sváb 1981, John 1971, Winer 1971). The applied fertilizer, irrigated treatments and setup were considered during the preparation of the analysis, using the yields in the average of ten maize hybrids.

During the regression analysis we have used a quadratic function. We have minimized the square sums of the deviations. In order to determine if the analysis was good, we have considered the multiple R value, the result of the F probe and the average amplitude of the square residual MQ (Huzsvai 1994). The parameters of the function were tested with a t-probe.

The evaluation was done with the help of an IBM compatible computer and the SPSS software.

Results and Conclusions

The effect of fertilization on yield were evaluated with the help of regression in irrigated and non-irrigated forms, in the average of three years and annually for the years of the 2000-2002 period, on the basis of dosage experiment setup on the experimental farm of Látókép of the University of Debrecen, Center for Agricultural Sciences. During our calculations we have applied deviation calculations and we have characterised natural nutrient utilization with the help of this.

We have checked whether the function is correct along with multiple R-value with the variance analysis of the regression, with F probe and its accuracy by determining the standard error of the estimate. The correctness of the equation's parameters were checked with the help of the t-probe, and applied a bilateral symmetrical test to consider significance.

Following the calculations of regression equations, we have carried out the derivation of functions and with the help of this we have determined the quantity of fertilizer dosage necessary for yield maximum and the maximum yield of maize.

Table 1: The effect of fertilization on the yield of maize

Active compound of fertilizer kg/ha	Unirrigated			
	2000	2001	2002	Average
Control	4,16	5,16	3,9	4,41
1	5,99	7,58	4,89	6,15
2	7,56	9,3	5,81	7,56
3	8,2	10,26	6,68	8,38
4	9,13	9,01	6	8,05
5	9,08	8,22	5,01	7,44
Average	8,37	8,25	5,38	7,33
Active compound of fertilizer kg/ha	Irrigated			
	2000	2001	2002	Average
Control	6,01	5,99	5,01	5,67
1	7,79	7,97	6,17	7,31
2	9,12	10,45	7,41	8,99
3	9,64	11,97	9,01	10,21
4	10,19	11,29	8,8	10,09
5	10,73	10,37	7,76	9,62
Average	8,91	9,67	7,36	8,65

1=30 kg N+22,5 kg P₂O₅+27,5 K₂O; 2=60 kg N+45 kg P₂O₅+ 53 K₂O 3=90 kg N+ 67,5 kg P₂O₅+ 70,5 K₂O 4=120 kg N+90 kg P₂O₅+ 98 K₂O 5=150 kg N+112,5 kg P₂O₅+ 125,5 K₂O

2000 was a dry year. In the growing season, 180 mm less precipitation fell than in the average of 50 years (340 mm), in the winter period however more precipitation fell than in average years. In the case of all fertilizer scales, the yield of the De 377 hybrid – both in the irrigated and unirrigated treatments – was average. The maximum yield was 10,003 t/ha, which was achieved with the application 277 kg NPK mixed active compound.

Precipitation in 2001 was average, or slightly higher than average. This period was more favourable for maize than the previous year, precipitation that fell during the growing season met the average of 50 years. In the precipitation data of the winter term significant deviation appeared, about twice as much precipitation fell between the harvest of pre-sowing and sowing than in the same term of the previous year. The maximum yield was 11,542 t/ha, which was achieved with the application of 277 kg of mixed NPK active compound.

In 2002, the growing season was dry. A 100 mm less precipitation fell, than the average of 50 years. This mainly affected the first half of the growing season, and accordingly it had great effect on the yields. The precipitation of the winter term was average, this influenced the great

precipitation deficiency favourably. The maximum yield was 8,596 t/ha, which was achieved with the application of 287 kg of fertilizer active compound.

The validation of fertilization in the unirrigated treatments

The results of the statistical evaluation regarding unirrigated treatments are shown in table 2-4. On the basis of statistical evaluation of unirrigated treatments, the multiple R-values were between 0,80-0,92 during the three years, which on the basis of the F-probe were proved to be significant under the level of 0,1 % with the help of unilateral test. The parameters of the equation, both the linear and the squared term were significant under the level of 0,1 % on the basis of t-probe.

During the three years, the average error of the estimate was between 600-900 kg/ha. We have carried out in all three years, the series correlation of residual values. Their values fluctuated between 0,07 – 0,17. We have determined, that the accuracy of our estimate did not depend on the magnitude of the yield average.

On the basis of the collective evaluation of the three years, we have got the highest yield, 9,864 t/ha with the application of 245 kg of NPK mixed active compound. In this case, the last kilogram applied mixed compound resulted a 13 kg yield increase, thus from an economic point of view it is not worth it to apply this fertilizer dosage.

With the help of the function's derivatives, we have determined the quantity of NPK fertilizer active compound which, in 2000 with a dosage of 384 kg /ha fertilizer active compound resulted 9,133 t/ha, in 2001 with a dosage of 245 kg/ha NPK dosage resulted 9,864 t/ha, and in 2002 with a dosage of 236 kg/ha resulted 6,289 t/ha maximum yield.

Table 2: The statistical result of the De 377 maize hybrid, unirrigated, Debrecen 2000.

The source of variance	SQ	FG	MQ	F-value	Significance level
Regression	75,494223	2	97,747111	58,41827	0,0000
Residue	13,569203	21			
Independent variables	Regression coefficient	Error of the coefficient	Standardized regression coefficient	t-value	Significance level
Fertilizer	0,025861	0,004316	1,811921	5,3992	0,0000
Fertilizer²	-0,0003364	0,000010464	-0,972288	-3,215	0,0042
Constant	4,163266	0,364779		11,413	0,0000

Table 3: The statistical result of the De 377 maize hybrid, unirrigated, Debrecen 2001.

The source of variance	SQ	FG	MQ	F-value	Significance level
Regression	61,095322	2	30,547661	45,02057	0,0000
Residue	14,249063	21	0,678527		
Independent variables	Regression coefficient	Error of the coefficient	Standardized regression coefficient	t-value	Significance level
Fertilizer	0,038737	0,004423	2,950822	8,759	0,0000
Fertilizer ²	-0,000079089	0,000010723	-2,484884	-7,376	0,0000
Constant	5,120599	0,373806		13,699	0,0000

Table 4: The statistical result of the De 377 maize hybrid, unirrigated, Debrecen 2002.

The source of variance	SQ	FG	MQ	F-value	Significance level
Regression	44,384815	2	22,192408	30,47543	0,0000
Residue	15,292337	21	0,728207		
Independent variables	Regression coefficient	Error of the coefficient	Standardized regression coefficient	t-value	Significance level
Fertilizer	0,027223	0,004582	2,330085	5,942	0,0000
Fertilizer ²	-0,000047483	0,000011109	-1,676289	-4,274	0,0003
Constant	4,694414	0,387248		12,122	0,0000

The evaluation of fertilization effect in irrigated treatments

The results of statistical evaluation in irrigated treatments are shown in table 5-7. The multiple R values were between 0,86-0,95 during the three years. According to the F-probe, fertilization and the yield of maize shows strong correlation under the level of 0,1% significance in all three years. The approximation with a quadratic function varied between 0,8-1,2 t/ha. The t-probes proved the significance of linear and squared members at less than 0,1 %. The differences between the estimated and observed yield averages are independent, they do not depend on the quantity of the yield.

With the help of the function's derivatives, we have determined the quantity of NPK fertilizer active compound which, in 2000 with a dosage of 423 kg /ha fertilizer active compound resulted 10,003 t/ha, in 2001 with a dosage 277 kg/ha NPK dosage resulted 11,542 t/ha, and in 2002 with a dosage of 287 kg/ha resulted 8,596 t/ha maximum yield.

Table 5: The statistical result of the De 377 maize hybrid, irrigated, Debrecen 2000.

The source of variance	SQ	FG	MQ	F-value	Significance level
Regression	70,116186	2	35,058093	102,05615	0,0000
Residue	7,213872	21	0,343518		
Independent variables	Regression coefficient	Error of the coefficient	Standardized regression coefficient	t-value	Significance level
Fertilizer	0,023026	0,003147	1,731315	7,317	0,0000
Fertilizer ²	-0,000027194	0,0000076299	-0,843355	-3,564	0,0018
Constant	5,128675	0,265973		19,283	0,0000

Table 6: The statistical result of the De 377 maize hybrid, irrigated, Debrecen 2001.

The source of variance	SQ	FG	MQ	F-value	Significance level
Regression	98,696295	2	49,348147	54,87805	0,0000
Residue	18,883891	21	0,899233		
Independent variables	Regression coefficient	Error of the coefficient	Standardized regression coefficient	t-value	Significance level
Fertilizer	0,042480	0,005092	2,590354	8,343	0,0000
Fertilizer ²	-0,000076793	0,000012345	-1,931371	-6,221	0,0000
Constant	5,667770	0,430327		13,171	0,0000

Table 7: The statistical result of the De 377 maize hybrid, irrigated, Debrecen 2002

The source of variance	SQ	FG	MQ	F-value	Significance level
Regression	44,384815	2	22,192408	30,47543	0,0000
Residue	15,292337	21	0,728207		
Independent variables	Regression coefficient	Error of the coefficient	Standardized regression coefficient	t-value	Significance level
Fertilizer	0,027223	0,004582	2,330085	5,942	0,0000
Fertilizer ²	-0,000047483	0,000011109	-1,676289	-4,274	0,0003
Constant	4,694414	0,387248		12,122	0,0000

- Examining the slope of the quadratic function we can determine that we get a great yield at relatively low nutrient levels. Following this, the slope is moderate and around the yield maximum a longer constant section can be observed. In this section the quantity of yield barely changed. The slope of the quadratic function is so small in this function that with the decrease of fertilizer belonging to maximum yield, the quantity of the yield decreases only on a small scale. This means, that even with lower levels of fertilization we get closely maximum yield and this is a very important result from a practical point of view.
- During the examined three years, the maximum total yield was achieved with the application of 277 kg/ha NPK mixed active substance. This fertilizer dosage can be recommended, because in this case the marginal efficiency of fertilization is 21 kg/kg,

so it can be considered favourable. In the case of the maximum yield, yield increase compared to the unfertilized treatment varied between 2,6 and 5 t/ha, the average increase for 1 kg fertilizer was 13 – 19 kg (table 8).

- In the case of the irrigated treatments, the yield increasing effect of fertilization was greater than in unirrigated treatments. Greater yield however, does not always mean greater fertilizer dosages. About the marginal efficiency of fertilization we can say, that usually – excluding the year of 2000. – the marginal efficiency of the irrigated treatments is higher than that of the unirrigated treatments.
- The quantity of the economic fertilizer dosage always depends on the economic environment. In order to determine the quantity of the economical fertilizer dosage – by using the data of the experiment – we have determined the fertilizer active compound quantities belonging to 15 kg grain yield, so the these values can be benchmarked to different economic conditions quite well. We have carried out the evaluation for both unirrigated and irrigated parcels. In the case of irrigated treatments, the marginal efficiency of fertilization was 10 kg/kg in 2001, so in this case the value of boundary productivity is –5, so it is worth to increase the quantity of fertilization, while in the irrigated treatment this unfavourable situation arose in 2000.
- The conclusion from all this, that on sites similar to the experimental location 236-384 kg/ha mixed active compound without irrigation while in irrigated treatments the application of 277-423 kg/ha NPK active compound can be recommended, in the case of the De 377 hybrid.

Table 8: Values belonging to maximum yield, Debrecen 2000-2002

Years	NPKmax.	Yield t/ha	Increase t/ha	Average fertilizer efficiency kg/kg
Non-irrigated				
2000	384	9,133	4,969	13
2001	245	9,864	4,743	19
2002	238	6,289	2,574	11
Average				
Irrigated				
2000	423	10,003	4,874	12
2001	277	11,542	5,875	21
2002	287	8,596	3,902	14
Average				

Table 9: The average efficiency of fertilization

Years	Marginal efficiency 15 kg/kg fertilizer	Yield t/ha	Increase t/ha	Average fertilizer efficiency kg/kg
Non-irrigated				
2000	161	7,461	3,297	20
2001	150	9,153	4,032	27
2002	74	5,073	1,358	18
Average				
Irrigated				
2000	148	7,934	2,805	19
2001	179	10,81	5,142	29
2002	129	7,412	2,717	21
Average				

Acknowledgements

This research was supported by the Hungarian National Research Fund (OTKA T042749).

References

- Anderson F. L. – Kamprath F. J. – Moll, R. H.: 1985 Prolificacy and N-fertilizer effects on yield and N utilization in maize. *Crop Sci* 25: 598-602.
- Berzsenyi, Z.: 1993: The effect of N-fertilization and year on the grain yield of maize hybrids and on N-fertilizer reaction, in long term experiments in the years of 1970-1991. *Növénytermelés* 42: I 49-63
- Bocz, E.-Nagy, J.: 1981 Optimizing the water- and nutrient supply of maize and its effect on the weight of the yield. *Növénytermelés* 30:6 539-549
- Boksz. G. E. P.- Wilson K. B.: 1951 On the Experimental Attainment of Optimum Conditions. *Journal of the Royal Statistical Society* 13:1
- Debreczeni, B.: 1980. Artificial fertilization. *Acta Agronomica* 29: 117-225.
- Debreczeni, B.-Debreczeni, B-né: 1983. Correlation of nutrient and water supply. *Mezőgazdasági Kiadó, Budapest*
- Győrffy, B.: 1966. The effect of different plant cultivation factors on the yield of maize. *Komplex I. In: Kukoricatermesztési Kísérletek 1961-1964. (szerk. I'so I.) Akadémiai Kiadó, Budapest, 67-74*
- Győrffy B.: 1979. Breed, plant density- and fertilizer effect in maize cultivation. *Agrártud. Közl.* 38: 309-331
- Hall D. O.- Scurlock, J. M. O.-Bolhar-Nordenkamp, H. R.-Leegood, R. C.-Long, S. P.: 1994. *Photosynthesis and Production in a Changing Environment*, Chapman and Hall, London
- Hanway, J. J.-Bussel W. A.: 1969. Dry-matter accumulations in corn plants: Comparisons among singlecross hybrids. *Agron J.* 61: 947-951
- Huzsvai, L.: 1994. Comparing the biometrical methods of plant cultivation and land use experiments. Doctorate thesis, Debrecen
- Irvine, F. R.: 1963. *Doils and crops*. Oxford University Press London
- John p. W.: 1971. *Statistical Design and Analysis of Experiments*. New York, McGraw-Hill
- Káposzta, J.: 1974. Winter and spring tillage, and the effect of direct sowing in maize production. *Talajtermékenység V.* 19-32
- Kovács, G. J.: 1982. The critical ecophysical correlation of water- and nutrient dynamics of maize. *Növénytermelés* 31. 4. 355-365
- Nagy, J.: 1988. The effect of fertilization and irrigation on the yield of maize hybrids.I. *Növénytermelés* 37:4 327-336
- Nagy, J.: 1988. The effect of fertilization and irrigation on the yield of maize hybrids II. *Növénytermelés.* 37:5 45-48
- Winer, B. J.: 1971. *Statistical Principles in Experimental Design*. new York, McGraw-Hill

EFFECT OF FERTILIZATION AND IRRIGATION ON MAIZE (ZEA MAYS L.) PRODUCTION IN A LONG-TERM EXPERIMENT

A. Megyes*, T. Rátonyi, L. Huzsvai

Department of Land Use and Rural Development, Centre of Agricultural Sciences, Debrecen University
Böszörményi u. 138., H-4032 Debrecen Hungary
Tel: +36 (52) 485 709, Fax: +36 (52) 413 385
E-mail: megyesat@helios.date.hu

Abstract

In a long-term field experiment set up in the Látókép experimental station of the Center of Agricultural Sciences of Debrecen University, the data of the last five years (1995-1999) were analyzed to determine the crop production factors with the greatest influence on maize production and the relationship and interactions between irrigation and fertilization.

In the extremely dry year of 1995 fertilization was found to cause substantial yield depression in the absence of irrigation. According to results of analysis of variance fertilization significantly reduced the maize yield by 40-90 % compared to control plots. Under irrigated conditions there was a considerable increase in the maize yield, the yield surplus being 4.4-9.4 t ha⁻¹, depending on the nutrient supply level.

During the period from 1996-1999, when the rainfall conditions were favorable for maize, fertilization significantly increased the maize yield even without irrigation over the average of the four years. The yield surplus due to fertilization was 3.9-4.6 t ha⁻¹, depending on the fertilization rates. The maximum yield surplus was obtained on plots fertilized with 120 N kg ha⁻¹, while at the rate of 240 N kg ha⁻¹ the maize yield did not differ significantly from this value. During the period examined corn yield was significantly higher at all three nutrient supply levels as the result of irrigation than in the non-irrigated treatment. As in the case of non-irrigated conditions, the highest fertilizer dose did not result in a substantial yield increase. An analysis of the interaction between fertilization and irrigation indicated that the yield-increasing effect of fertilization was not significantly different under irrigated and non-irrigated conditions. The significant year x irrigation interaction was confirmed by the fact that the yield surplus (1.3-2.3 t ha⁻¹) differed greatly from the irrigation effect recorded in 1995.

Introduction

Both the Hungarian both the foreign scientific publications agree that, from the factors influencing fertilizer effect - weather, soil characteristics, water supply, uniformity of plant stock, the cultivated plant and the fertilizer reaction of the strain are the most decisive. Weather – since it regulates the heat and moisture supply of the growing site – has an effect on the transformation of materials, the growth of plants, nutrient uptake and thus on the influence of fertilizers (Kramer 1963, Kovács 1982, Nagy 1996). The amount of precipitation, or the moisture stored in the soil modifies the need for manure as well as the effect of fertilization. The effect of fertilization increases when approaching optimal water supply and decreases when harmful water excess is reached (Nagy 1994). The irrigation and fertilization experiment results

of Nagy (1995, 1997) have justified, that irrigation increases the efficiency of fertilization and there is a strong correlation between fertilizer utilization and the water supply of plants. In irrigated treatment – which means a higher yield level – due to the positive correlation between irrigation x fertilization, the economic fertilizer doses are greater than without irrigation. In irrigated cultivation the effect of year is moderate and yield fluctuation decreases.

Results of experiments have proved, that irrigation in general increases the yield of maize and especially in cases of drought. If precipitation and the easily accessible water supply of the soil do not satisfy the needs of the plant, then the deficiency has to be compensated with irrigation (Petrasovits 1978). Irrigation will be more and more important, on certain parts of the country, for safe and intensive production of maize (Szőke Molnár 1977). Especially the period from the second half of the 1980's until the mid 1990's, which was extremely droughty, put irrigation in the center of attention. Accurate irrigation forecast can only be given if there is knowledge about precipitation and soil moisture conditions regarding the plot (Balogh 1978).

Materials and Methods

The conditions of the experiment. We have examined the correlation and existing relationships among the factors that are of great significance, especially between irrigation and fertilization, on the basis of evaluating the data of the past 5 years (1995, 1996-1999) of experiments carried out at Látókép of the Center for Agricultural Sciences, Debrecen University. The location of the examinations was the multi-factorial long-term experiment set up at the Experimental Station of Látókép, on mid-bound chernozem soil with lime deposits. The long-term experiment was in split-split-plot set up, the soil cultivation and irrigation variants were in the main plot without repetitions. On the primary subplots, the maize hybrids were set up in 30-50-70-90 thousand-plant densities, while on the secondary sub-plots the fertilizer treatment was in four repetitions in random order. One soil cultivation block takes up 8756 m², which is divided into an irrigated and unirrigated block. The plot of the fertilizer treatments is 2918m², in four repetitions. The examined hybrid was the Dekalb 471 SC hybrid. In our experiments, we had winter tillage (27 cm) cultivation method. The examinations were carried out on unfertilized (control) plots with N₁₂₀P₉₀K₁₀₈ kg ha⁻¹ and N₂₄₀P₁₈₀K₂₁₆ kg ha⁻¹ doses, with 70000 ha⁻¹ plant density, in unirrigated and irrigated treatments. The total amount of fertilizer was applied in the fall, without any division. During irrigation, an amount close to the water needs of the maize stock was applied. Our research in this topic was supported by the Hungarian Scientific Research Fund (T029276, T31989).

Soil characteristics: The soil of the Experimental Station is lowland chernozem with lime deposits. The N- and P- supply of the soil is medium, its K- content is high (humus content =2.8-3.0%, Total N=0.14-0.18%; $\text{Al-P}_2\text{O}_5 = 130\text{-}200 \text{ mg kg}^{-1}$, $\text{Al-K}_2\text{O} = 240\text{-}280 \text{ mg kg}^{-1}$). The thickness of the humus layer is 70-90 cm. The pH_{KCl} value is 6.2; the coefficient suggested by Arany is 43. Microelement deficiency cannot be detected. The ground water level is between 6-8 m. The VK_{min} value of the soil is 27-29 tf%. The 0-100 cm soil layer is able to withhold 275 mm, while the 100-200 cm can store 265 mm of moisture. The useful water capacity in the 0-100 cm soil layer is 157 mm, in the 100-200 cm layer it is 150 mm.

Weather characteristics: In 1995, during the growing season 114 mm while in the winter season 23 mm less precipitation fell than compared to a fifty-year average. Only 3 mm of rain fell in July. The period in July and August during flowering and grain filling, lasting 50 days without rain and was paired with a maximum 30°C temperature, unfavorably affected yield results. Due to the effect of 1995 and the previous droughty years, yield depression occurred in the fertilized, unirrigated treatments. The weather of period between 1996 and 1999 was significantly favorable for maize. Both in the winter term both in the vegetative period sufficient precipitation fell. The distribution as well as the amount of precipitation was favorable, especially in the period of July and August, which is so critical for the development maize plants. Contrary to the year of 1995, in 1998 and 1999 the flood-like rain, which well exceeded the average of many years caused problems.

Statistical evaluation. Our research program was designed with up-to-date experiment planning, to achieve a reliable evaluation , using the further developed version of the *Box & Wilson* (1951) method. The evaluation of the experimental data was done with variance analysis, by breaking down the variance components (Sváb 1981). We have used the 9.0 version of the SPSS for Windows to evaluate the data.

Results and Discussion

We have examined the effect of fertilization in irrigated and unirrigated treatments, at three fertilizer levels, in four repetitions by using the yield data of five years set up at the experimental station at Látókép. The evaluation of experimental results were done with variance analysis. The period between 1996-1999, that covers the wet years, was evaluated in the average of four years and we have compared the dry and droughty data of 1995.

According to our examinations, irrigation and fertilization has shown a strong correlation with yield results. The effect of irrigation changed depending on the natural water supply and

nutrient supply of soil, and the specific fertilizer doses. On the basis of analysis results we have found, that both fertilization both the effect of irrigation was significant on yield results. The correlation of year and examined cultivation technology elements or factors were also reliable. In the average of years the yield increasing effect of fertilization differed reliably in irrigated treatments. When examining the years separately, the correlation between the two factors was not significant in the period of 1996-1999, which had more precipitation. The results of examinations are shown in table 1.

Table 1: Results of analysis of variance (Debrecen, 1995, 1996-1999)

Source of variance	SS	df	MS	F	α -error
Year	500.93	1	500.93	328.93	≈ 0.0000
Irrigation	372.50	1	372.50	44.60	≈ 0.0000
Fertilization	81.20	2	40.60	26.66	≈ 0.0000
Year x Fertilization	131.02	2	65.51	43.01	≈ 0.0000
Irrigation x Fertilization	24.64	2	12.32	8.09	≈ 0.0005
Error	164.47	108	1.52		
Total	1420.21	118			

In the especially dry, droughty year of 1995, when evaluating the effect of fertilization, we have found that without irrigation the fertilizer doses cause yield depression. According to the results of variance analysis, fertilization significantly decreased the yield of maize. In the fertilized treatments, compared to the results of control plots, yield was 40-90% lower depending on the level of fertilization. The negative fertilizer effect was the consequence of lasting water deficiency which occurred during flowering, as well as the significantly high daily temperature exceeding 30°C. Due to the effect of medium and high doses of fertilization, in the beginning of the growing season, a significant assimilation surface developed, increasing the risk of excessive evaporation. In the second half of the vegetative period – which overlapped the significantly droughty period – the high LAI, as well as due to the increased water need maize was in a state of severe water deficiency, the considerable yield decrease occurred as a result of this.

In 1995, the yield of maize increased significantly in irrigated conditions, the surplus yield reached around 4.4-9.4 t/ha depending on the level of nutrient supply. The greatest irrigation effect was achieved on the fertilized plot of 120 kg ha⁻¹ nitrogen active substance, however when applying 240 kg ha⁻¹ N-dose, the efficiency of irrigation was very low and yield was lower, compared to the results of 120 kg ha⁻¹ N-dose about 3 tons less, practically identical with the output of unfertilized control plots (table 2.). It is clear from the data, that the yield of maize in 1995, on the fertilized plots did not reach the measured averages of the unirrigated, fertilized

treatments of the 1996-1999 period. Comparing the control, unfertilized plots of the two periods, the yield of maize was reliably higher by 1.3 t/ha than that of the unirrigated 1996-1999 period which was high in precipitation (figure 1.) All this implies, that the cumulated droughty years of the 90's, the period between 1992-1995, due to the negative water balance evolved during the growing season, water supply stored in the soil was relatively low compared to the control plots with fertilized treatments and natural nutrient supply.

Table 2: Effect of fertilization and irrigation on yield of maize (Debrecen, 1995, 1996-1999)

Fertilizer rates	Non-irrigated					
	1995	1996	1997	1998	1999	Average (1996-1999)
N ₀ P ₀ K ₀ kg ha ⁻¹	3.83	7.85	5.54	6.44	8.02	6.96
N ₁₂₀ P ₉₀ K ₁₀₈ kg ha ⁻¹	1.60	10.23	11.82	11.74	12.60	11.60
N ₂₄₀ P ₁₈₀ K ₂₁₆ kg ha ⁻¹	0.42	8.75	11.21	11.50	12.01	10.87
Average	1.95	8.94	9.52	9.89	10.88	9.81
Irrigated						
N ₀ P ₀ K ₀ kg ha ⁻¹	8.26	9.78	6.18	8.24	8.65	8.21
N ₁₂₀ P ₉₀ K ₁₀₈ kg ha ⁻¹	11.02	11.84	13.23	14.15	13.30	13.13
N ₂₄₀ P ₁₈₀ K ₂₁₆ kg ha ⁻¹	8.04	13.21	12.49	13.08	13.38	13.04
Average	9.11	11.61	10.63	11.82	11.78	11.46
Irrigation	0.39					0.44
LSD _{5%} Fertilization	0.51					0.55
Irrig. x Fert.	0.86					Non-significant

The period of 1996-1999, which was favorable as regards to precipitation for maize, fertilization reliably increased the yield of maize even without irrigation, in the average of four years. The surplus yield of fertilization was 3.9-4.6 t/ha depending on the level fertilizer treatments. The surplus yield reached its maximum on the plot where the lower 120 kg nitrogen dose was applied. In the case of 240 kg N/ha application, the yield of maize did not differ from this previous value.

Due to the effect of irrigation, yield was significantly higher at all three nutrient-supply levels compared to the unirrigated treatments. The highest fertilizer dose – just like in unirrigated conditions – did not increase the yield of maize considerably. Upon evaluating the correlation of fertilization and irrigation the yield increasing effect of fertilization did not differ in irrigated and unirrigated treatments in a way that could be statistically proven (table 2.) The reliable year or year x irrigation correlation supports, that yield surplus (1.3-2.3 t ha⁻¹) significantly differed from the irrigation effect measured in 1995.

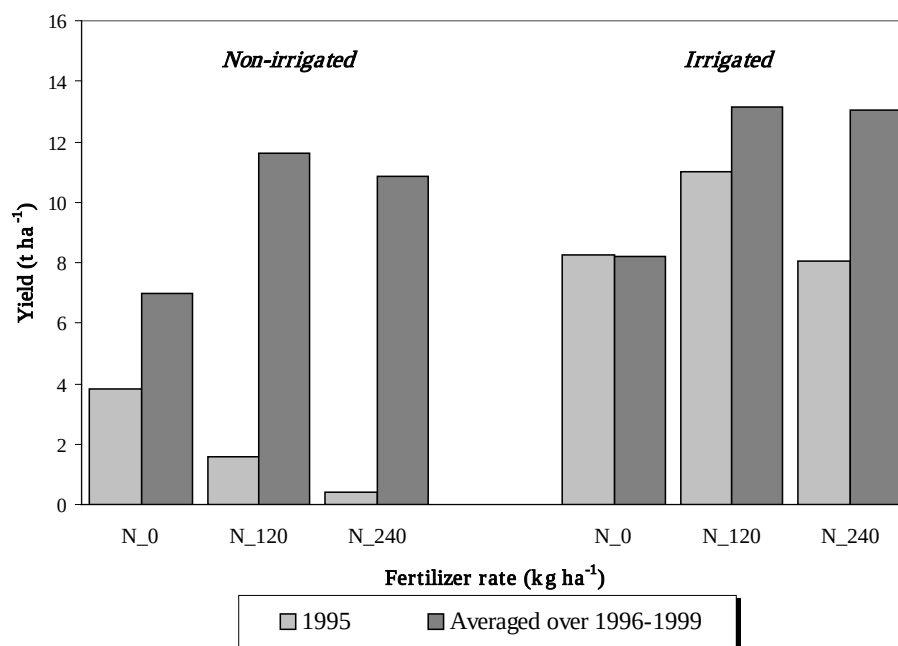


Figure 1: Effect of fertilization on maize yield under irrigated and non-irrigated conditions (Debrecen, 1995, 1996-1999)

Conclusion

When evaluating the results of the experiment we have found, that fertilization and year significantly influenced the efficiency of irrigated maize production. In irrigated cultivation, the condition of efficient farming is ensuring appropriate nutrient supply. Our experimental data have justified the results of previous research results according to which, the amount of precipitation or the moisture stored in the soil modifies the fertilizer effect, meaning that less fertilizer is needed with lower water supply.

According to the results of the experiment, the 240 kg nitrogen and the related P and K application is not recommended in any condition, since compared to the 120 kg ha⁻¹ N-dose, it did not increase the yield of maize considerably. In droughty years it caused significant yield decrease. This amount of N fertilizer dose, unambiguously results in over-fertilization, it decreases the profitability of maize production significantly and the farms can expect a great loss as a result. Along with this, it also means a constant, potential source of danger since in irrigated cultivation the high dose of N-fertilizer can multiple the amount of nitrate leaching from the root zone, increasing the harm on ground waters. When determining the optimal

amount irrigation, we have to consider the amount of applied N-fertilizer as well as the NO_3 content of the soil in order to avoid leaching from the upper layer.

Acknowledgements

This research was supported by the Hungarian National Research Fund (OTKA T042749).

References

- Balogh J. 1978. Calculating water needs in irrigated treatments. Mezőgazdasági Kiadó, Budapest.
- Box, G. E. P. - Wilson, K.B. 1951. On the Experimental Attainment of Optimum Conditions. Journal of the Royal Statistical Society, 13:1.
- Kovács G. J. 1982. The critical ecophysical correlation of water- and nutrient dynamics of maize. Növénytermelés, 31.4: 355-365.p.
- Kramer, P. I. 1963. Water stress and plant growth. Agron J. Madison, 55: 31-35.
- Nagy J. 1994. The effect of fertilization and irrigation on the yield of maize (*Zea mays* L.) hybrids with various genotypes. Unipress, Padova, 421-440.
- Nagy J. 1995. Evaluating the effect of fertilization on the yield of maize (*Zea mays* L.) in different years. Növénytermelés, 44:5-6. 493-506.
- Nagy J. 1997. The effect of fertilization on the yield of maize (*Zea mays* L.) in irrigated and unirrigated treatments. Agrokémia és Talajtan, 46:1-4. 275-288.
- Petrasovits I. 1978. Main questions of agrohydrology. Akadémiai Kiadó, Budapest.
- Sváb J. 1981. Biometrical methods in research. Mezőgazdasági Kiadó, Budapest.
- Szőke Molnár L. 1977. Economical questions of irrigated maize production. kukoricatermelés Akadémiai Kiadó, Budapest.

INTERNET-BASED FARMER DECISION SUPPORT FOR FERTILIZER APPLICATION

T. Dövényi-Nagy

Department of Land Use and Rural Development, University of Debrecen, Hungary

Abstract

The change in the economic structure in the 1990s has significantly worn down Hungarian agriculture. During the distribution of land, the structure of agricultural production was drastically altered, as land fell into the hands of two million small-holders. In such a situation, the role of professional consultancy becomes increasingly important and the various internet technologies provide new opportunities for web presence.

The Centre of Agricultural Sciences has a proven track record in Eastern Hungary, both in the areas of research and professional training. Furthermore, the Centre has provided consultancy services throughout the region for years. Now, based on its years of experience in all these activities, it would like to expand its efforts through the use of electronic media.

The framework of the system is an agricultural news portal, which can integrate various services, among these the application of different models to calculate the appropriate fertilizer quantity.

Introduction

Unfortunately, the drastic restructuring of Hungarian agriculture in the 1990s often lacked professional foresight and in the current of political and social changes it was obliged to find its own way. As a result of dragging compensation and land distribution, many large co-operatives and plants were closed down but close to two million people obtained land. Often, not only was land parceled out in economically unrealistic sizes, but the professional competency was also lacking that would have ensured the continuation of efficient production activities. Professional competency is still an area in need of attention, if agricultural production is to grow properly in the future.

Several production indicators characterize how shocking the structural changes were to the agricultural sector. The downturns cannot be grouped around one cause: the lack of capital, cease and realignment of export markets, uncertainty, lack of co-operation, and lack of expertise can all be blamed.

In the given conditions, the assistance of agricultural consultancy is more vital than ever before. The new forms of consultancy are interlocked with the internet, the development and expansion of various internet technologies in Hungary. While a number of surveys are being published about the spreading internet use in Hungary, very little information exists about the internet use of agricultural ventures and no comprehensive analysis exists about the internet penetration of

the national agricultural sector. This may not be accidental, since my experiences indicate that though the number of internet connections is constantly increasing, agricultural ventures are struggling in this field, and only a fraction of the opportunities offered by the web are being exploited:

In most cases, this is limited to professional news, mostly project and tender calls, and the results of those tenders. The internet presence of agricultural ventures or operating an own website is rare.

Considering the above mentioned we can assert that creating a market based agricultural portal in Hungary is not topical. The portals that are currently on the market do not imagine their operation to be a short term investment, the primary aim is gaining experiences, the presence and getting into common knowledge.

Material and methods

The portal that is about to be introduced, presently being developed – let's call it Center of Agri-Knowledge – does aim to test the different web technologies and applications in an agricultural context, and act as a framework for our web-based consultancy to help farmers among other things to calculate the appropriate fertilizer rate they should apply.

The computer model presently uses the guidelines of the Hungarian Ministry of Agriculture and Rural Development (MÉM-NAK), but there's a simple way to adapt any other optimization methods

When establishing the portal, the basic task that occurs is to decide upon the background environment. Our portal uses Apache, PHP and MySQL.

- As the forerunner of the world's web servers, Apache runs on 63%² of them and is platform independent.
- The server-side programming languages have greatly increased recently, but during a simple decision making process PHP was chosen. It is platform independent, free, open source and perfectly documented.
- In the case of the database server, our choice was the popular MySQL, which is platform independent, free, open source software, not to mention that presently it is the world's fastest running alike application.
- Finally, as we can see, the question of the operating system is solved by the other three components. The applied programs are all platform independent, which makes the task of development significantly easier. The development itself, can happen on a simple

² Netcraft Web Server Survey

computer, in any Windows environment, and the finished portal can simply be copied onto a Unix/Linux server.

Content management

The determining service of the portal is the professional database, designed on the basis of agriculture related printed news and electronic press sources. It was extended on a daily basis even in the development phase, thus means a comprehensive, searchable archive.



Figure 1: Screenshot of the portal

The main component of the portal is the presently operating content management system (CMS), which helps in displaying and managing news. The simplicity of operating comes from the fact that it uses commonly known web forms. In practice, we can talk about a simplified internet database handling system, where the records contain the characteristics of the article/news (title, subheading, lead, body, topic, number of downloads, time of creating and publishing etc.)

The diversity in the source of professional news, articles along with the national press includes foreign agricultural portals, the national professional organizations but even departments of universities where the news could directly be uploaded from.

Keeping records

The portal offers an opportunity to organize farm records on a field-by-field basis. These records should include: historical yields, soil test values, management history, including past fertility, tillage, pest management practices.

Further directions of development

The new directions of further development are such widespread but rarely exploited or not so popular services in local practise such as the internet forum or electronic marketplace etc.

In the beginning of the portal development – and of course since then –services of hundreds of agriculture related sites were organized. Beyond the relatively standard services (news, forum, gallery etc.) a few very interesting solutions could be found which could play a role in the further development and could help the professional consultancy in the field of nutrition:

Dictionaries, encyclopedias

Online dictionaries find the selected word without the press of a button by a simple click with the mouse. New words or full dictionaries can simply be integrated into the application that operates with a database server background. Beyond the convenient manageability, daily occuring new and unknown words in our language justify the grounds for similar applications.

At this point of the development work on a weed information catalogue based on the above mentioned technology is in progress, but an online encyclopedia including words and expressions in the feeld of fertilizing and plant nutrition is planned too.

Afterword

Though, the Center of Agri-Knowledge is still in the phase of development, it has already aroused interest at a couple of forums. In the case of Hungarian internet services we can see similar initiatives, but the unique value behind its wide spectrum of services lies in the professional competency of the Debrecen University.

References

Dövényi-Nagy T., Herdon M., 2002: Internetportálok fejlesztése és agrárgazdasági alkalmazása, in Innováció, a tudomány és a gyakorlat egysége az ezredforduló agráriumban, p. 259.

Section 4

Increasing the fertilizer use efficiency in extensive farming

DETERMINATION OF PHOSPHOROUS FERTILIZER REQUIREMENT OF WINTER WHEAT GROWN UNDER IRRIGATED CONDITIONS IN TOKAT AND AMASYA REGIONS

K. Çağatay¹, A. R. Brohi² and M. Eker¹

¹Research Institute of Rural Services, Tokat, Turkey

Tel: 0356-2521250-51, Fax: 0356-2521253, e-mail: kcagatay@khgm.gov.tr

²Gaziosmanpaşa University, Agriculture Faculty, Soil Science Department, Taşlıçiftlik kampüsü
Tokat, Turkey, e-mail: rbrohi@gop.edu.tr

Abstract

This experiment was conducted to determine the phosphorus fertilizer requirement of winter wheat grown under irrigated conditions in Tokat and Amasya region. The experiments were conducted during the years 1984-1993. The experiments were designed as a randomized block with 4 replications. The rates of phosphorus fertilizer were 0, 40, 80, 120, and 160 kg P₂O₅/ha. The regression analysis was calculated between grain yield and phosphorus rates in this study. A regression coefficient of $Y = 2774 + 9.63X - 0.034 X^2$ ($R = 0.992^*$) for fields containing 0 – 30 kg P₂O₅/ha. For fields containing 30 – 60 kg P₂O₅/ha, it was $Y = 3606.9 + 7.08 X - 0.033 X^2$ ($R = 0.990^*$). These relationships were significant up to 95 %. With the help of these regression equations, an optimum rate of 130 kg P₂O₅/ha and 90 kg P₂O₅/ha was found for fields containing 0 - 30 kg P₂O₅/ha and for fields containing 30 - 60 kg P₂O₅/ha respectively. An economic rates of 107 kg P₂O₅/ha and 72 kg P₂O₅/ha were found for fields with 0 -30 kg P₂O₅/ha and for fields containing 30-60 kg P₂O₅/ha respectively when keeping in view the price of the wheat grain and phosphorus of the year 2000

Keywords: Wheat, phosphorus rates, Grain yield

Introduction

Wheat is an important crop. Thus it is an important food crop for human beings in the world. Due to this, wheat crop occupies very important place among other crops. Hence in Turkey it occupies 51% of the area among field crops. Among cereal crops it occupies 67 % in Turkey (Anonymous, 1998).

Similar data is true for wheat in Tokat and Amasya regions. It occupies 55 % area among field crops and 77 % among cereal crops in Tokat region. The data for Amasya region is 58 % and 82 % respectively (Anonymous, 1998).

The possible means of fulfilling the food requirements of increasing population, it is only possible to increase the yields of agricultural crops. This increase is not possible with increasing the area of cropping, because it is impossible under present situation of the world. Hence modern agricultural techniques and inputs are the only means of increasing the crop yield of a particular country. Among the inputs fertilizers play an important role for this aspect.

Soils of Turkey are generally poor in available phosphorus, thus this deficiency is fulfilled with phosphorus fertilizer applications. Similarly soils in Tokat and Amasya region are also poor in available phosphorus. 84 % of the soils of Tokat region are poor in phosphorus content (this is ranging from extremely poor to medium poor). Thus this much area needs phosphorus fertilization. However 16 % of the area in Turkish soils are sufficient in available phosphorus content and need no phosphorus fertilization (Anonymous, 1984a). Similar status is also present for the soils of Amasya region. 83.8 % of the soils of Amasya region are also poor in phosphorus content (this is ranging from extremely poor to medium poor). Thus this much area needs phosphorus fertilization (Anonymous 1984b).

Deficiency of phosphorus is mainly related with phosphorus fixation as has been reported by Yurserver (1971); Aktaş (1991); Unal and Başkaya (1981). Phosphorus applied through P fertilizers is fixed to the extent of 70 to 90 % in the soil and only 10- 30 % is available to plants as has been reported by Kacar and Katkat (1997) under Turkish soils. This is the reason that soil analysis must be made before phosphorus fertilizer application for fertilizer economy and also to guarantee the crop yields. The purpose of this study is to determine the requirements of phosphorous fertilizer rates for winter grown wheat under irrigated conditions in Tokat and Amasya region.

Material and Method

This research work was conducted in different villages of Tokat and Amasya region during the years 1984-1993 at 25 locations. The climatic data regarding the study regions (Tokat and Amasya) is given in table 1.

Table 1: Climatic data of the study region (Anonymous 1984-1993)

Location	Climatic Elements	Months												
		X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Average or Total
Tokat	Av.Temp. (C°)	12.3	6.7	2.2	0.2	1.5	6.8	12.7	15.5	19.5	21.9	21.8	17.3	11.5
	Av.Precip.(mm)	47	66	49	41	38	31	65	72	48	10	6	13	486
Amasya	Av.Temp. (C°)	14.1	8.4	3.2	2.4	3.2	7.8	13.6	17.2	21.2	23.2	23.5	19.8	13.1
	Av.Precip.(mm)	44	51	46	30	27	30	55	52	43	14	8	11	411

Soil samples were collected for P analysis before conducting the experiments so as to see the phosphorus status of the soils. Hence experiments were conducted on P deficient soils. The soil properties of the study area are given in table 2.

Table 2: Some physical and chemical properties of the experimental fields

Locations	Year	Soil properties					Grain yield kg/ha)				
		Field capacity (%)	pH	Available (kg/ha)		Org. mat. (%)	Fertilizer rates (kg P ₂ O ₅ / ha)				
				P ₂ O ₅	K ₂ O		0	40	80	120	160
Nıksar-Beyçayırı	1984	55	7.62	18.9	1130	1.65	3440	3650	4070	4140	4140
Nıksar-Günlüce	1984	66	7.46	6.9	900	2.62	1750	2360	2890	3220	3330
Nıksar-Buzköyü	1984	47	7.50	4.8	580	1.58	3560	3970	4110	4100	3980
Erbaa-Ballıbağ	1986	62	8.33	20.1	1160	1.78	2760	2940	3050	3320	3100
Merzifon-Yalnız	1988	69	7.99	24.3	1240	1.17	1990	2220	2490	2520	2390
KHAE*	1991	68	8.06	29.6	340	1.49	3960	4130	4020	4520	4420
Erbaa-Aşağıçandır	1993	78	7.96	13.2	890	1.38	2060	2270	2440	2580	2540
Average (0-30 kg P₂O₅/ha)							2790	3080	3300	3490	3410
Turhal-Bahçebaşı	1985	66	7.52	34.7	850	2.13	2460	2690	2770	2930	2900
KHAE-5C	1986	80	8.48	33.7	870	2.35	6240	6560	6820	6510	6250
Erbaa-Salkımören	1986	46	8.28	33.8	850	1.92	1910	2040	2260	2090	1960
KHAE-4A	1987	81	7.47	39.6	760	2.82	5050	5440	5450	5440	5610
Merzifon-Aktarla	1987	81	7.69	33.6	1820	1.70	3170	3430	4040	3890	3240
KHAE-1B	1988	68	7.32	36.6	670	1.88	4150	4540	4680	4920	4710
Suluova-Yolpınar	1988	68	7.41	31.3	1390	1.65	1230	2300	2560	3250	2340
Suluova-Ayrancı	1988	83	7.44	52.9	1970	2.19	3790	4100	4470	4250	4010
Zile-Kireçli	1990	53	7.70	38.4	540	1.69	3130	3390	3000	3240	3190
Suluova-Eraslan	1990	49	7.60	30.0	690	1.21	4370	4410	4310	4480	4490
Artova-Çelikli	1991	61	7.92	46.8	670	2.50	3460	3540	3930	3800	3660
Nıksar-Köklüce	1991	73	8.08	58.1	1000	2.26	3900	3800	3790	3700	3780
Taşova-Elmakırı	1991	61	7.89	51.1	880	2.09	3430	3530	3600	3800	3870
Suluova-Kurnaz	1992	59	7.65	45.2	1410	2.55	5950	6200	5860	5900	6080
KHAE-7A	1993	57	7.58	42.9	410	2.33	4270	3990	4510	4980	4760
KHAE-5C	1993	65	7.83	50.4	910	1.38	3800	3880	3980	3820	4210
Suluova-Kurnaz-1	1993	66	8.69	37.2	1170	1.72	2250	2420	2730	2310	2220
Suluova-Kurnaz-2	1993	71	8.75	44.6	1200	1.73	2580	2360	2580	2600	2300
Average (30-60 kg P₂O₅/ha)							3620	3810	3960	4000	3870

* = Rural services researh Institute Tokat

The experiments were conducted as a randomized block design with 4 replications and 5 treatments. The treatments are as under: 0, 40, 80, 120 and 160 kg P_2O_5 /ha. Plots have an area of $2.10 \times 10.00 \text{ m} = 21.00 \text{ m}^2$ at the time of sowing and $1.82 \text{ m} \times 9.00 \text{ m} = 16.38 \text{ m}^2$ at the time of harvesting.

Bezostaya wheat variety (generally used in Turkey) was used in all location for this study. For the normal growth of the wheat crop 100 kg N/ha nitrogen as an ammonium sulfate (21%) was applied in all the experiments at sowing. Whereas ammonium nitrate (26%) was applied at the joint growth stage (at spring). However P was applied in the shape of triple super phosphate (42-44 % P_2O_5) before sowing. Irrigation was applied two times that is once at heading at second at milk grain formation depending on the climatic conditions of the study area.

A regression coefficient analysis was calculated between P fertilizer rates and wheat yield for these experiments. Thus the parameters like a, b and c were calculated from the equation $Y = a + bx - cx^2$. The economic P fertilizer rate was calculated taking into consideration the price of fertilizer bought and the selling price of wheat for the year 2000.

Results and Discussions

Effect of phosphorous fertilizers on the grain yield of wheat crop

The yield data obtained from these experiments (conducted at Tokat and Amasya region) is given in table 3.

Table 3: Regression coefficients obtained between phosphorous fertilization and wheat yield

Available phosphorous (kg P_2O_5 /ha)	Variation	Calculated F	F test		Regression equation	Correlation Coefficient (R)
			0.05	0.01		
0 – 30	Regression	61.44*	19	99	$Y=2774+9.63X-0.034 X^2$	0.992*
30 – 60	Regression	51.90*	19	99	$Y=3606.9+7.08X-0.033 X^2$	0.990*

A regression analysis was done for each location in order to see the effect of phosphorus fertilization on the yield of wheat crop. The regression analysis done from these data was $Y = 3174 + 9.59 X - 0.049X^2$ ($R = 0.984^*$) for Amasya and $Y = 3494 + 7.02 X - 0.028 X^2$ ($R = 0.997^*$) for Tokat region. An optimum rate of 90 kg P_2O_5 /ha was found for Amasya and 110 kg P_2O_5 /ha was found for Tokat region by solving the above regression equations. Since, due to the similar climatic conditions, soil conditions and almost similar wheat cultivation techniques applied in the region and as well as the regression analysis results obtained were also same,

hence collective evaluation was made in this study for practical approach. Thus due to collective evaluation, the soils are grouped as extremely poor (0- 30 kg P₂O₅/ha) and poor (30 – 60 kg P₂O₅/ha) soils. The experiments were conducted on these group of soils. Depending on these groups , it is possible to recommend P fertilization with soil analysis results. The regression coefficient analysis made between P fertilization and wheat yield was $Y = 2274 + 9.63 X - 0.034 X^2$ (R=0.992*) for soil groups with a P content of 0- 30 kg P₂O₅/ha and a regression coefficient of $Y = 3606.9 + 7.08 X - 0.033 X^2$ (R = 0.990*) was calculated for soil groups with a P content of 30 – 60 kg P₂O₅/ha. These equations are also shown in Fig.1 and fig.2.

The regression analysis results obtained from these data show that only few soils need P fertilization. Thus an optimum rate of 130 kg P₂O₅ /ha and 90 kg P₂O₅/ha is recommended for extremely poor and poor soils respectively. Taking into consideration the price of P fertilizer and grain selling price of the year 2000, an economic rate of 107 kg P₂O₅ /ha and 72 kg P₂O₅ /ha is recommended for extremely poor and poor soil groups under this study respectively. These results are in agreement with the results obtained by Alptürk (1979) , by Aydeniz and Brohi (1991) and by Bozkurt and Karaçal (1996).

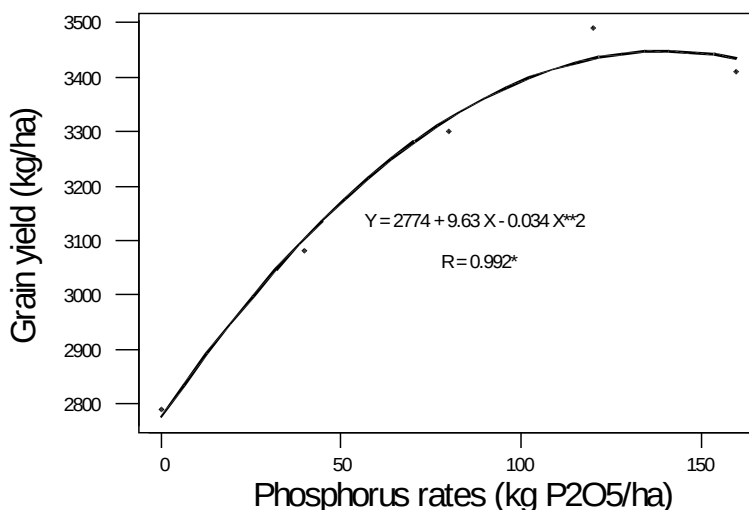


Figure 1: The phosphorus and yield relationship of soils having an available P content ranging between 0-30 kg P₂O₅/ha (extremely poor soils).

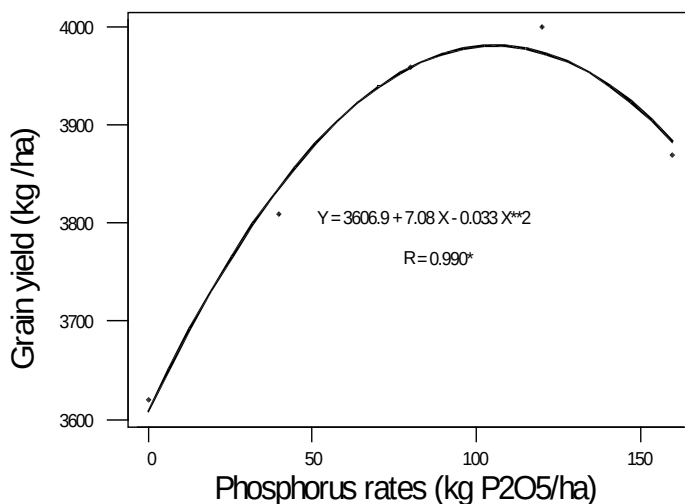


Figure 2: The phosphorus and yield relationship of soils having an available P content ranging between 30- 60 kg P₂O₅/ha (poor soils).

Under this study, the increasing rates of P fertilization increased the yield sharply and this increase was more as compared to control treatment, however the rest of the rates have no such sharp increase. This may be due to the effect of P fertilization on generative organs of the wheat plant, together with effects on photosynthesis, respiration and etc., as has been reported by Brohi et al. (1994), Kacar (1984) and Yurtsever (1971) under Turkish conditions. It is also possible that P fertilization made a positive effect on the uptake of other nutrients in this study. However positive effect of optimum rates of P application has been found on the uptake of nitrogen, with no positive effect was found on the uptake of nitrogen at higher rates of P fertilization (Aktaş 1991). Insufficient application of P fertilization to wheat crop has decreased ear head numbers /ha, decreased the photosynthesis rate and also has a negative effect on root growth of wheat crop as has been reported by Cook and Veseth (1991), Brohi et al. (1994) and by Kacar (1984). The low yield obtained in control treatment might be due to this factor.

As it is seen in Fig. 1 and 2 that, the regression curve gave a maximum peak at 130 kg P₂O₅/ha (for soil groups containing 0 – 30 kg P₂O₅ /ha) and at 90 kg P₂O₅ (for soil groups containing 30 – 60 kg P₂O₅/ha) and then after this curve decreased. This means that

application of P rates beyond this level would increase the soil P concentration and this cause an antagonistic effect on the uptake of other nutrients like Zn, Fe and Cu which in turn would have decreased the wheat yields as has been reported by Brohi et al. (1994), Aktaş (1991) and Özbek et al. (1993) under Turkish conditions.

The effect of P rates on the yield of wheat crop was dependent on the available P content of soils in this study (Table 4). The increasing available soil P content together with increasing P fertilizer rates decreased the % yield of wheat crop. Again low available soil P content necessitates the higher rates of P (130 kg P₂O₅ /ha) application in this study. Similar results were also obtained by Deniz (1993), Işık (1993), Özdemir and Güner (1983), Bilgin (1981) and Sefa (1981).

Relationship between soil available P and wheat yield

Keeping in view the relationship between soil available P and wheat yields, the yield increase percent was calculated for 23 experiments by comparing the results with control treatments of each location (Fig. 3).

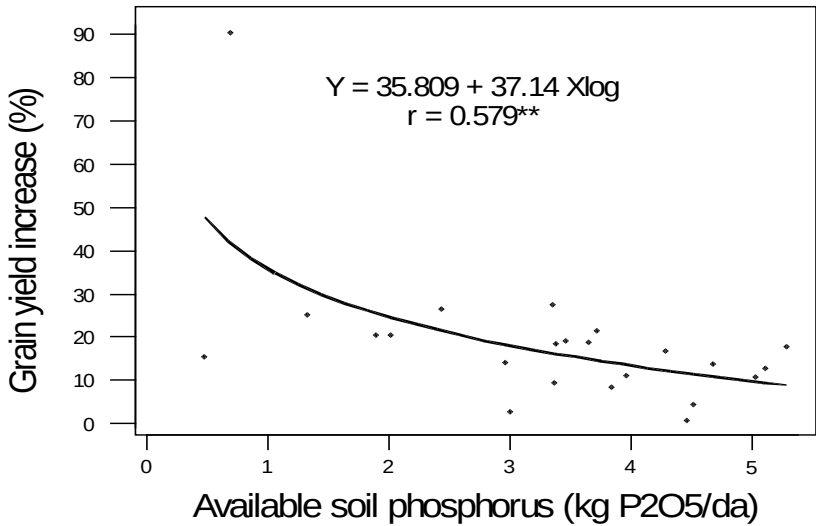


Figure 3: shows the relationship calculated between the percent increase of wheat yield obtained with the application of P fertilization and soil P values obtained by Olsen method of P analysis.

As it is seen in Fig. 3 that there is a significant relationship between percent increase of wheat yield obtained with the application of P fertilizer and soil P values obtained by Olsen method. This increase in the wheat yields caused by P fertilizer application was dependent on soil P values. Thus this logarithmic increase (Log X) of these values decreased the yields (Y) in all these experiments. This relationship when mathematically evaluated, we will get the following equation: $Y = 35.8 - 37.1 X \log$. By solving this equation we will find that the available P content of soil when reached to a extent of 90 kg P₂O₅/ha, the yield increase would be stagnant. In other words the available soil P content beyond this value needs no P fertilizer application. Similar results were also obtained by Deniz (1993), Işık (1993), Özdemir and Güner (1983), Bilgin (1981) and Sefa (1981). Katkat et al (1989) and Katkat et al. (1984). These workers didn't find the effect of P application on the yield of wheat crop when available soil P content was higher than the above mentioned value.

The soil available P content of the study soils were grouped as extremely deficient (0 – 30 kg P₂O₅/ha) and deficient (30 – 60 kg P₂O₅/ha). P fertilization was done on these two groups to see the effect of P rates on the yield of wheat crop. Thus percent increase of the yields were calculate and presented in Table 4.

Table 4: Relationship between available soil P content and wheat yield

Available soil P content (P ₂ O ₅ kg/ha)	P rates (kg P ₂ O ₅ /ha)				
	0	40	80	120	160
0-30 (varied between (4.8-29.6)	2790	3080	3300	3490	3410
Yield increase (%)*		10.4	7.1	4.8	-2.3
Yield increase (%)**			18.3	25.1	22.2
30-60 (varied between (3.0-58.1)	3620	3810	3960	4000	3870
Yield increase (%)*		5.2	3.9	1.0	-3.3
Yield increase (%)**			9.4	10.5	6.9

* % increase in yield among the fertilizer rates

** Percent increase in the yields as compared to control treatment

As it is seen in table 4 that with no application of P fertilizer an average yield of 2790 kg /ha and 3620 kg/ha was obtained on soils groups containing 0-30 kg P₂O₅/ha and 30-60 kg P₂O₅/ha respectively. These fields gave highest yields because they contained sufficient available soil P. In other words they need no P fertilization. More over P present in the rhizosphere zone could be made available with the help of root secretions for sufficient plant response. The young

wheat plants could secret 20 % of their photosynthesis compounds through roots and these secretions have an acidic properties as has been reported by Aktaş (1991).

The uptake of soil available P by plants depend on soil properties and also on plant variety used as has been reported by Yurtsever (1971). The research work conducted on wheat shows that soil P effectiveness coefficient was higher than fertilizer P effectiveness coefficient as has been reported by Deniz (1993), Işık (1993), Özdemir and Güner (1983), Bilgin (1981) Sefa (1981) and Gedikoğlu and Yurtsever (1993). This is the reason that we obtained wheat yields of 2790 and 3620 kg /ha on soils containing soil P ranging from 0 - 30 kg P₂O₅/ha and from 30 – 60 kg P₂O₅/ha respectively, with out any P fertilization (Table 4). This represents an increase of 29.7 % . However this much increase in yields was not obtained even with fertilized P plots. This might be due to fixation of P in these soils. Since it has been proved that plants can utilize only 10- 30 % of applied P, whereas 70 – 90 % remained in the soil as has been reported by Kacar and Katkat (1997), Yurtsever (1971) and Ünal and Başkaya (1981) under Turkish soil conditions.

Conclusion

It has been found that P fertilization has significantly increased the wheat yields in these experiments. But the effect of P fertilization is dependent on the available P content of the soils. Hence it is necessary to recommend P fertilization according to the results of the soil P analysis. The results so obtained are recommendable only for those soils which are extremely poor or poor in P. This is the reason that for winter grown wheat under irrigated conditions in Tokat and Amasya regions, the economic P fertilizer rates are 107 kg P₂O₅ /ha and 72 kg P₂O₅ /ha for soil groups ranging from 0 – 30 kg P₂O₅ /ha and from 30 – 60 kg P₂O₅ /ha respectively. The available soil P content of 90 kg P₂O₅ /ha or more than this level soils need no application of P fertilizers.

References

- Aktaş, M., 1991. Bitki besleme ve toprak verimliliği, Ankara Üniversitesi Ziraat Fakültesi Yayınları:1202, Ders Kitabı:347, Ankara.
- Alptürk,C., 1979. Konya ovası koşullarında bezostaya-1 buğday çeşidinin ticaret gübreleri isteği, Konya Bölge Topraksu Araştırma Enstitüsü Müdürlüğü Yayınları, Genel Yayın No:89, Rapor Yayın No:73, Konya.
- Anonymous, 1984a. Tokat ili verimlilik envanteri ve gübre ihtiyaç raporu, Toprak su Genel Müdürlüğü Yayınları, TOVEP Yayın No: 12, Genel Yayın No: 740, Ankara.
- Anonymous, 1984b. Amasya ili verimlilik envanteri ve gübre ihtiyaç raporu, Toprak su Genel Müdürlüğü Yayınları, TOVEP Yayın No: 21, Genel Yayın No: 753, Ankara.
- Anonymouse 1984-1993. Araştırma raporları (1984-1993), Köy Hizmetleri Tokat Araştırma Enstitüsü Müdürlüğü Yayınları, Tokat.
- Anonymous, 1998. Tarımsal yapı (1996), Devlet İstatistik Enstitüsü, Yayın No: 2097, Ankara.

- Aydeniz,A., A.,Brohi, 1991.** Gübreler ve gübreleme, Cumhuriyet Üniversitesi Tokat Ziraat Fakültesi Yayınları:10, Ders Kitabı:3, Tokat
- Bilgin A.E., 1981.** Ege koşullarında yerli buğdayların ticaret gübre isteği ve Olsen fosfor analiz metodunun tarla denemeleri ile kalibrasyonu, Menemen Bölge Toprak su Araştırma Enstitüsü Müdürlüğü Yayınları, Genel Yayın No:72, Rapor Serisi No:46, Menemen.
- Bozkurt.M.A., İ., Karaçal, 1996.** Azotlu ve fosforlu gübrelerin yayla-305 buğday çeşidinde azot fosfor ve potasyum içerikleri ile alımlarına etkisi, Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi Dergisi, 6(4):165-176. Van.
- Brohi,A., A., Aydeniz, M.R., Karaman, S., Erşahin, 1994.** Bitki besleme, Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi Yayınları: 4, Kitaplar serisi:4, Tokat.
- Cook, R.J., R.J., Veseth, 1991.** Wheat health management, The American Phytopathological Society, Minnesota,USA.
- Deniz, Y., 1993.** Bolu ovasında buğdayın fosforlu gübre isteği ve olsen fosfor analiz metodunun kalibrasyonu, Ankara Araştırma Enstitüsü Müdürlüğü Yayınları, Genel Yayın No: 189, Rapor Seri No:96, Ankara.
- Gedikoğlu,İ., N., Yurtsever, 1993.** Ankara yöresinde yaygın olarak yetiştirilen yüksek verimli ekmeklik buğday çeşitleri için Olsen fosfor analiz metodunun kalibrasyonu, Toprak ve Gübre Araştırma Enstitüsü Müdürlüğü, Genel Yayın No: 193, Rapor Seri No: 111, Ankara.
- Işık, Y., 1993.** Konya yöresi sulu şartlarında buğdayın fosforlu gübre isteği ve olsen fosfor analiz metodunun kalibrasyonu, Konya Araştırma Enstitüsü Müdürlüğü Yayınları, Genel Yayın No:157, Rapor Seri No:130, Konya.
- Kacar,B., 1984.** Bitki besleme, Ankara Üniversitesi Ziraat Fakültesi Yayınları: 899, Ders Kitabı: 250, Ankara
- Kacar, B., A.V., Katkat, 1997.** Tarımda fosfor, Bursa Ticaret Borsası Yayınları, No:5, Bursa.
- Katkat,A.V., N., Çelik, N., Yürür, M., Kaplan, 1984.** Bursa ovası ekolojik koşullarında Libelulla buğday çeşidinin azotlu ve fosforlu gübre isteğinin belirlenmesi, Uludağ Üniversitesi, Ziraat Fakültesi Dergisi, 3:55-62, Bursa.
- Katkat, V., A.,Özgümüş, M., Kaplan, 1989.** Azotlu ve fosforlu gübrelemenin cumhuriyet – 75 buğday çeşidinde tane verimi ile tanelerin N, P ve K kapsamları üzerine etkileri, 10. Bilimsel Toplantı Tebliğleri, Toprak İlmi Derneği, Yayın No:5, Ankara.
- Özbek, H., M., Gök, H., Kaptan, 1993.** Toprak bilimi, Ç.Ü. Ziraat Fakültesi Genel Yayın No: 73, Ders Kitapları Yayın No: 16, Adana.
- Özdemir,O., S.,Güner, 1983.** Samsun yöresinde buğdayın azotlu ve fosforlu gübre isteği ile Olsen fosfor analiz metodunun kalibrasyonu, Samsun Bölge Toprak su Araştırma Enstitüsü Müdürlüğü Yayınları, Genel Yayın No:30, Rapor Seri No:25, Samsun
- Sefa,S., 1981.** Batı geçit bölgesi sulanır koşullarında buğdayın azotlu gübre isteği ve Olsen fosfor analiz metodunun kalibrasyonu, Eskişehir Bölge Topraksu Araştırma Enstitüsü Müdürlüğü Yayınları, Genel Yayın No:161, Rapor Yayın No:120, Eskişehir
- Ünal, H., H.S., Başkaya, 1981.** Toprak kimyası, Ankara Üniversitesi Ziraat fakültesi Yayınları:759, Ders kitabı: 218, Ankara.
- Yurtsever, N., 1971.** Trakya bölgesi topraklarının fosfor ihtiyaçlarının tayininde kullanılan olsen metodu sonuçlarının tarla denemeleriyle kalibrasyonu üzerinde araştırmalar (Doktora), Ankara.

THE RESIDUAL EFFECT OF P FERTILIZATION, MEASURED IN A LONG-TERM P EXHAUSTION FIELD TRIAL, SET UP ON A CALCAREOUS CHERNOZEM SOIL

P. Csathó and I. Kádár

Research Institute for Soil Science and Agricultural Chemistry, Budapest, Hungary
Email: csatho@rissac.hu

Introduction

Phosphorus makes up about 0.12% of the earth's crust, and is essential for both animal and plant growth. In comparison to other plant nutrients the mobility of P in soil is low because of the generally low solubility of phosphate compounds and the strong P-binding capacity of soil components (Peck, 1990). On the other hand, residual effect of previous P application (Kádár et al., 1994) is more long lasting than that of potassium (Csathó, 1999), and especially than that of nitrogen (Bircsák et al., 2003). For providing the P requirement of crops, soils need a sufficient pool of plant-available P (Johnston et al., 1986). On the other hand, upper critical P levels must also be elaborated for reducing P losses from soils to surface and subsurface waters via wind- and water erosion, surface runoff and leaching (Sibbesen and Sharpley, 1997).

Phosphorus is considered as the second most important macronutrient in Hungary, following nitrogen. The magnitude of responses to P application is influenced not only by the available P levels in soil, but by the crops as well. Wheat is considered as a phosphorus-demanding crop.

Having strongly negative P balances since 1990, Hungarian agriculture is still living on the residues of previous P (and K) applications, but these reserves are becoming smaller and smaller. It is essential to know how long the previous P application provides adequate P for crops as a function of residual effects (Németh, 1998).

Material and Methods

The P-exhaustion field trial with 0, 40, 80, 120, 240, 360, 480, 600 and 720 kg ha⁻¹ initial build-up P₂O₅ doses was established in the autumn of 1972, on a light loamy calcareous Mollisol, originally poorly supplied with P (Table 1).

Every second year following that, once on one build-up P dose, starting on the initial 0 level in autumn 1974, continuing on the initial 40 kg ha⁻¹ P₂O₅ level in autumn 1976, on the initial 160 kg ha⁻¹ P₂O₅ level in autumn 1978, on the initial 240 kg ha⁻¹ P₂O₅ level in autumn 1980, etc., fresh 0, 40, 80, and 120 kg ha⁻¹ P₂O₅ doses were applied, in order to compare the effect of fresh

P to the residual effect of „older” and „older” previous P application, based on the P balances (Table 1).

Table 1: Experimental plan of build-up („old”) and maintenance (fresh) P application, kg P₂O₅ ha⁻¹

Build-up („old”) K application In Autumn 1972 kg P ₂ O ₅ ha ⁻¹	Maintenance (Fresh) B	C	P application level (kg P ₂ O ₅ h D	Year
-	40	80	120	1974 Autumn
40	40	80	120	1976 Autumn
80	40	80	120	1978 Autumn
120	40	80	120	1980 Autumn
240	40	80	120	1982 Autumn
360	40	80	120	1984 Autumn
480	40	80	120	1986 Autumn
600	40	80	120	1988 Autumn
720	40	80	120	1990 Autumn

In the first 8 years of the trial winter wheat, in the 9th year millet, in the 10 to 12th year alfalfa, in the 13th year spring barley, and in the 14 to 22nd years again winter wheat was the test crop.

Results and Discussion

Changes in ammonium-lactate- (AL, Egner et al., 1960) soluble P contents, as a function of time are shown in Figure 1.

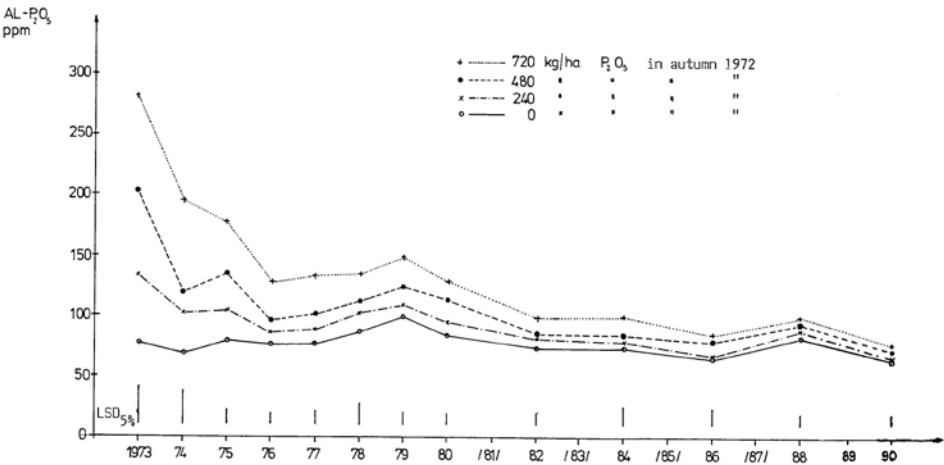


Figure 1: Changes in the AL- soluble P₂O₅ content of the soils in the first 18 years of the P exhaustion trial. Calcareous Mollisol, 1973-1990

Following build-up P fertilization, ammonium-lactate- (AL, Egner et al., 1960) soluble P contents diminished strongly for 4 years, then a 3-year equilibrium was observed in this light loamy, calcareous Mollisol, not strongly fixing phosphorus. This was followed by another 3-year fixing period. However, this time the P fixation was not as strong as it was in the first 4 year. Then another 6 year equilibrium period was observed. Difference in AL- P_2O_5 contents of the highest, 720 kg ha⁻¹ build-up dose and the P control plots was 190 mg kg⁻¹ in the first year, and it diminished to 130 mg kg⁻¹ in the second year, to 110 mg kg⁻¹ in the third year, to 40 to 50 mg kg⁻¹ in the 4th to 9th years, and to 10 to 20 mg kg⁻¹ from the 10th year of the trial (Figure 1).

Residual effect of the initial build-up 240 kg P_2O_5 ha⁻¹ provided adequate P for winter wheat for 4 years, of the 480 kg P_2O_5 ha⁻¹ dose for 6 years, of the 720 kg P_2O_5 ha⁻¹ dose for 8 years (1.4 to 1.5 t ha⁻¹ grain yield surpluses) (Table 2). Although in lower and lower yield levels, P residual effects were detectable even in the 9th to 20th years: 0.1 to 0.2 t ha⁻¹ surpluses in the 240 kg P_2O_5 ha⁻¹, 0.4 to 0.5 t ha⁻¹ surpluses in the 480 kg P_2O_5 ha⁻¹, and 0.6 to 0.7 t ha⁻¹ surpluses in the 720 kg P_2O_5 ha⁻¹ initial dose. In the 21st and 22nd years, however, no P residual effect was observed on this light loamy, calcareous chernozem soil, originally poorly supplied with P, not strongly fixing phosphorus (Table 2).

Millet did not show residual P effects in the 9th year (0.1 to 0.2 t ha⁻¹ surpluses). Residual effects in alfalfa in the 10th to 12th were as much as 1.5 t ha⁻¹ hay yield surpluses. Spring barley in the 13th year showed only slight, 0.3 t ha⁻¹ surplus as residual P effect (Table 2).

As a function of time, four year average main yield levels in the P exhaustion trial were 4.4 t ha⁻¹; 4.2 t ha⁻¹; 3.1 t ha⁻¹; 2.5 t ha⁻¹; 3.0 t ha⁻¹ and 1.9 t ha⁻¹ cereal units, indicating the worsening P supply in the P exhaustion trial (Table 2).

Fresh 0, 40, 80, and 120 kg ha⁻¹ P_2O_5 application given every second year, once on one build-up P dose, resulted in 1.0 to 1.5 t ha⁻¹ winter wheat grain yield surpluses, 2.0 to 2.5 t ha⁻¹ alfalfa hay yield surpluses, and 1.5 t ha⁻¹ spring barley grain yield surpluses. The effect of fresh P application on millet grain yield surpluses was minimal: 0.2 t ha⁻¹ (Table 3).

The fresh P equivalence of the previously added initial P was expressed in surpluses in main yields (Figure 2, Table 4). As time passed, the fresh P equivalency of the previously added build-up P doses diminished significantly. In case of 2 years older P, the residual effect reached 126% of the fresh P effects. The four years older P application referred to 61%, the six years older

Table 2: Residual effect of initial build-up P fertilization on grain/hay yields, t ha⁻¹, 4 year averages in cereal units. Calcareous Mollisol, Nagyhörcsök, Hungary, 1973-94.

Initial P ₂ O ₅ kg ha ⁻¹ in autumn 1972	Years											
	1 st cycle, 1973-1976 4 years w. wheat			2 nd cycle, 1977-1980 4 years w. wheat			3 rd cycle, 1981-1984 millet, 3 years alfalfa			4 th cycle, 1985-88 s. barley, 3 years w. wheat		
	Yield t ha ⁻¹	D t ha ⁻¹	D %	Yield t ha ⁻¹	D t ha ⁻¹	D %	Yield t ha ⁻¹	D t ha ⁻¹	D %	Yield t ha ⁻¹	D t ha ⁻¹	D %
0	3.27	-	100	3.24	-	100	2.86	-	100	2.21	-	100
240	4.65	1.38	142	4.14	0.90	128	3.02	0.16	106	2.32	0.11	105
480	4.88	1.61	149	4.55	1.31	140	3.23	0.37	113	2.58	0.37	117
720	4.84	1.57	148	4.76	1.52	147	3.42	0.56	120	2.92	0.71	132
LSD _{5%}	0.17	0.17	5	0.19	0.19	6	0.14	0.14	5	0.15	0.15	6
Mean	4.41	1.52	146	4.17	1.24	138	3.13	0.36	113	2.51	0.40	118

Initial P ₂ O ₅ kg ha ⁻¹ in autumn 1972	Years					
	5 th cycle, 1989-1992 4 years w. wheat			6 th cycle, 1993-1994 2 years w. wheat		
	Yield t ha ⁻¹	D t ha ⁻¹	D %	Yield t ha ⁻¹	D t ha ⁻¹	D %
0	2.65	-	100	2.02	-	100
240	2.78	0.14	105	1.86	-0.16	92
480	3.13	0.49	118	1.92	-0.10	95
720	3.30	0.65	125	1.92	-0.10	95
LSD _{5%}	0.38	0.38	14	0.13	0.13	6
Mean	2.96	0.43	116	1.93	-0.12	94

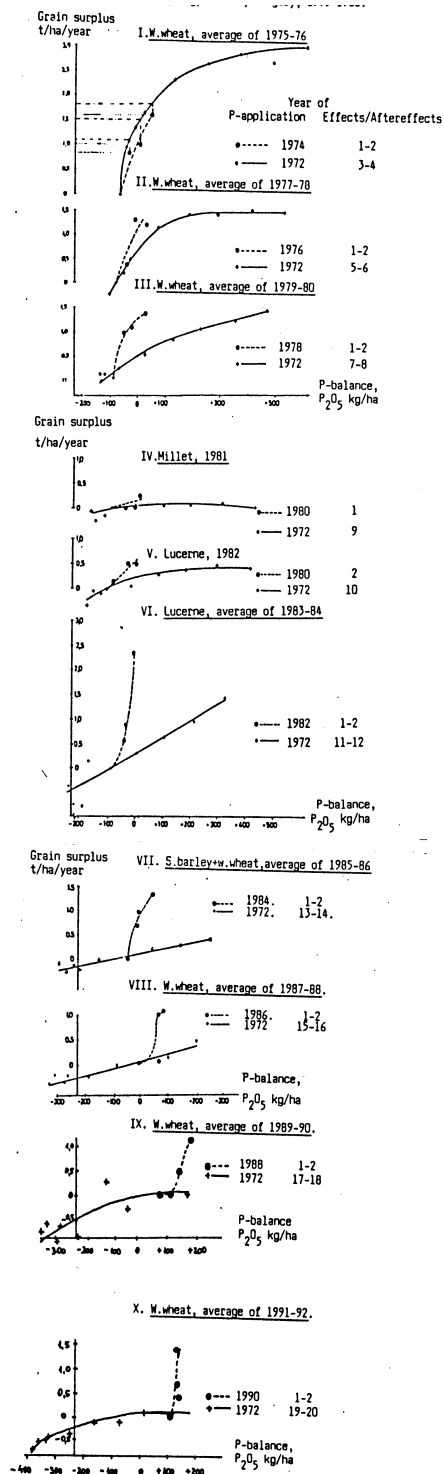


Figure 2: Comparison of the residual effect of previous P and the effect of fresh P application as a function of K balances and corn grain surpluses. Calcareous Mollisol, Nagyhorcsök, 1992-2001.

to 37%, while the eight years older to 33% of the fresh effect. Later on, the residual P effects seemed to stabilize on a very low level: the residual effect of 10 to 20 years older P only reached 5 to 17% of the fresh P application, as compared to the mutual P balance intervals. Under temperate, continental climate, the decrease in the residual effect of previously added P fertilizers can be explained by crop P uptake and P fixation. However, even the 19th to 20th year residual effect of the initial build-up 720 kg P₂O₅ ha⁻¹ application is still significant on the grain yields (0.6 to 0.7 t ha⁻¹) (Figure 2, Table 4).

Table 3: Effect of fresh P application on main yields, t ha⁻¹. Calcareous Mollisol, Nagyhörcsök, 1975-1992

Years	Fresh P ₂ O ₅ kg ha ⁻¹					Note	Crop
	0	40	80	120	LSD _{5%}		
„Old” P level: 0 kg ha ⁻¹ P ₂ O ₅ , applied in the Autumn of 1972							
1975	1.37	2.70	2.62	2.95	1.00	1st year effect	Winter wheat
1976	2.07	2.49	2.84	3.80	0.85	2nd year effect	Winter wheat
„Old” P level: 40 kg ha ⁻¹ P ₂ O ₅ , applied in the Autumn of 1972							
1977	3.10	3.33	4.38	4.15	1.13	1st year effect	Winter wheat
1978	4.00	4.57	5.31	5.41	0.97	2nd year effect	Winter wheat
„Old” P level: 80 kg ha ⁻¹ P ₂ O ₅ , applied in the Autumn of 1972							
1979	1.60	2.59	2.53	2.89	0.49	1st year effect	Winter wheat
1980	4.54	5.46	5.80	5.99	0.76	2nd year effect	Winter wheat
„Old” P level: 120 kg ha ⁻¹ P ₂ O ₅ , applied in the Autumn of 1972							
1981	1.76	1.78	1.76	1.97	0.58	1st year effect	Millet
1982	5.43	5.56	5.95	5.93	0.53	2nd year effect	Alfalfa
„Old” P level: 240 kg ha ⁻¹ P ₂ O ₅ , applied in the Autumn of 1972							
1983	9.96	10.76	11.25	12.37	1.87	1st year effect	Alfalfa
1984	5.81	6.16	6.34	8.11	1.15	2nd year effect	Alfalfa
„Old” P level: 360 kg ha ⁻¹ P ₂ O ₅ , applied in the Autumn of 1972							
1985	3.11	3.99	4.22	4.64		1st year effect	Spring barley
1986	2.33	2.77	3.21	3.39		2nd year effect	Winter wheat
„Old” P level: 480 kg ha ⁻¹ P ₂ O ₅ , applied in the Autumn of 1972							
1987	3.10	3.05	3.70	3.39		1st year effect	Winter wheat
1988	1.15	1.29	2.49	2.49		2nd year effect	Winter wheat
„Old” P level: 600 kg ha ⁻¹ P ₂ O ₅ , applied in the Autumn of 1972							
1989	3.33	3.37	4.14	4.48		1st year effect	Winter wheat
1990	2.90	2.82	2.92	4.14		2nd year effect	Winter wheat
„Old” P level: 720 kg ha ⁻¹ P ₂ O ₅ , applied in the Autumn of 1972							
1991	2.96	3.59	4.42	5.10		1st year effect	Winter wheat
1992	3.85	3.79	4.20	4.54		2nd year effect	Winter wheat

Table 4: Comparison of the residual effect of build- up P application and the effect of fresh P application at the mutual P balance intervals, 2 year average surpluses in cereal units, 1973-1992. Calcareous Mollisol, Nagyhorcsök, 1992-2001.

Fresh P Year	Residual P year	Year of the trial	Crop	Average grain/hay yield surpluses			
				t ha ⁻¹		%	
				Fresh P	Residual P	Fresh P	Residual P
1-2	-	1973-74	W.wheat	0.50	-	100	-
1-2.	3-4.	1975-76	W.wheat	1.18	1.49	100	126
1-2.	5-6.	1977-78	W.wheat	0.98	0.60	100	61
1-2.	7-8.	1979-80	W.wheat	1.14	0.42	100	37
1-2.	9-10.	1981-82	Millet/Alfalfa	0.20	0.06	100	33
1-2.	11-12.	1983-84	Alfalfa1.27	0.22	100	17	
1-2.	13-14.	1985-86	S.barley/W.wheat	0.98	0.10	100	10
1-2.	15-16.	1987-88	W.wheat	0.70	0.06	100	9
1-2.	17-18.	1989-90	W.wheat	0.50	0.03	100	6
1-2.	19-20.	1991-92	W.wheat	0.87	0.04	100	5

Acknowledgement

This study was financially supported by the Hungarian National Research Fund (OTKA) under Grant No. T 034497

References

- Bircsák, É.; Csathó, P.; Németh, I.; Radimszky, L.; Baczó, G.; Németh, T. The Residual Effects of Previous N Application in Two Hungarian Long-term Field Trials. *Commun. Soil Sci. Plant Anal.* **2003**, *34*, 000-000. (In print).
- Csathó, P. The Residual Effect of K Fertilization in a Hungarian Corn Monoculture Long-term Field Trial, 1990-1999. *Commun. Soil Sci. Plant Anal.* 2002, *33*, 3105-3119.**
- Johnston, A.E.; Lane, P.W.; Mattingly, G.E.G.; Poulton, P.R. Effect of Soil and Fertilizer P on Yields of Potatoes, Sugarbeet, Barley and Winter Wheat on a Sandy Clay Loam Soil at Saxmundham, Suffolk. *Journal Agric. Sci. Cambridge*, **1986**, *106*, 155-167.
- Kádár, I.; Csathó, P.; Sarkadi, J. Residual Effect of Superphosphate Application in Winter Wheat Monoculture. I. Residual Effects on Soil P and Grain Yield. *Agrokémia és Talajtan*, **1984**, *33*, 375-390. (In Hungarian)
- Németh, T. The role of phosphorus in Hungarian agriculture. *Codes of good agricultural practice and balanced fertilization*. (Ed.: Fotyma, M.) Proceedings Int. Symposium CIEC, PFS and Workshops IMPHOS, IPI, September 27-30, **1998**, Pulawy, Poland. *Bibliotheca Fragmenta Agronomica*, Tom. 3:298-309.
- Peck, T.R. Soil Testing: Past, Presence and Future. *Commun. Soil Sci. Plant Anal.* **1990**, *21*, 1165-1186.
- Sibbesen, E.; Sharpley, A.N. Setting and Justifying Upper Critical Limits for Phosphorus in Soils. In *Phosphorus Loss from Soil to Water*. Tunney, H. et al., Eds.; CAB International: Wallingford-New York. **1997**, 151-176.

UTILIZATION OF ORGANOMINERAL FERTILIZERS ON LIGNITE SUPPORT, AN IMPORTANT MEANS TO IMPROVE THE FERTILITY OF SOILS WITH REDUCED HUMUS CONTENT

E. Dorneanu, A. Dorneanu and C. Preda

Research Institute for Soil Science and Agrochemistry, Bucharest, Romania.

Abstract

The research for producing the organomineral fertilizers on the basis of brown coal (lignite) dust started in Romania about three decades ago (Dorneanu, Popa et al., 1971). The purpose of this research was to create a series of fertilization products which, concurrently with the plant nutrition improvement, have the capacity to ensure a humic amelioration of both the sandy soils and the soils with a low humus content (Erodisols, Luvisols).

The organomineral fertilizers are products whose the nutrients are included in an organomineral matrix based on humic substances from brown coal (lignite). which contain 20-30 % nutrients (N, P) and 12-17 % humic acids. The humic substances of these fertilizers improve soil properties and plant nutrition. This matrix slows and prolongues the processes of hydrolysis, ammonification and nitrification of the nitrogen compounds, as well as the conversion of soluble phosphates into insoluble phosphates. Due to the long persistence in soil of the nutrients included in organomineral matrix, the plants benefit for a longer period of the nutrients in these fertilizers than of the nutrients in the mineral fertilizers and, therefore the utilization rate of nutrients is higher.

The utilization of this fertilizer category presents interest for sandy soils, eroded soils, humus-poor luvisols as well as irrigated soils with light texture having in view the prevention of nitrogen losses by leaching.

The yield increases obtained with these fertilizers are higher with 15-20 % than those achieved by the mineral fertilizers.

Keywords: organomineral matrix, leaching, utilization rate of nutrients

Introduction

The initiation of this research for producing organomineral fertilizers was based on the presence of some important coal deposits and of large areas of cultivated soils needing humic amelioration.

The procedures to obtain the organomineral fertilizers to rely on the activation of finely ground coal with a mineral acid (HNO_3 , H_2SO_4 , H_3PO_4) followed by a neutralization with a base (NH_4OH , NH_3) including the addition of different mineral salts before granulation (Rogoz et al., 1972, Dorneanu et al., 1984).

The fertilizers obtained by the mentioned procedures contain nutrients incorporated into an organomineral matrix with specific properties which positively influence their assimilation by plants as well as the humic amelioration of soils.

This paper presents the efficiency of fertilization with organomineral fertilizers on the basis brown coal (lignite) and their characteristics.

The research had in view the following aspects:

- To characterize their composition and physico-chemical properties;
- To determine their influence on maize yield taken as a plant test, cultivated on an irrigated sandy soil (Psammosol);
- To determine the utilization rate in the kernel yield of the main nutrients in these fertilizers;
- To determine the nitrogen leaching degree under the irrigation and high pluviometric regime conditions;
- To determine the influence of the repeated application of these fertilizers for 15 years on the evolution of the main agrochemical indexes.

Materials and Methods

In the study were taken 4 types of organomineral fertilizers on the basis of brown coal (lignite) obtained by different procedures, and namely: L-200 and L-300 (with nitrogen), SH-210 and SH-120 (with nitrogen and phosphorus) The contents of nutrients, humic acids, cation exchange capacity and pH were determined according to the standard procedures.

These types of organomineral fertilizers were tested in a field experiment with maize cultivated on an irrigated soil (Psammosol) for 5 years at the Research Development Station for Plant Growing on Sandy Soils, Dăbuleni-Dolj. The sandy soil is characterized by: 66 % coarse sand, 21 % fine sand, 7.7 % silt, 4.4 % clay, 0.065 % humus, 0.0164 % N, 8.4 ppm P_{AL} , 34 ppm K_{Al} and pH 7.49 in aqueous suspension (1:2.5). The fertilization rate was: N-200, P_2O_5 -100, K_2O -100 kg/ha.

The nitrogen leaching degree from these fertilizers was determined at SC Chimenerg SA Craiova using an original equipment with columns of plastic with the height of 1500 mm and the diameter of 190 mm. The columns were filled with sandy soil. In the upper part of the columns, special pots (column-head) filled with 5 kg of soil including 400 mg N/kg of soil were installed. The soil in the pots was cultivated with ryegrass (*Lolium multiflorum* Lam.). Every day 200 ml demineralized water was applied. Weekly, for ten weeks, an adequate irrigation with a moisture regime of 42 mm of water was applied. The total percolated water amounted to

420 mm. The nitrogen in the collected solutions from the bottom of the columns was determined by Kjeldahl distillation method.

The main agrochemical indexes of the sandy soil were determined in a lysimeter experiment for 15 years under the influence of organomineral fertilizers L-200 and L-300 as compared to the urea (Dorneanu, 1997). The annual fertilization rate was: N-200, P₂O₅-100, K₂O-100 mg/kg soil. The organic carbon was measured by the Walkley Black-Gogoasă method, the nitrogen by Kjeldahl distillation, the mobile phosphorus and potassium by the extraction with ammonium lactate acetate and the phosphorus determination by Troug-Meyer procedure and potassium by flame photometric procedure, respectively.

Results and discussion

The composition and physico-chemical properties of organomineral fertilizers are presented in Table 1.

Table 1: Composition and properties of organomineral fertilizers taken in the study

No	Specification	UM	L-200	L-300	SH-210	SH-120
1. Composition						
1.1	Brown coal (lignite) weight	%	47.0	35.0	40.2	54.5
1.2	Humic acids	%	16.0	10.0	17.0	12.70
1.3	Total nitrogen (N _t)	%	22.0	28.0	20.55	9.15
1.4	Phosphorus (P ₂ O ₅)	%	-	-	9.75	16.50
1.5	Potassium (K ₂ O)	%	0.255	0.197	0.226	0.307
1.6	Calcium (Ca)	%	0.012	0.009	0.011	0.014
1.7	Magnesium (Mg)	%	0.188	0.140	0.160	0.217
1.8	Iron (Fe)	%	0.930	0.693	0.795	1.08
1.9	Manganese (Mn)	%	0.006	0.004	0.005	0.007
1.10	Zinc (Zn)	%	0.027	0.020	0.023	0.032
1.11	Copper (Cu)	%	0.017	0.013	0.015	0.020
2. Properties						
2.1	Cation exchange capacity (CEC)	me/100g	48.0	35.77	41.0	55.70
2.2	pH (1:2.5) suspension in water	-	4.50	4.80	6.30	6.40
2.3	Aparent density	g/cm ³	0.738	0.707	0.720	0.813
2.4	Granules (1-5 mm)	%	82.0	86.0	79.3	88.6

The brown coal (lignite) used for producing these fertilizers is characterized by an average content of 55 % organic matter, 22.1 % SiO₂ and 18.0 % other mineral substances. The organic carbon content is 30.0 %.

In the L-200 and L-300 fertilizers with 22-28 % N, this element was incorporated into the coal mass by technological process. The other elements are native components of the coal mass. Due to the coal composition, these fertilizers contain 7.9-10.6 % humic acids and has a cation exchange capacity (CEC) over 35.7 me/100 g.

The SH-210 and SH-120 fertilizers contain over 9-20 %N and 9.75-16.5 % P₂O₅ incorporated into the coal mass by technological process. The other elements are native components of the coal. The humic acids represent 9-12.3 % and CEC is over 41 me/100 g.

By their composition and properties, these fertilizers are characterized as fertilization products with multiple functions.

Table 2 presents the influence of the organomineral fertilizers on maize kernel yield as compared to the mineral fertilization (urea, TSP, potash). All treatments with the organomineral fertilizers obtained yield increases significantly higher with 15.9 –20.8 %

Table 2: Influence of organomineral fertilizers (OMF) applied at maize irrigated, HF-420 cultivar, grown on Psammosol at the Research Development Station for Plant Growing on Sandy Soils, Dăbuleni-Dolj

No.	Treatments	Average kernel yield (5 years) kg/ha	Yield increase			kg kernel per kg of (N-P ₂ O ₅ -K ₂ O)
			kg/ha	% in comparison with		
				M ₁	M ₂	
1	Unfertilized (M ₁)	2808	-	100.0	-	-
2	Urea, TSP*, potassium salt (M ₂)	5290	2482	188.4	100.0	6.20
3	L-200 , TSP, potassium salt	6210	3402	221.1	117.4	8.50
4	L-300 , TSP, potassium salt	6136	3328	218.5	115.9	8.32
5	SH-210 , potassium salt	6353	3545	226.2	120.0	8.86
6	SH-120 , urea, potassium salt	6359	3587	227.7	120.8	8.96

LSD (0.05)

625

(0.01)

880

*) TSP – triple superphosphate

The utilization rates (UR) of N, P and K in kernel yield (Table 3) from the treatments with organomineral fertilizers are higher than the treatment with the mineral fertilizers. As a result, the utilization rate of fertilizers (MF+OMF) is between 56.36 –59.90 %, but the utilization rate

obtained only on the basis the organomineral fertilizers UR (OMF) were 14.70 – 18.24 % (Figure 1)

Table 3: The utilization rate (UR) of fertilizer nutrients (N, P and K) and (UR) of organomineral fertilizers (OMF) applied at irrigated maize, grown on Psammosol

Treatments	Average yield (5 years) kg/ha	Utilization rate of nutrients						UR of (MF+ OMF) %	UR of OMF %
		N %	URN %	P %	URP %	K %	URK %		
Control	2808	1.65	-	0.174	-	0.23	-	-	-
Urea, TSP potassium salt	5290	1.83	25.23	0.225	7.02	0.30	9.41	41.66	-
L-200, TSP, potassium salt	6210	1.84	33.97	0.238	9.89	0.32	13.41	57.27	15.61
L-300, TSP, potassium salt	6136	1.86	33.90	0.241	9.90	0.31	12.56	56.36	14.70
SH-210, potassium salt	6353	1.86	35.91	0.245	10.68	0.30	12.60	59.19	17.70
SH-120, urea, potassium salt	6395	1.87	36.65	0.251	11.16	0.29	12.08	59.90	18.24
LSD (0.05)		0.182		0.017		0.024			
(0.01)		0.260		0.023		0.034			

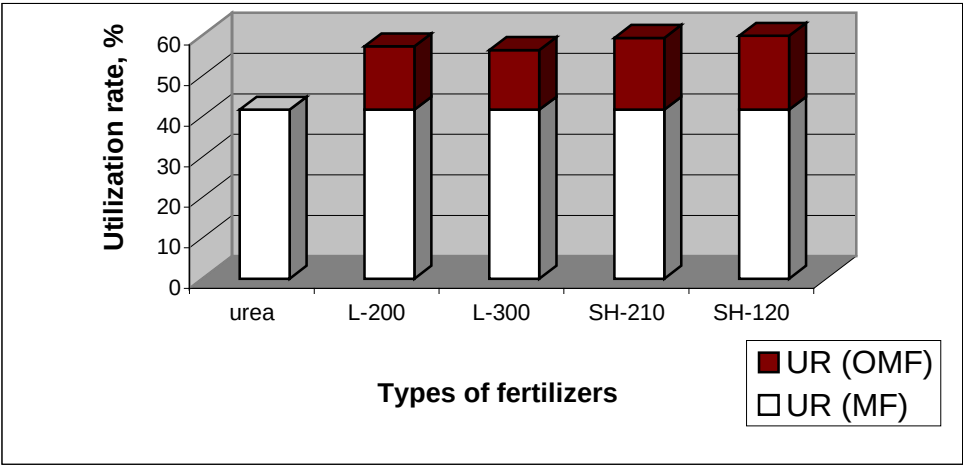


Figure 1: Utilization rate of nutrients from organomineral fertilizers (OMF) applied at maize irrigated on sandy soil as compared to mineral fertilizers (MF) for 5 years

The high efficiency of the organomineral fertilizers concerning the yield and its quality is due to the multiple effects of these fertilizers which slow down and prolong the process regarding the hydrolysis, ammonification and nitrification of nitrogen compounds and the retrogradation of the soluble phosphates. Due to the longer persistence in easily assimilable forms, the incorporated nutrients are efficiently used by plant in a higher proportion than the nutrients in the mineral fertilizers.

Data regarding the nitrogen leaching degree from the organomineral fertilizers as compared to the urea, determined in columns filled with sandy soil irrigated at a level of 420 mm water (Table 4) reveal that the organomineral matrix has also a positive role in reducing the nitrogen losses by leaching. The nitrogen losses were lower with 34 % in the L-300 treatment and as compared to the treatment with urea

Table 4: The nitrogen leaching degree (NLD) from organomineral fertilizers determined in columns filled with sandy soil (Psammosol) under ryegrass crop (*Lolium multiflorum* Lam.). The amount of applied fertilizer was 2 g N/column.

No	Types of fertilizers	N removed by harvest		mg N remained in the soil	Leached total N mg/420 mm percolated water	NLD	
		mg	%			mg N/mm H ₂ O	%
1	Urea	832	100.0	1168	1157	2.75	100.0
2	L-200	985	118.3	1015	838	1.99	72.4
3	L-300	1062	127.6	938	819	1.95	70.9
4	SH-210	1240	149.0	760	731	1.74	63.3
5	SH-120	1122	134.8	878	864	2.05	74.5

In the Table 5 to present the influence of the L-200 and L-300 fertilizers as compared to urea consecutively applied for 15 years to the maize cultivated in lysimeters with a capacity of 48 kg sandy soil. Both the yield increase and the agrochemical indexes of the L-300 treatment are significantly higher than those obtained with urea. These values prove that the fertilization with such fertilizers, by long-term application, causes a higher improvement both of the soil organic matter content and the main agrochemical indexes. The carbon and nitrogen contents are almost doubled after 15 years fertilization, because the leaching losses recorded are lower (Table 4).

Table 5: Influence of organomineral fertilizer, L-200 and L-300, on sandy soil agrochemical indexes applied for 15 years at maize grown in lysimeter with the capacity of 48 kg soil (Dorneanu, 1997)

Treatments	Average kernel yield (15 years)		Agrochemical indexes				
			Corg %	CEC me/100 g	N _t %	P _{AL} ppm	K _{AL} ppm
	g/lysimeter	%					
Unfertilized	104.9	100.0	0.55	3.04	0.016	18.5	28.5
Urea, TSP, potassium salt	193.2	184.2	0.59	3.09	0.027	74.2	47.5
L-200, TSP, potassium salt	218.8	208.6	0.60	3.10	0.051	87.8	52.3
L-300, TSP, potassium salt	218.2	208.2	0.99	3.92	0.048	85.8	52.7
LSD (0.05)	17.0	-	0.011	-	0.09	3.5	4.0
(0.01)	24.0	-	0.016	-	0.13	5.2	5.6

Taking into account the humic amelioration effects, higher utilization rate and low nitrogen leaching degree, it can be concluded that the organomineral fertilizers represent an important fertilization mean under the ecological protection conditions.

Table 6 presents the economic efficiency obtained taking into account the yield increases, prices of fertilizers and expenses of application. It reveals that, although, the prices of these organomineral fertilizers are higher than those of the mineral fertilizers, their application on sandy soils assures a higher economic efficiency with 45.5-58.2 %.

Table 6: Economic efficiency of OMF applied at maize grown on sandy soil

No.	Types of fertilizers	Yield increase	Income obtained by yield increase*	Prices of fertilizers + Expenses of application	Net income	
					USD/ha	%
1	Urea, TSP, Potassium salt	2482	266	120	158	100.0
2	L-200 , TSP, potassium salt	3402	364	100	146	180.8
3	L-300 , TSP, Potassium salt	3328	356	116	264	164.3
4	SH-210 , potassium salt	3545	379	94	264	195.2
5	SH-120 , urea potassium salt	3587	384	91	285	200.7

*) 107 USD/ton kernel maize.

Conclusions

As compared to the mineral fertilizers which have a reduced efficiency on sandy soils due to the more intensive leaching processes of nutrients, the organomineral fertilizers represent an important means of fertilization under ecological protection conditions.

Due to the specific properties of the organomineral matrix, the utilization rate of the organomineral fertilizers is higher with 14.7-18.24 %, and the nitrogen loss by leaching is lower in comparison with urea.

By their properties and economic efficiency, the organomineral fertilizers are worth to be priorly used on sandy soils as well as other soils with low organic matter content.

References

1. DORNEANU A., POPA O., ROGOZ J., 1971. Perspective de introducere în practica agricolă a îngrășămintelor complexe organominerale. Conferința de Chimie Craiova, 101-116.
2. DORNEANU A., DORNEANU EMILIA, 1984. Concepții moderne în fertilizarea organică a solului. Ed. Ceres, București.
3. DORNEANU A., POPA O., DORNEANU EMILIA, et al., 1987 - Organomineral fertilizers with lignite and urea-aldehyde, important means for fertilization of irrigated crops on sands. Bull. de l'Academie des Sciences Agricoles et Forestieres, nr. 16, 59-66.
4. DORNEANU A., DORNEANU EMILIA, ALEXANDRESCU ARIADNA et al., 1997. Eficacitatea complexă a îngrășămintelor cu azot în funcție de natura surselor cărbunoase. Journal of the Romanian National Society of Soil Science, 29, 64-73.
5. DORNEANU EMILIA, 1997 – Cercetări privind efectul unor îngrășăminte produse industrial cu azot mineral și organic asupra plantelor și însușirile chimice ale psamosolurilor cultivate. Teza de doctorat
6. DORNEANU EMILIA, DORNEANU A., 2001. Studies on agrochemical properties of urea and its derivatives. Their efficiency in long-term fertilization on sandy soil. In: Role of fertilizers in Sustainable Agriculture. Proceedings. International Symposium of CIEC, 21-22 August, 2000, Suceava, Romania, 245-254
7. NIGRO C., 1969. Fixarea azotului pe materia organică prin tratare cu acid azotic, prepararea humoazotaților prin amonificarea lignitului. Agrochimia 14 (1).
8. ROGOZ J., POPA O., DORNEANU A., et al., 1972. Procedeu de obținere a unui îngrășământ complex organomineral cu azot și fosfor, Brevet nr.77638, România.
9. ROGOZ J., POPA O., DORNEANU A., et al., 1972. Procedeu de obținere a unui îngrășământ complex organimineral cu azot. Brevet nr. 77639, România.

THE PERFORMANS OF *AZOLLA MEXICANA* (2026) ON THE AEGEAN REGION CONDITIONS IN TURKEY

M. N. Gevrek¹ and B. Yağmur²

¹Ege Uni., Faculty of Agriculture, Dept. Of Crop Science, Bornova-Turkey, mng@ziraat.ege.edu.tr

²Ege Uni., Faculty of Agriculture, Soil Science Dept., Bornova-Turkey, bulentyagmur@mynet.com

Introduction

Azolla (*Azolla anabaenae*) is an aquatic fern. It lives on water surface of rice fields, small ponds, canals and rivers. It quickly covers the surface of water. It lives harmoniously under the conopy of rice plants, but does not affect its growing. Generally it multiplies vegetatively, and often sexually. Its size is 1-5 cm. There are a lot of lops on the azolla's leaves. The blu-green algae *Anabaena azollae* lives upon lops and in symbiosis with azolla plant. It fixes nitrogen as high as 3-5 kg N per day under the optimum condition. Because it contains nitrogen fixing blue-green algae, *Azolla* plant develops at a fast rate and can double it's weight within 3 to 5 days (1-2-3).

Azolla is sensitive to desiccation. When water depth over soil is a few cm, it grows well. *Azolla* multiplies at the daily mean temperature of 15-30⁰C. Optimum temperature is about 25⁰C. *Azolla* can tolerate (survive) up to -5⁰C. Under nutrient deficient and strong light conditions, *Azolla* becomes red. During hot summer or cold winter, it also turns red or brownish red. Under shaded conditions or nutrient-rich conditions, it remains green. *Azolla* absorbs nutrient from water. *Azolla* is very dependent upon phosphorus fertilizer. The application of phosphhorus as superphosphate can significantly increase nitrogen fixation. *Azolla* prefers slightly acidic pH 4-7. Lepidoptera, Pyralidae larva are most harmful insect pests to azolla (4-5-6).

Because of symbiotic nitrogen fixation, and consequently, high nitrogen content, and *Azolla* has been used as a green manure and organic matter resourc for wetland rice in northern Vietnam, and central to southern China for centuries (6). About 70 % of *Azolla* N contents were mineralized to NH₄+H after 20 days of incorporation. Rice plant can use easily NH₄+H form (7-8). When in excess, it is also converted into compost to be used for dry land crops and vegetables. At present, *Azola* is used in more than a million hectares of rice land in China. Similarly, 400.000 hectares are under this crop in Vietnam.

The use of *Azolla* in rice areas in the Philippines is increasing. It has been estimated that 44% of rice land will be fertilized with *Azolla* in near future (9). *Azolla* has a high protein content of approximately 23-37 percent (dry-weigt basis). *Azolla* has been used as feed for pig, duck, and

fish. Fresh Azolla can also be used in salads and sandwiches, just as alfalfa and bean sprouts are used (10-11).

Materials and Methods

This research was carried out at three locations (Izmir and Aydın located in the Aegean region and Antalya located in the Mediterranean coast, Turkey) in 1999, 2000 and 2001, but it was only given the results of Izmir location in this paper. *A. mexicana*-2026 strain was used in this study. The study was supported by TUBITAK (The Scientific and Technical Research Council of Turkey. Project No: TARP-2183).

Fresh azolla plants were inoculated at the rate of 300 g m⁻² into 4 m x 4 m (16 m²) ponds. About 20 cm of water level was constantly stagnant in all ponds. To promote the vegetative development of azolla plants and nitrogen fixation of *Anabaena* algae, 0.2 g m⁻² of P₂O₅ was applied into the ponds as triple super-phosphate in seven-day intervals (12, 13).

Fresh azolla plants were collected once by hand 14 days after inoculations and following measurements were done: fresh weight (g m⁻²), dry matter (g m⁻²), dry weight rate (%), organic matter (%), C/N, water holding capacity. Macro and micro nutrient elements in harvested azolla plants from the locations were also determined in order to evaluate the potentiality of the organic matter as a biofertilizer. Dry matter content was determined after drying at 65 °C for 24 hours in an air-forced oven. The dried samples were ground in a grinding machine. The ground samples were mixed with HNO₃+HClO₄ and wet burning was done. K, Na, and Ca were measured by flame photometry and Mg, Fe, Zn, Mn and Cu by ASS (Kacar, 1972). Total P was measured according to vanado- molybdo phosphoric yellow colour method. Total nitrogen in the plant samples was measured by the modified Kjeldahl method (13).

The physical and chemical properties of research ponds based on the samples there are shown in Table 3. Surface mixed soil samples (0-25cm) were collected, air dried in the laboratory and then sieved through 2 mm sieves. pH values of the sieved soil samples were measured by pH-meter after saturation of soil with pure water (14). Total water soluble salts of same soil paste were determined with the help of reduction monogram after measuring the resistance with conductometer. Lime of soil was measured by volumetric method and texture of the soil was determined as hydrometric fractions. Texture properties were defined by using the soil triangle. Organic matter was determined by fresh burning method and total nitrogen by using a modified Kjeldahl method (15). Utilizable P was measured colorimetrically by water extraction method, whereas K, Na, Ca and Mg were extracted with 1N NH₄OAC. The measurements of K, N and

Ca were made by flame photometry and that of Mg by atomic absorption spectroscopy (AAS) (16). Usable Fe, Zn, Mn and Cu were measured by AAS after extraction with DTPA (17). It was given some soil properties of the research field of the Izmir location below (Table 1).

Table 1: Selected physical and chemical properties of soil samples from the research fields (Izmir).

PH	7.0	Organic matter (%)	1.4
Total salt (%)	0.1	Total N (%)	0.06
Lime (%)	9.2	P (ppm)	3.7
Texture	Silty loam	K (ppm)	300.0

The experiment was arranged in a 2X2 factorial design (location X time) replicated in three years (1999, 2000 and 2001). Results were analyzed statistically by analysis of variance using the Statistical Analysis System (SAS) computer package.

Results and Discussion

The Ege region on the west coast of Turkey has a distinct climate-temperature ranges from 15-35°C from the beginning of April to the first week of September, rainfall average 500-600 mm, and relative humidity is 57 %. Summer is warm and dry while winter is like mild and rainy.

The inoculated amount of fresh weight (300 g/m²) reached to 1299 g/m² after 14 days (333 %). Statistical analysis showed that the first inoculation dates resulted in comparatively better yield performance than any other inoculation dates based on Duncan's multiple range test. the best time for Azolla inoculation was the first week of July (1481 g/m²) (see table 2).

Table 2: Average growth and nitrogen accumulations in the Azolla-inoculated field plot (m⁻²) at Izmir, 1999, 2000, and 2001.

Treatments	Inoculation date	1 (°C)	2 (%)	Amount harvested. (g m ⁻²) fresh	% increase in fresh wt.	Total N (g m ⁻²) ⁴
1	April	22.6	63.8	1481.0 a ³	394	3.12
2	May	27.1	57.2	1216.0 b	305	2.44
3	June	31.5	49.6	0	0	0
4	September	30.0	61.9	1200.0 b	300	3.05
Av				1299.	333	2.87

¹ Monthly air temperature °C, ² Average relative humidity (%), ³ Duncan (%5), ⁴ at 65°C

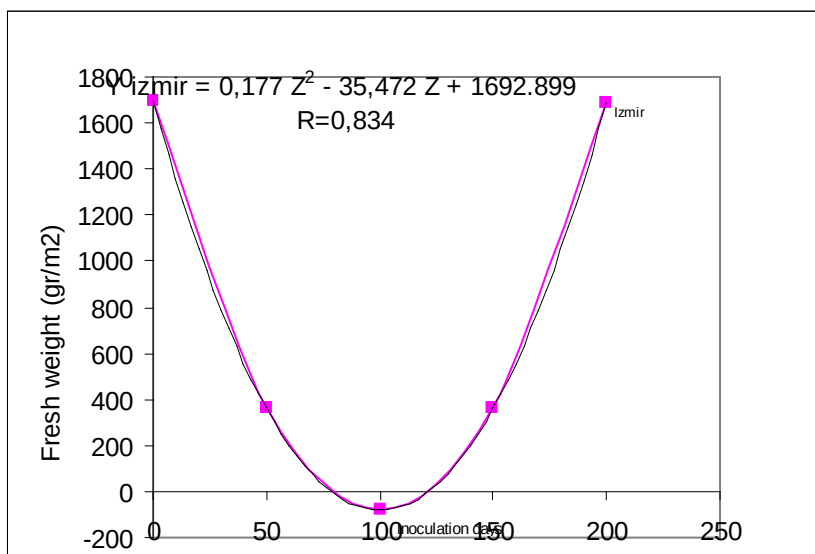


Figure 1: Fresh weight as a function of inoculation days starting from April to October (0-200 days)

The period to get two fold increase was 3.53, 4.60 and 4.90 days for April, May, and September at Izmir averaged over years, respectively (Table 2) and the result was similar to the findings of Hove (1989)(12) and Thomas et al. (1982)(14). The highest % increase rates were 394 %, 305 %, and 261 % in April, May and September months, respectively (Figure 1).

There are two temperature factors important for the growth of azolla, air temperatures and water temperatures. Of these, water temperature is generally more important during summer and air temperature is more important during winter. During the summer the mid-day temperature of surface water is often 4-7 °C higher than that of the air temperature and can be 15-20 °C higher at night. On very sunny summer days surface water temperatures may reach up to 42-45 °C, while the same water in rice fields covered with Azolla only reaches to 39-40 °C. When temperatures rise to 30 °C or above, growth slows down and even dies if temperatures rise much above 40 °C for more than a few hours. Azolla strain and varieties have different tolerances to temperature extremes, and as a result some can survive within a very wide temperature range while others can only survive within a very narrow temperature range. *A. filiculoides* and *A. rubra* are quite tolerant to low temperatures, while *A. mexicana*, *A. microphylla*, *A. caroliana* and certain varieties *A. pinnata* possess considerable tolerance to high summer temperatures (14). The maximum air temperature in June reaches above 30 °C. Since the water temperature is often 4-7 °C higher than the air temperature, the plant growth slows down, yield decreases and eventually plant dies.

Dry weight rate and dry matter values were 7.35 % and 95.58 g m⁻² averaged over years. The dry weight of azolla has been reported to range from 4.8 % to 5.6 % (15)(16).

C/N ratio in this experiment was 10.71 which indicates that decomposition and mineralization of azolla occurs in a very short time. Gevrek and Yağmur (1996), reported that *A. mexicana* genotype increases soil organic matter to 32.0 and 38.8 % and total nitrogen ratio to 38.0-56.0 % in 2-3 weeks. Appreciably organic matter (55.40 %) was obtained at Izmir, and organic matter ranged between 53.87 %, and 58.00 % among locations averaged over years. However, 104.40 m⁻² dry matter amount was obtained at Izmir in April (Table 3).

The total N content was between 2.9-3.1 % averaged over years (Table 3). The dry weight nitrogen content of azolla has been reported to be as high as 6.5 % but will probably be closer to 3.5-4.0 % (15).

Azolla may be transferred to a medium poor in phosphorus where it will carry on flourish by using its reserves. The total P content in dry matter was between 0.43 and 0.44 averaged over years. Azolla can accumulate P and its content is up to 1 or 2 % of dry matter (12).

Table 3: The analysis of *A. mexicana* 2026 grown at Izmir in 1999, 2000, and 2001 (65⁰C).

Analysis	April	May	October	Aprox.
Dry weight rate (%)	7.00	6.80	8.27	7.35
Dry matter amount (g m ⁻²)	104.40	83.35	99.00	95.58
C/N	10.67	10.60	10.87	10.71
Organic matter (%)	54.33	53.87	58.00	55.40
Water holding capacity (%)	411.67	408.33	416.67	412.22
Total protein (%)	17.04	16.72	17.61	17.12
Total N (%)	2.99	2.93	3.09	3.00
“ P (%)	0.43	0.43	0.44	0.43
“ K (%)	1.33	1.37	1.18	1.29
“ Ca (%)	3.07	3.53	3.77	3.45
“ Mg (%)	0.95	0.93	0.88	0.92
“ Fe (%)	0.37	0.32	0.41	0.36
“ Na (%)	1.12	1.29	1.24	1.21
“ Cu ppm	14.77	16.40	18.23	16.46
“ Zn ppm	673.33	689.33	508.3	623.66
“ Mn ppm	1100.00	1083.33	1266.67	1150.00
Doubling time of fresh weight increase (days)	3.53	4.60	4.90	4.34

The total K content (%) in dry weight was found between 1.18 and 1.37 % averaged over years. Ca, Mg, Fe and Na elements were also found in different amounts (Table 3). The dry weight K content of azolla has been reported to be as high as 6.0 % (14).

Water holding capacity of the dry azolla was determined as 400-500 % and could be alternative to turf used as a growing media.

The total protein ratio in dry weight of azolla plants was determined between 16.7 and 17.6 %.

Discussion

A. mexicana-2026 strain showed high performance with respect to vegetative development and fresh weight increase rate in Aegean and Mediterranean climate and can be grown successfully in Mediterranean countries. Especially early inoculations (April) give better results in terms of fresh weight increase rate and total organic matter when the air temperatures are between 10 to 30 °C and 50 to 60 % relative humidity. The growth was strictly restricted in June, July, August, and September due to higher air and water temperatures and the production should be done in April, May, and October in the regions where Mediterranean climate is dominant.

References

- Watanabe I., R. A. Roger, J. K. Ladha, and C. Van Hove, Biofertilizer Germplasm Collections at IRRI, 1992.
- Roger, P.A., Kulasoornya, S.A., Blue-Green Algae and Rice, IRRI, 1980.
- Watanabe, I., Brotonogoro, S., Nitrogen Fixation, In Paddy Fields, V:1, 241-263 Clarendon press, London, 1981.
- Berja, N. S., Growth of Four Species of Azolla as Affected by Temperature, Aquatic Bot, 15: 175-185, 1983.
- Talley, S. N., B. J. Talley and R. W. Rains, Nitrogen Fixation by *Azolla* in Rice Field, D. A. Hollaender et al. Plenum Press, 259-281, New York, 1977.
- Khan, M. M., A primer on *Azolla* Production and Utilization in Agriculture, UPLB, PCARRD and SEARCA, Los Banos, 1983.
- Watanabe, I., Use of Symbiotic and Free-Living Blue-Green Algae in Rice Culture, Outlook on Agric., 13 (4):166-172, Great Britain, 1984.
- Watanabe, I., Biological Nitrogen Fixation in Rice Soils, In Soils and Rice, IRRI, 465-477, 1985.
- Singh, P. K., Panigrahi, B. C. and Satapathay, K. B., Comparative Efficiency of Azolla, Blue Green Algae and Other Organic Manures in Relation to N and Availability in a Flooded Rice Soil, Plant soil, 62, 35-44, 1981.
- Lumpkin, T.A. and Plucknett D.L., Azolla as a Green Manure: Use and Management in Crop Production. Westview Tropical Agriculture Series, No.5. Colorado. 230 pp.
- Wagner, G.M., Azolla: A review of its biology and utilization. Botanical Review. 63(1). 1-26.
- Hove, C. Van. 1989. Azolla and its multiple uses on Africa, F.A.O, 42.
- Khan, M.M. 1987. Is Azolla a viable supplement and/or substitute for chemical fertilizer SERCA technical bulletin 3, 1-12.
- Kacar, B. 1972. Bitki ve Toprağın Analizleri II. Bitki Analizleri. A. Ü. Ziraat Fak. Yayınları, 453. A. Ü. Basımevi, Ankara, 155.
- Jackson, M.L. 1962. Soil Chemical Analysis. Prentice Hall, Inc. Englewood. Cliffs, N.J. 27-28
- Bremner, J.M. 1965. Total Nitrogen in Methods of Soil Analysis. In C. A. Black, ed., Amer. Soc. of Agr. Inc. Pub. Madison Wisconsin, USA. 11749-1178.
- Pratt, P.F. 1965. Potassium in methods of soil analysis. In C. A. Black, ed., Amer. Soc. of Agr. Inc. Pub. Madison Wisconsin, USA. 1022.
- Lindsay, W.L. and Norwell, W.A. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Amer. Jour. 42:421-428.
- Pratt, P.F. 1965. Potassium in methods of soil analysis. In C. A. Black, ed., Amer. Soc. of Agr. Inc. Pub. Madison Wisconsin, USA. 1022.
- Thomas, A. Lumpkin, and Plucknett, D.L. 1982. Azolla as a Green Manure: Use and Management in Crop Production. Westview Tropical Agriculture Series, No.5, Library of Congress Catalog Card Number 82-50919 ISBN 0-89158-451-X.
- Peters, G.A., Toia, R.E., Evans, W.R., Crist, D. K. Mayne, B.C. and Poole, R.E. 1980. Characterization and comparisons of five N₂ fixing Azolla-Anabaena associations. I. Optimization of growth conditions for biomass increase and N content in a controlled environment. Plant, Cell and Environment 3:261-269.
- Gevrek, M.N. and Yağmur, B. 1996. Azolla (*Azolla anabaena*)'nın Toprağın Azot Oranına ve Organik Yapısına Etkisi, Ege Ün. Ziraat Fak. Dergisi, 33: 97-103.

RICE STRAW AND SULPHUR ON THE GROWTH AND YIELD OF RICE

S. A. Haque

Department of Soil Science, Bangladesh Agricultural University
Mymensingh-2202, Bangladesh

Abstract

Bangladesh is an agrarian country with rice as the dominant cereal crop. In recent years, sulphur has been found to be highly deficient in most of the rice fields, which covers roughly 80% of the total cultivable lands. Rice straw is a major agricultural by-product in Bangladesh. Management of crop residues should be considered as a means of reducing the S requirement of a cropping system. Therefore, a field experiment was carried out to investigate the effects of addition of rice straw, fertilizer S and rice straw and fertilizer S together on growth and yield of high yielding variety of rice (BR-30) under flooded condition and changes on post harvest soil.

The experiment was undertaken on an Old Brahmaputra Floodplain soil. The experimental site was characterized by silt loam texture with mild acidic reaction and in general poor nutrient status. The experiment was conducted in the wet season (July-November) of 2000. There were four treatments, such as: (1) Control (-S), (2) Rice straw @ 6 t ha⁻¹, (3) Fertilizer S @ 20 kg S ha⁻¹, and (4) Rice straw @ 6 t ha⁻¹ + Fertilizer S @ 20 kg S ha⁻¹. Gypsum was used as the source of fertilizer S. Basal application of fertilizers such as urea @ 70 kg N, TSP @ 40 kg P₂O₅, MP @ 40 kg K₂O and ZnO @ 3 kg Zn ha⁻¹ were used. The treatments were laid out in completely randomized block design with three replications of each treatment. The test crop used was HYV rice BR-30.

Dry matter yield of rice plants significantly increased at panicle initiation stage in rice straw treatment over control. Yield contributing attributes of rice plants such as effective tillers hill⁻¹, panicle length, filled grains panicle⁻¹ and 1000-grain weights were recorded at harvest. The number of effective tillers hill⁻¹ ranged from 7.27-10.10, panicle length from 21.19-24.25 cm and the number of filled grain panicle⁻¹ from 88.81-98.08, while 1000-grain weight varied from 23.20-23.57g only. There were significant increases in all yield contributing attributes of the crop except, 1000-grain weight in both rice straw and fertilizer S treatments over control. Grain and straw yields of rice significantly increased due to application of rice straw and fertilizer S together over the control treatment. Grain yield increases were 11.90, 19.76 and 25.95% in rice straw, fertilizer S and rice straw and fertilizer S treatments respectively over the control treatment. Both maximum grain (5.29 t ha⁻¹) and straw (6.04 t ha⁻¹) yields were recorded in the treatment, where rice straw was applied with fertilizer S. The application of rice straw slightly decreased soil pH, while it significantly improved organic matter content, total N, exchangeable K and available S in post harvest soil.

Keywords: Rice straw, Sulphur, crop yield, post-harvest soil

Introduction

Bangladesh is an agrarian country with rice as the dominant cereal crop. Bangladesh agriculture is dominated by intensive rice production. 80% of the cultivable lands are under rice cultivation and the major cropping patterns are rice-based. However, average yield of rice is still quite low (around 2 t/ha) compared to other rice growing countries such as China, Korea and Japan

(above 5 t/ha). As such, identification and management of soil fertility problems are important factors in optimizing crop yield. Among the soil fertility problems, S has been identified as a major nutritional problem for rice. Sulphur deficiency has been recognized in most of the soils of Bangladesh (Majid, 1986), which covers not less than four million hectares of cultivable lands (Hussain, 1990).

The major causes of S deficiency in Bangladesh are due to cropping round the year, use of S free fertilizers, depletion of organic matter with little or no addition of manures, leaching of S in high rainfall areas and particularly leaching loss in light textured soils with flood irrigation. Haque (1997) reported of higher S requirement under wetland rice with phosphate fertilization, which is the major rice cultivation practice in Bangladesh. Gregg and Goh (1982) found that S fertilization resulted in greater release of S from organic matter. Rice straw is a major agricultural by-product in the country. Management of crop residues, particularly that of rice should be considered as a means of reducing S requirement of a cropping system. The turn over of S from crop residues has become increasingly important for maintaining supplies of S to the plant, where other inputs of S to soil-plant system such as fertilizer and atmospheric S decreases. Therefore, a field experiment was carried out to investigate the effects of addition of rice straw, fertilizer S and rice straw and fertilizer S together on growth and yield of high yielding variety of rice (BR-30) under flooded condition and changes on post harvest soil.

Materials and Methods

The experiment was carried out at Bangladesh Agricultural University farm under the 'Sonatola' soil series, which belonged to Old Brahmaputra Floodplain agro-ecological zone. The experiment was conducted in the Aman season (July-November) of 2000. The soil was characterized by silt loam in texture with pH 6.8, organic matter content 2.75%, CEC 12 m.e.%, total N 0.17%, available P 11.0 ppm, exchangeable K 0.15 m.e.%, available S 8.0 ppm, available Zn 1.11 ppm.

The treatments used in the experiment were (1) Control (-S), (2) Rice straw @ 6 t ha⁻¹, (3) Fertilizer S @ 20 kg S ha⁻¹, and (4) Rice straw @ 6 t ha⁻¹ + Fertilizer S @ 20 kg S ha⁻¹. Gypsum was used as the source of fertilizer S. Basal fertilizers such as urea @ 70 kg N, TSP @ 40 kg P₂O₅, MP @ 40 kg K₂O and ZnO @ 3 kg Zn per hectare were applied along with gypsum at the time of transplanting of rice seedlings. Nitrogen was applied in three equal splits, at transplanting, maximum tillering and panicle initiation stage. The treatments were laid out in

completely randomized block design with three replications of each treatment. The test crop used was HYV rice BR-30.

Results and Discussion

Dry matter yields of the rice plants were recorded both during the maximum tillering and the panicle initiation stages. At maximum tillering stage, dry matter yield of rice plants ranged from 0.81–0.99 t ha⁻¹. Significant variations at maximum tillering stage were not found between the treatments. During panicle initiation stage, dry matter yield of rice plants rose from 3.34-4.59 t ha⁻¹. At panicle initiation stage, dry matter yield produced by the treatment with rice residue was significantly higher compared to the control treatment and similar to that of the fertilizer S treatment. Maximum dry matter yield of rice plants (4.59 t ha⁻¹) was obtained in the treatment, where rice straw and fertilizer S used together. It increased the dry matter yield of rice plants by 37.43 % over the control treatment (Table 1).

Table 1: Effects of rice straw and S on dry matter yield of rice at maximum tillering and panicle initiation stages

Treatment	Maximum tillering stage		Panicle initiation stage	
	DM yield (t ha-1)	Increase (%)	DM yield (t ha-1)	Increase (%)
1. Control (-S)	0.81 b	3.34 c	-	
2. Rice straw @ 6 t ha-1	0.88 b	8.64	4.27 b	27.84
3. Sulphur @ 20 kg S ha-1	0.97 a	19.75	4.36 b	30.54
4. Rice straw @ 6 t ha-1 and Sulphur @ 20 kg S ha-1	0.99	22.22	4.59 a	37.43

Figures in a column having common letters do not differ significantly at 5% level of significance.

Yield contributing attributes of rice plants such as effective tillers hill⁻¹, panicle length, filled grains panicle⁻¹ and 1000-grain weights were recorded at harvest. The number of effective tillers hill⁻¹ ranged from 7.27-10.10, panicle length from 21.19-24.25 cm and the number of filled grain panicle⁻¹ from 88.81-98.08, while 1000-grain weight varied from 23.20-23.57g only. There were significant increases in all the yield contributing parameters except 1000-grain weight in both rice straw and fertilizer S treatments over the control (Table 2). Grain and straw yields of rice significantly increased due to application of rice straw and fertilizer S applied together as well as singly over the control treatment (Table 3). Grain yield increases were 11.90, 19.76 and 25.95% in rice straw, fertilizer S and rice straw and fertilizer S treatments respectively over the control treatment. Both maximum grain (5.29 t ha⁻¹) and straw (6.04 t ha⁻¹)

¹⁾ yields were obtained in rice straw and fertilizer S treatment. Application of rice straw slightly decreased pH, while it significantly improved organic matter content and plant nutrients in post harvest soil (Table 4).

Table 2: Effects of rice straw and S on yield contributing characteristics of rice

Treatment	Effective tillers hill ⁻¹ (no.)	Panicle length (cm)	Filled grains panicle ⁻¹ (no.)	1000-grain weight (g)
1. Control (-S)	7.27 c	21.19 b	88.81 c	23.20
2. Rice straw @ 6 t ha-1	9.07 b	23.93 a	93.08 b	23.40
3. Sulphur @ 20 kg S ha-1	9.93 a	24.21 a	97.46 a	23.50
4. Rice straw @ 6 t ha-1 and Sulphur @ 20 kg S ha-1	10.10 a	24.25 a	98.08 a	23.57

Figures in a column having common letters do not differ significantly at 5% level of significance.

Table 3: Effects of rice straw and S on grain and straw yields of rice

Treatment	Grain yield (t ha ⁻¹)	Increase over control (%)	Straw yield (t ha ⁻¹)	Increase over control (%)
1. Control (-S)	4.20 c	-	4.45 c	-
2. Rice straw @ 6 t ha-1	4.7 bc	11.90	4.83 bc	8.54
3. Sulphur @ 20 kg S ha-1	5.03 ab	24.21 a	5.47 ab	22.90
4. Rice straw @ 6 t ha-1 and Sulphur @ 20 kg S ha-1	5.29 a	24.25 a	6.04 a	35.86

Figures in a column having common letters do not differ significantly at 5% level of significance.

Table 4: Effects of rice straw and S on changes in properties of the post-harvest soil

Treatment	pH	O.M. (%)	Avail. S (ppm)	Total N (%)	Avail P (ppm)	Exch. K (m.e.%)
1. Control (-S)	6.76 a	1.60 b	12.4 d	0.19 b	12.0 b	0.14 c
2. Rice straw @ 6 t ha-1	6.65 b	1.65 a	14.2 c	0.22 a	12.8 ab	0.19 a
3. Sulphur @ 20 kg S ha-1	6.70 ab	1.60 b	15.4 b	0.20 ab	12.2 b	0.14 c
4. Rice straw @ 6 t ha-1 and Sulphur @ 20 kg S ha-1	6.58 ca	1.64 a	16.0 a	0.21 ab	13.2 a	0.16 b

Figures in a column having common letters do not differ significantly at 5% level of significance.

Conclusion

Dry matter yield of rice plants increased significantly at panicle initiation stage due to applied rice straw and fertilizer S. Similar results were obtained with yield contributing attributes at harvest stage with the exception of 1000-grain weight, which did show any significant variation

among treatments used. Grain and straw yields of rice significantly increased due to application of both rice straw and fertilizer S. However, maximum yield of rice grain (5.29 t ha^{-1}) was obtained in the treatment with rice straw and fertilizer S applied together, an increase of 25.95% over the control treatment. Application of rice straw also significantly improved organic matter content and plant nutrients in post harvest soil.

Acknowledgement

The financial support of this research by Bangladesh Agricultural University Research System (BAURES) of Bangladesh Agricultural University is gratefully acknowledged.

References

- Gregg, P.E.H. and Goh, K.M. 1982. Field studies with radioactive sulphur labelled gypsum fertilizer. 4: Recover by pasture and soil components. N.Z.J. Agric. Res. 25: 345-353.
- Haque, S.A. 1997. Phosphate fertilization affecting sulphur balance in soil. Proceedings, 11th World Fertilizer Congress on Fertilization for Sustainable Plant Production and Soil Fertility. Ghent, Belgium, Vol-II: 140-145.
- Hussain, S.G. 1990. Sulphur in Bangladesh agriculture. Sulphur in Agriculture. Vol. 14, 25-28.
- Majid, S.A. 1986. The response of major crops to sulphur. Proceedings, International Symposium on Sulphur in Agricultural Soils. BARC, Dhaka. 18-28.

EFFECT OF DIFFERENT NITROGEN LEVELS ON THE YIELD AND NUTRIENT UPTAKE OF EGGPLANT (*SOLANUM MELANGENA L.*) GROWN UNDER GLASSHOUSE

C. F. Özkan, A. Deviren, T. Ateş, A. Arpacioğlu and A. Öztürk

Citrus and Greenhouse Crops Research Institute, Antalya-Turkey

Abstract

The aim of this study was to determine amount of N,P,K removed by eggplant, applied four nitrogen doses, grown single crop production in glasshouse heated only for anti frost. Yield and amount of N,P,K taken up from soil by leaf ,stem and fruit of eggplant were determined.

This study was conducted Mediterranean Terra Rose soil in Antalya Province of Turkey. Eggplant that Faselis F1 were used as a plant materyal. The fertilizer application of the experiment were four N levels, 0, 50, 100, 150 mg/lt and uniformly supplied 40 mgP/lt, 180 mgK/lt applied with drip irrigation system. The amount of water applied were 435 mm.

According to the results, effect of different N levels on yield and total N,P,K derived from soil were significant statistically. The maximum yield 9380 kg/da achieved with 100mgN/lt (43.50kgN/da) It was found 22.96 kg N 10.47 kg P₂O₅, 44,31 kg K₂O taken up from soil with this yield. Also derived N and K with stem and fruit, P only with fruit were effected from N levels. The most amount of N,P,K were taken up with fruit respectively % 79.06, % 84.92, %71.72. N/P/K ratios for eggplant were found as 1/0.44/1.79.

Keywords: Eggplant, nutrient uptake, nitrogen doses

Introduction

Eggplant (*Solanum melangena L.*) is an important vegetable in Turkey with a production of 214 642 ton/year grown under protected cultivation (Anonim, 2001). The growing season and harvest extend over a long period of time and the crop produces many fruits in greenhouse conditions. As a result it requires large amount of nutrients.

Eggplant is very effective in making use of plant nutrients already available in the soil than other solanaceous vegetables. It develops a strong taproot with a branched root system that responds positively to well drained soils that medium texture, pH 6.5–7.2 with rich organic matter and nutrients (Anonim, 1992; Hedge, 1997)

The quantity of nutrients to be applied depends on the yield potential of the cultivar, the level of available nutrients in the soil, and growing conditions. Such practise will be environmentally friendly with minimize nutrient losses. So that It is important to know that amount of plant nutrients taken up by the plants for fertiliser recommendations.

The objective this study were to determine N requirement and quantity of N, P, and K uptaken by leaf, stem and fruit of eggplant applied four N doses grown in glasshouse conditions heated only anti frost.

Materials and Methods

This study was conducted on a Mediterranean Terra Rose soils in Antalya Province of Turkey. Eggplant was grown as a single production in a glasshouse heated only for anti frost. At the begining of the experiment the surface 30 cm soil were indicated 53% sand, 13% silt and 34% clay determined by hidrometer method (Bouyoucos,1951), pH value of 7.5 with 1/ 2.5 (Jackson,1962), found 1.08% organic matter with Walkley-Black method (Jackson,1962), 10 ppm of phosphorus determined Olsen method (Olsen et al.1954) and 396 ppm of exchangeable potassium with 1 N ammonium acetate, 49ppm $\text{NH}_4^- \text{N}$, 36ppm $\text{NO}_3^- \text{N}$ with KCl extractable(Kacar,1994).

The experiment consisted of three randomised blocks, each divided into four plots. Each plot was 3.60m wide, and 4.95m long and contained four plant rows.

The fertiliser applications of the experiment were four nitrogen rates 0, 50, 100,150 mgN/lit and supplied uniformly to the all treatments 40 mgP /lit and 180 mgK /lit with drip irrigation system. The amount of the water to be applied for each experiment was calculated according to Class A Pan using the procedure described by the FAO (Anonim,1984). The plants were irrigated total 435 mm at the whole growing season.

Eggplant seedlings (*Solanum melangena* L.) of a determinate hybrid Faselis F₁ were planted on 3 September 1997. The mature fruits of eggplants were harvested once a week over a 25 week period beginning on 1 December 1997 until on 15 June 1998.

Harvested plants were separated into leaves, stems and fruits. They were dried at 70°C, weighed, ground and analysed. Total N was determined using Micro Kjheldal method. P was determined using Vanadomolipdo yellow color method with Spectrophometer and K was measured by Atomic absorbtion spectrometry at the wet digested with $\text{HNO}_3\text{-HClO}_3$ plant materyal (Kacar,1972).

Results

Total amounts of N applied with drip irrigation stream were 0, 21.75, 43.50, 65.25 kgN/da for No, N₁, N₂, and N₃ respectively.(1da: 1000m²)

The yields of eggplant applied different N rates were given Table- 1. The different doses of N fertilizer effected the yield. The highest yield (9380kg/da) was achieved in the N₂ 100 mg N/lt (43.75 kgN/ da) treatment. N₁ level with the yield 9170 kg/da was followed with N₂. But the yield applied highest level of N (65.25 kgN/ da) was reduced compared the N₁ and N₂ treatments. No application gave the lowest yield.

Although dry matter yield of leaf and stem were not affected, fruit dry matter and total dry matter (leaf+stem+fruit) were significantly affected by the N treatments (Table-2). Fruit and total dry matter were the lowest in the No application. The other treatments were the same group.

The effect of different N doses on %N values of leaf, stem, fruit and amount of uptaken N by that plant parts were given Table-3. Although % N values of stem and fruit were not affected, %N of leaf was increased with the N application. The highest N value of leaf with % 4.80 was found in the highest (N₃) doses. N₁ and N₂ treatments were on the second row, and it was the lowest (% 3.75) No application. Increasing N doses increased % N values of leaf.

N uptake of eggplant with leaf were not affected by N application, however derived N with stem was significantly increased. The highest values for stem were obtained in the N₃ treatments, N₂ was second, N₁ and No were lower the others. Also derived N by fruit was not affected from the N doses except nil treatment. Total N uptake (leaf+stem+fruit) were affected significantly and it was the lowest (13.34kgN/da) in the No treatment. The other applications were the greater No.

P values of leaf, stem and fruit were not affected by N treatments (Table-4). Amount of derived P₂O₅ with leaf and stem were not affected by the N doses too. But P₂O₅ uptake with fruit was significantly affected by N treatments. It was the lowest with nil treatment, and the other treatments were the same row. N treatments significantly affected total P₂O₅ uptake of eggplant (leaf+stem+fruit). It was found 10.47, 9.64, 8.78 and 6.59 kgP₂O₅/da for N₂, N₁, N₃ and No treatments respectively.

The different rates of N fertilizer didn't affect % K values of leaf and stem (Table-5). But K values of fruit was affected by N treatments. It was the lowest in the N₃ application. The other treatments were same row.

Although amount of K₂O taken up with leaf was not affected, derived K₂O with stem and fruit was affected significantly by different N doses. The highest K₂O (8.51kg/da) derived with stem was found in the N₂ treatment. No, N₁ and N₃ applications were the same group.

K₂O uptake with fruit in the N₁ and N₂ treatments were significantly greater than No and N₃ applications. The different N applications significantly affected the total K₂O uptake by leaf, stem and fruit. It was the lowest in the nil treatment, the others were 44.31, 39.22, 32.52 kgK₂O/da for the N₂, N₁ and N₃ respectively.

Discussion

Amount of N, P₂O₅, K₂O removal from soil with the total yield(Fruit+leaf+stem) according to N treatments were shown Table-6. The results related to yield showed that N₂

100 mgN/lt (43.50 kgN/da) treatment was found the highest with the 9380kg/da total yield for grown single crop eggplant in this experiment conditions.

Duranti et al.(1983) reported similar results that 0, 10, 20, 40 kgN/da were applied to eggplant and the highest yield (7.85 ton/da) was obtained by 40 kgN/da. But there were some suggestions for eggplant such as 0-140mg/lt N, 0-31 mg/lt P, 78-195 mg/lt K according to soil fertility by Anonim (1989); and Papadopoulos (1993) suggested 130-170mg/lt N, 50-60mg/lt P, 150-200mg/lt K and reported that fertigation recipes should based on soil fertility, crop requirements and climatic and other conditions.

Also it was determined that 22.96kgN/da, 10.47kgP₂O₅/da and 44.31 K₂Okg/da by (9380 kg/da) the highest total yield were taken up in the 43.50 kgN/da (N₂)application. But there were different results obtained previous studies. Magein (1992) reported that 25 kgN,

4 kg P₂O₅ and 30 kgK₂O were taken up by the yield 5 ton/da, Gnanakumari and Sathyanarayana (1971) obtained that an eggplant crop yielding about 6 ton/da of fruit removes 19 kgN, 10.9 kg P and 12,8 kg K. Likewise Jose at.al.(1983) who studied that effect of organic and inorganic N sources on nutrient uptake and yield of eggplant, 13.6 kgN, 14.6kg P and 10.5 kg K were taken up by the yield 4.6 ton/da.

Although in the N₂ (43.50 kg/da)and N₃ (65.25 kg/da)treatments were applied twice and three times more N from N₁ (21.75kg/da), N uptake by the total yield in that treatments were found as much as N₁ application that were 21.86kg/da, 22.96kg/da, 23.46kg/da for N₁, N₂, N₃ respectively. Rosaiti and Traisi (2001) reported similar results that 20 kgN/da was uptaken in the 25 kgN/da rates applied to the eggplant.This data can be important for reducing N loss into the environment.

It was determined in this study that 2.43 kgN, 1.06 kgP₂O₅ and 4.32 kg K₂O were removal by per ton eggplant yield. Also N / P₂O₅/ K₂O ratios for nutrition of eggplant were found 1 / 0.44/

1.79. Hedge (1997) reported that to produce 1ton fresh fruit, eggplant need to absorb 3-3.5 kg N, 0.46-0.69kg P₂O₅ and 3-3.6 kg K₂O.

It was found that partitioning of nutrient uptake by eggplant into different plant part were shown in Table-7. The most amount of total dry matter, N, P and K were taken up by fruit % 64.16, % 79.06, % 84.92, % 71.72 respectively. Although N and P were taken up by fruit, leaf and stem, K and total dry matter were derived by fruit, stem and leaf respectively.

Hedge (1997) noted that fruit and fruiting part in the solanaceous vegetable group contain 45-60% total N, 50-60%total P, 55-70% total K absorbed by the plants.

It was reported that different results on amount of nutrient uptake by eggplant were obtained. Because the amount of nutrients taken up by the crops depends on the number of fruit and the amount of dry matter produced. This is influenced by a number of genetic and environmental variables(Mengel and Kirkby,1978;Hedge,1997;Anonim,1992).

So that , more researches are needed to achieve high yield, to improve quality and nutrient uptake of eggplant with different nutritional status under greenhouse condition in the Mediterranean region.

References:

- ANONIM,1984. FAO Guidelines For Predicting Crop Water Requirements Irrigation Drainage Paper 24, p.30,Rome,ITALY.
- ANONIM,1989.Bemestingsatliesbasis Glastuinbouw. Commissie Standaardisatie Bemestingsatliesbasis Glastuinbouw. Ministerie van Landbouw en Visserij Wageningen
- ANONIM,1992. IFA World Fertilizer Use Manuel. Int.Fert.Assoc.Paris,FRANCE.
- ANONIM,2001.Tarımsal Yapılar ve Üretim Kayıtları.DİE.Ankara
- BOUYOUCOS,G.J.,1951. A Recalibration of the Hydrometer Method for Making Mechanical Analysis of Soils. Agronomi Journal. 43: 434-438.
- HEDGE, D.M.,1997. Nutrient Requirements of Solanaceous Vegetable Crops. <http://www.Agnet.org/library/article/eb441.html>
- JACKSON,M.L.,1962. Soil Chemical Analysis. Prentice-Hall, Inc.183:219-284.
- JOSE,D.,K.G.Shanmugavelu, and S.Thamburaj.1988. Studies on the Efficiency of Organic and Inorganic Form of N in Brinjal. Indian Journal of Horticulture 45:100-103.
- KACAR,B.,1972. Bitki ve Toprağın Kimyasal Analizleri. II Bitki Analizleri. A.Ü.Z.F. Yayın No: 3.Ankara.
- KACAR,B.,1994. Bitki ve Toprağın Kimyasal Analizleri. III Toprak Analizleri. A.Ü.Z.F. Yayın No: 453.Ankara.
- MAGEIN,H.,1992.Expert Consultation Work Shop on Greenhouse in the Antalya Region.13-17 January Antalya,TURKEY.
- MENGEL,K.and E.A.Kirkby.,1978.Principle of Plant Nutrition.IPI.Berne.Switzerland.
- OLSEN,S.R.,Cole,V.C.,Wantanabe,F.S. and Vean,L.A.,1954. Estimation of Available Phosphorus in Soil by Extraction with Sodium bicarbonat. U.S.Dept. of Agric.Circ.939.
- PAPADOPOULOS,I.1993. Fertigation of Vegetables under Protected Conditions.Regional Consultative Meeting on Greenhouse Production in the Mediterranean Region. 15-18 Nowember. Agadir,MOROCCO.
- ROSAITI,A. and A.Traisi.2001.Seasonal Patterns of N uptake in Eggplant Grown with Different M Fertigation Levels.Acta Hort.563:24-28.

Table 1: Yield of eggplant applied different N doses.(**:%1 significant)

Treatments	Yield (kg/da)
No	6240 c
N ₁	9170 ab
N ₂	9380 a
N ₃	8710 b
	**

Table 2: Dry matter of plant and fruit of Eggplant as influenced by N application.

Treatments	Leaf (kg/da)	Stem (kg/da)	Fruit (kg/da)	Total (kg/da)
No	47.0	165.5	309.9 b	522.5 b
N ₁	53.5	166.1	516.6 a	736.2 a
N ₂	67.8	225.4	468.9 a	762.1 a
N ₃	49.8	210.4	496.5 a	756.6 a
	ns	ns	**	**

(**:%1 significant ; ns: nonsignificant)

Table 3: N Uptake of Eggplant Influenced Different N Application.

Treatments	Leaf		Stem		Fruit		TOTAL N uptake (kg/da)
	N uptake Kg/da	%N	N uptake Kg/da	%N	N uptake Kg/da	%N	
No	1.79	3.75 c	1.39 c	0.86	10.17 b	3.23	13.34 b
N ₁	2.29	4.27 b	1.40 c	0.87	18.17 a	3.51	21.86 a
N ₂	2.97	4.35 b	1.99 b	0.90	18.00 a	3.81	22.96 a
N ₃	2.40	4.80 a	2.56 a	1.23	18.50 a	3.70	23.46 a
	ns	**	**	ns	*	ns	**

(*:%5 significant, **:%1 significant ; ns: nonsignificant)

Table 4: P₂O₅ Uptake of Eggplant Influenced Different N Application.

Treatments	Leaf		Stem		Fruit		TOTAL P ₂ O ₅ Uptake (kg/da)
	P ₂ O ₅ Uptake kg/da	%P	P ₂ O ₅ Uptake kg/da	% P	P ₂ O ₅ Uptake kg/da	%P	
No	0.60	0.56	0.58	0.15	5.41 b	0.76	6.59 b
N ₁	0.57	0.47	0.53	0.14	8.54 a	0.72	9.64 a
N ₂	0.87	0.56	0.75	0.14	8.85 a	0.83	10.47 a
N ₃	0.69	0.60	0.70	0.15	7.39 a	0.65	8.78 b
	ns	ns	ns	ns	*	ns	**

(*:%5 significant, **:%1 significant ; ns: nonsignificant)

Table 5: K₂O Uptake of Eggplant Influenced Different N Application.

Treatments	Leaf		Stem		Fruit		TOTAL K ₂ O Uptake (kg/da)
	K ₂ O Uptake kg/da	%K	K ₂ O Uptake kg/da	%K	K ₂ O Uptake kg/da	%K	
No	2.91	5.16	5.97 b	3.04	19.72 b	5.31 a	28.60c
N ₁	3.45	5.36	5.53 b	2.89	30.24 a	4.90 a	39.22 ab
N ₂	4.88	5.99	8.51 a	3.13	30.92 a	5.52 a	44.31a
N ₃	3.27	5.53	6.85 b	2.46	22.40 b	3.76 b	32.52 bc
	ns	ns	**	ns	**	*	**

(*:%5 significant, **:%1 significant ; ns: nonsignificant)

Table 6: Amount of N,P₂O₅,K₂O Removal from Soil with the Yield.

Treatments	Yield (kg/da)	N (kg/da)	P ₂ O ₅ (kg/da)	K ₂ O(kg/da)
No	6240 c	13.34 b	6.59 b	28.60 c
N ₁	9170 ab	21.86 a	9.64 a	39.22 ab
N ₂	9380 a	22.96 a	10.47 a	44.31 a
N ₃	8710 b	23.46 a	8.78 ab	32.52 bc
	**	**	**	**

(**:%1 significant)

Table 7: Partitioning of Nutrient Uptake (%) in Eggplant.

	Dry Matter%	% N	% P ₂ O ₅	% K ₂ O
Leaf	7.94	11.83	7.78	10.00
Stem	27.90	9.11	7.30	18.28
Fruit	64.16	79.06	84.92	71.72

Section 5

Micronutrient fertilization

CALCIUM AND MICRONUTRIENTS COMPLEXES IN THE SPANISH FERTILIZER MARKET

J. J. Lucena*, A. Gárate, I. García-Salas and M. Villén

*juan jose.lucena@uam.es, Spain

Introduction

In Spanish Agriculture, Ca and micronutrient deficiencies are usually corrected using synthetic chelates or both natural or synthetic complexes. Normally, complexes are cheaper so they can be used in a larger number of crops despite their lower efficacy. Also, they are usually biodegradable, then they are more environmental friendly than synthetic chelates. However, due to the lack of knowledge, the European Regulation on Fertilisers does not list the complexing agents allowed to complex metals. Moreover, most of these products, mainly the natural ones, have a variable chemical structure, so its classification and the quantification of its complexing capacity is difficult.

The main objective of this work is to review the presence of different compounds used as complexing agents in commercial products in the Spanish market for the last twelve years (1990-2002). The number of brands in the market has been obtained from the information given by Liñán 1990, 1995, 2000 and 2002. Also, information from the Fertilizers Registry (M.A.P.A.) has been considered.

As a second objective a review the analytical methods that allow to evaluate the complexing capacity is provided.

Market's Trend

This study is made along twelve years, since 1990 to 2002 using Vademecums. Due the large number of molecules used as complexing agents they were classified in six types:

- ✓ Lignosulfonates (LS): lignosulfonic acids, lignosulfonates and lignins.
- ✓ Amino acids (AA): amino acids and short peptides.
- ✓ Organic acids (OA): acetic, phenolic and polyphenolic acids, carboxylic, polycarboxylic and polyhydroxycarboxylic acids.
- ✓ Gluconic acids (GA): gluconic, heptagluconic and hexagluconic acids.
- ✓ Humic and Fulvic acids (HFA)
- ✓ Flavonoids (F): flavonoids y poliflavonoids.

The complexed nutrients studied in this paper are Ca, Fe, Cu, Zn and Mn.

The trend of these products is shown in table 1. The total number of formulations has increased more than four times in this twelve years, from 84 products in 1990 to 386 in 2002. Lignosulfonates were one of the most important types in 1990 representing the 13% of the products while in 2002 they represent 46% of the products in the market.

Table 1: Number of products in the Spanish market that contain complexing agents

	LS	AA	OA	GA	HFA	F	TOTAL
YEAR	N. PRODUCTS						
1990	11	13	24	8	6	22	84
1995	80	36	40	20	19	14	199
2000	150	71	57	39	33	6	356
2002	177	29	77	59	37	7	386

On the other hand, the products based on flavonoids (F) were the most important in the firsts years of the study but their percentage respect the total decrease from 26% to 2% in the last years. The presence of organic acids (OA) decreases also, but in smaller amount. The tendency for gluconic (GA) and humic and fulvic acids (HFA) is a slight increase: gluconic acids represents 10% in 1990 and 15% in 2002; for the humic and fulvic the percentage increase from 7% to 10% in the twelve years.

The 58% of the brands marketed in these years only contain one element in their formulation and 42% contain several elements.

1. Products that only contain one element

a) Calcium:

The total number of formulations has increased more than seven times in these years, from 9 products in 1990 to 67 in 2002. The types of compounds more representatives in 1990 are amino acids and flavonoids with the 44% and 33% respectively, but their presence decrease until 6% and 1% in 2002.

A similar trend is observed for the organic acids because in the first years the number of these formulations decrease with respect to the total, although in 2002 they are a little recovery. On the contrary, lignosulfonates has a large increase representing the 42% of the brands in the market in the year 2002.

Table 2: Distribution of Ca products among complexing agents from 1990 to 2002.

	LS	AA	OA	GA	HFA	F	TOTAL
YEAR	N. PRODUCTS						
1990	1	1	4	0	0	3	9
1995	10	6	6	5	1	1	29
2000	28	21	13	11	6	1	80
2002	29	4	16	13	4	1	67

Gluconic acids and humic and fulvic acids appears in the market in 1995 and increases slightly during the years of the study till represents 19% and 6% respectively in 2002.

b) Iron:

The total number of formulations are the double in 2002 that in 1990. The tendency for iron lignosulfonates, aminoacids and flavonoids is the same than for Ca complexes. For the first years, the number of lignosulfonates increase until representing the 34% with respect to total and the other ones have an important decrease.

The products that contain gluconic acids as complexing agents increases from 3% in 1990 to 15% in 2002.

Table 3: Distribution of Fe products among complexing agents from 1990 to 2002.

	LS	AA	OA	GA	HFA	F	TOTAL
YEAR	N. PRODUCTS						
1990	5	3	6	1	5	10	30
1995	19	8	7	2	10	6	52
2000	23	8	8	6	19	2	66
2002	21	2	15	9	13	2	62

The total number of products with humic and fulvic acids is greater in 2000 than in 2002. However, the relative presence of the organic acids decreases along ten years (1990-2000) and in 2002 increases being one of the most abundant products with more brands in the market.

c) Other micronutrients (Cu, Mn and Zn)

The trend for these formulations is the same that has been shown for calcium and iron. lignosulfonates increase for all metals while flavonoids and amino acids decrease largely. For the rest of the types studied, even though the number of products increase, their percentage with respect to the total is similar along the years.

2) Products that contain several elements

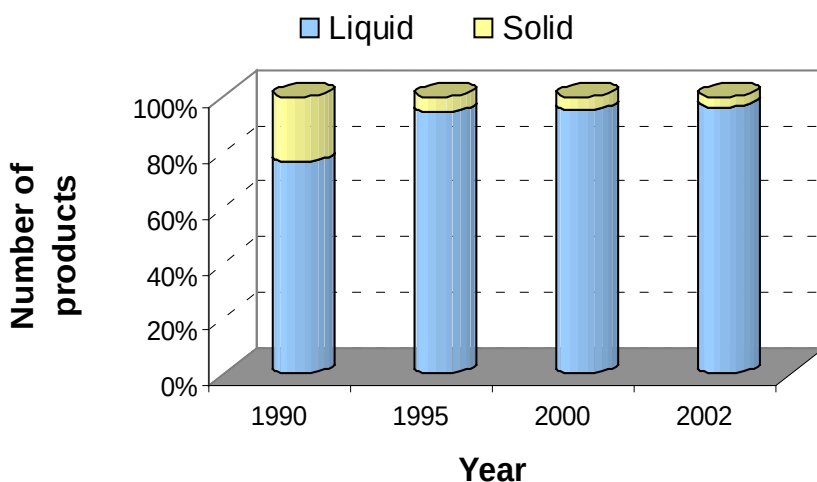
Most of the products containing several nutrients in the market does not include calcium, so there are no formulations containing Ca as GA and F. From 1995, the most representative products for lignosulfonates, amino acids, organic and gluconic acids contain zinc and manganese, some of these products complex also other elements as iron or copper.

Since 2000, some of the formulations with amino acids present also other complexing agents as lignosulfonates, organics acids or chelates.

3) Physicals state and purity

Both solids and liquids products are present in the Spanish market. Most formulations are

Figure 3. *Distribution between liquid and solid products.*



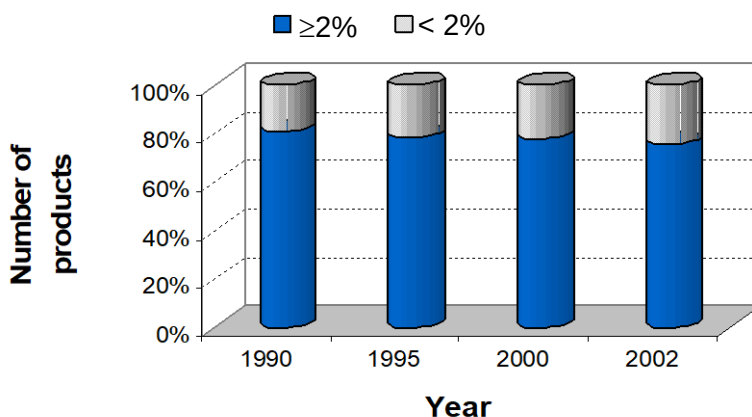


Figure 4: Distribution of liquid products in the Spanish market.

liquids along the twelve years. In 1990 the percentage of liquids products is 77% and increase till 94% in 1995. This percentage is similar for the follows years. The European Regulation on Fertilizers, requires liquid products to have at least a 2% of element and solid ones, to have a minimum of 5% soluble element.

In figure 4 the distribution of liquid products in funtion of their element content is presented. Around 80% complies with the Regulation for all the years.

For solids products the number of formulations with a purity higher than 5% decreasing along time (figure 5.)

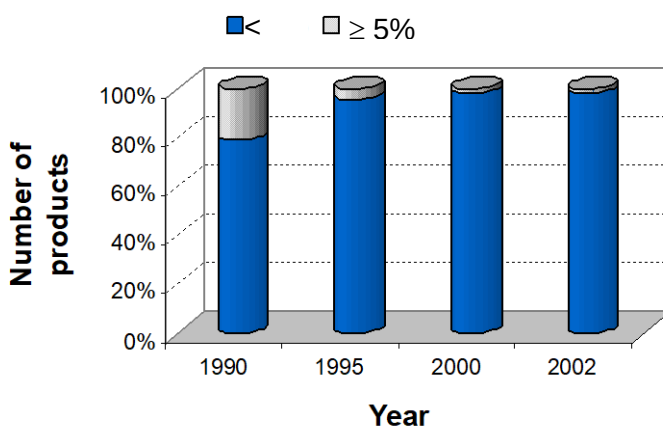


Figure 5: Distribution of solid products in the Spanish market.

Contribution of complexing agents in Ca and micronutrients market

In table 4 the contribution of complexing agents to the total Ca and micronutrients market is presented. The market has been divided in: *Chelates* (DTPA, HEDTA, EDTA, EDDCHA, EDDHA, EDDHMA and EDDHSA), *Complexing agents*, *Salts* (inorganic salts) and *Others* (products with vitamins, citoquinones and molecules without indentification).

Table 4: Distribution of global market.

TYPE OF PRODUCT				
	Chelate	Complexing	Salt	Other
YEAR	N. PRODUCTS			
1990	106	84	21	100
1995	240	199	52	104
2000	509	356	114	162
2002	566	386	143	156

The number of products used for corrected Ca and micronutrient deficiencies has increased four times in these years. Chelates are the more abundant products all the years and complexing agents increase slightly.

Analytical Methods

Analytical methods to evaluate the complexing capacity of these products has been rewied.

Resin exchange method (CEN, EN:13366:2001) is based in the retention of the cations into a sulfonated resin. Then, only the neutral or negative charged species of the metal are measured in the supernatant ($ML^{(-,0)} + M^+ + M(Y)^+ + Resin-SO_3^- \leftrightarrow [Resin-SO_3^-M(Y)] + ML^{(-,0)}$) while the positive species are retained. It is considered that only the neutral or negative are the organic complexes while positive are inorganic forms. It has been tested for Ca and micronutrients and it is not valid because during the procedure, the equilibrium of formation of the complexes can be displaced toward the formation of the inorganic forms ($ML^{(-,0)} \rightarrow M^{m+} + L^{n-}$) reducing the amount of element determined as complexed. This is well explained in the case of the lignosulfonates since they have the same functional groups than the resin. In that case, a large amount of sulfonic groups from the resin compete with a small amount of sulfonic groups of the lignosulfonates. Also positive complexes (as some amino acids complexes) are not considered.

AOAC method was also proposed to determine chelated iron and it is based on the precipitation of the inorganic forms as iron oxide ($\text{Fe}^{3+} + 3\text{H}_2\text{O} \rightarrow \downarrow \text{Fe}(\text{OH})_3 + 3\text{H}^+$), at pH 9. Several modifications have been made in this method to be successfully used also with another micronutrients. Also some displacement of the reaction may occur, but as metal complexes are used to maintain elements in solution, they should be stable enough to avoid the precipitation on those conditions.

For calcium, no precipitation is expected so the AOAC modified method is not valid. However the difference between total Ca in solution (as determined by Atomic Absorption Spectrophotometry) and the free Ca (as determined using Ca electrodes) should give the complexed calcium. This methodology should be more deeply considered.

Conclusions

The number of products with complexing agents has risen more than four times in the last twelve years in the Spanish market.

There is an increase in the number of products containing lignosulfonates, gluconic acids and humic and fulvic acids. In 2002, lignosulfonates are the most representative products in the market (46%). Organic acids and amino acids have a slight decrease along the years of the study. Flavonoids are the most important formulations in 1990, but now only seven products are marketed.

Most of the products are liquid and around 80% comply with the minimum amount required by the Regulation.

The contribution of complexing agents to the Ca and micronutrient fertilisers market has increased, although the most important products are chelates.

Among the analytical methods reviewed, the determination of the complexing capacity by precipitation of the excess of the element at pH 9 and determination of the bound element by AA after destruction of the organic matter (AOAC modified) seems the more reliable for micronutrients.

References

- Álvarez, A.** 2000. Calidad y eficacia de quelatos férricos (FeEDDHA, FeEDDHMA, FeEDDHSA y FeEDDCHA) como fertilizantes. Ph. D. Universidad Autonoma de Madrid.
- AOAC.** Official Method 983.03.
- CEN,** 2001 EN: 13366: Fertilizers - Treatment with a cation exchange resin for the determination of the chelated micro-nutrient content and of the chelated fraction of micro-nutrients
- European Directive.** 76/116/CEE (D.O.C.E. L.24, 30-1-76) modified by 98/3/CE
- Liñán, C.** 1990. Correctores de carencias. pp.:347-387. In: Vademecum de productos fitosanitarios y nutricionales. 6th Ed. Agrotecnias, S.L., Madrid, España.
- Liñán, C.** 1995. Correctores de carencias. pp.:464-538. In: Vademecum de productos fitosanitarios y nutricionales. 11th Ed. Agrotecnias, S.L., Madrid, España.
- Liñán, C.** 2000. Correctores de carencias. pp.:503-596 In: Vademecum de productos fitosanitarios y nutricionales. 16th Ed. Agrotecnias, S.L., Madrid, España.
- Liñán, C.** 2002. Correctores de carencias. pp.:523-617. In: Vademecum de productos fitosanitarios y nutricionales. 18th Ed. Agrotecnias, S.L., Madrid, España.

This work has been supported by the Spanish Ministry of Sciences and Technology project AGL2001-1142.

ROLE OF LONG-TERM FIELD EXPERIMENTS WITH TRACE ELEMENTS IN THE ENVIRONMENTAL RESEARCH IN THE NORTH HUNGARIAN REGION

L. Szabó and L. Fodor*

SZIU, College of Economics and Agriculture, Gyöngyös, Hungary
E-mail: lszabo@mail.gyfk.hu, lfodor@mail.gyfk.hu

Introduction

Szent István University, College of Economics and Agriculture is the centre of the agricultural education and research in the North Hungarian Region. The environmental research and education are one of the most important activities of the College. Recent research priorities mostly concern sustainable soil management and fertilizer use, control of movement and accumulation of trace elements in the soil-plant system and development of sustainable cropping systems [4].

Nowadays, pollution is a serious threat to all part of the environment including the soil. The industrialization, urbanization and intensification of agricultural production have caused adverse environmental effects in North Hungarian Region: in fact polluted areas cover about 15% of the region, but affect nearly 40% of the population [2,3,4].

Contaminated soils mostly are found in industrial and urban areas, in surrounding of metal-mines, along motorways and in arable lands treated with heavy application of sewage sludge. The accumulation of potentially dangerous chemical compounds and elements, particularly toxic trace elements result irreversible changes in the environment [1,5,6]. In order to monitor of dynamics of harmful trace elements (eg. heavy metals), their accumulation in the topsoil and transfer into the field crops, a long-term field experiment was initiated in 1994 at the College Farm of Gyöngyös College. This field experiment belongs to a country-wide research program started and conducted by the Research Institute for Soil Science and Agricultural Chemistry of Hungarian Academy of Sciences (RISSAC). This research program (Contamination of the environment with heavy metals) covers three different experimental sites representing three of the main soil types of Hungary: such as calcareous loamy chernozem, calcareous sandy soil and brown forest soil. Research stations adopt the same methodology.

Materials and Methods

The soil type of the experiment field is a slightly acid chernozem brown-forest soil, which represents the main soil type of the region. Its main characteristics are as follows: $\text{pH}_{(\text{H}_2\text{O})}=6,4$;

$pH_{(KCl)}=5,4$; $y_1=9,5$; $CaCO_3\%=0$; humus content=3%; upper limit of plasticity (K_A)=45; $L\%=70$; $hy=4,8$. This is a silty-clay soil, its bulk density is $1,21\text{ g/cm}^3$. The cation exchange capacity of the soil is 40 meq/100 g soil . Total amounts of the exchangeable cations are 36 meq/100 g soil . The main exchangeable cations are Ca^{++} (83%), Mg^{++} (10%), Na^+ (6%), K^+ (1%).

The field trial was set up with 8 elements (Al, As, Cd, Cr, Cu, Hg, Pb, Zn), on 3 levels each ($0/30, 90, 270\text{ kg element} \cdot \text{ha}^{-1}$), i.e. 24 treatments all in triplicate with 72 plots altogether. Plot sizes are 35 m^2 each. In the experiment arranged in split-plot design the main plots include the 8 selected elements and sub plots means the 3 load levels. Treatments were carried out once at initiation using soluble salts of examined microelements (Table 1).

Table 1: Treatments of the field trial (Gyöngyös, 1994)

Element	Loading levels $\text{kg element} \cdot \text{ha}^{-1}$			Form of salt applied
	1	2	3	
Al	0	90	270	$Al(NO_3)_3 \cdot 9H_2O$
As	30	90	270	$NaAsO_2$
Cd	30	90	270	$3CdSO_4 \cdot 8H_2O$
Cr	30	90	270	K_2CrO_4
Cu	30	90	270	$CuSO_4 \cdot 5H_2O$
Hg	30	90	270	$HgCl_2$
Pb	30	90	270	$Pb(NO_3)_2$
Zn	30	90	270	$ZnSO_4 \cdot 7H_2O$

The experimental plants were winter wheat in 1995, maize in 1996 and sunflower in 1997. Experimental plots were cultivated with commonly used agrotechnics.

Soil samples were collected in 1995 and 1997 from the ploughed layer (0-30 cm) of each plot. The mobile element fraction of soil samples was determined by NH_4 -acetát+EDTA extraction. The total amount of the elements in homogenized soil samples was measured using $cc.HNO_3+cc.H_2O_2$ extractions. Plant samples were taken yearly during the vegetation period at phenophases characterised by intensive nutrient uptake. The total element content was determined in the plant samples after microwave digestion using $cc. HNO_3+cc.H_2O_2$. The composition of prepared soil- and plant samples were determined using inductively coupled plasma mass spectrometry (ICP-MS) detecting 25 elements in the lab of RISSAC.

Mathematical, statistical analyses of data were carried out using variance analysis of split-plot experiments, and the $LSD_{5\%}$ was calculated.

Results

Change of element contents in the soil

With the exception of Al, the extractable element content was increased considerably in the ploughed layer by treatments. With time, the amount of soluble fractions was decreased in the ploughed layer, but the fixation was different for each element (Table 2). Cr and Hg showed the most expressed fixation. Soluble fractions transformed into less available forms very quickly. The available element content in the ratio of total amount was only 2% and 8% in case of these elements. According to results of soil analysis (Table 2) Cd, Pb and Cu showed increased mobility in the soil. When the mobile fractions were taken and expressed in the percentage of the total amount, the following mobility order was reached: Cd (85%) > Pb (64%) > Cu (61%) > Zn (33%) > As (26%) > Hg (8%) > Cr (2%).

Table 2: Results of soil analysis in the 0-30 cm layer of plots with 270 kg·ha⁻¹ element load (Gyöngyös, 1996)

Element	Total amount mg·kg ⁻¹	Available amount mg·kg ⁻¹	Available fraction as a percentage of the total amount	Getting back of added amount %	
				cc.HNO ₃ +cc.H ₂ O ₂ digestion	NH ₄ -acetate+EDTA extraction
As	75	19,9	26	73	22
Cd	90	76,6	85	99	85
Cr	101	2,2	2	79	2
Cu	82	49,9	61	63	48
Hg	39	3,3	8	43	4
Pb	46	29,4	64	29	25
Zn	150	49,2	33	72	43

In the control soil:

Total, mg·kg⁻¹: As 9, Cd 0.6, Cr 30, Cu 25, Hg 0, Pb 20, Zn 85

Mobile, mg·kg⁻¹: As 0, Cd 0.3, Cr 0, Cu 7, Hg 0, Pb 7, Zn 10

Using cc.HNO₃+cc.H₂O₂ digestion to determine amounts of examined elements added to plots in the fall of 1994, it can be stated that

- Cd was almost totally measurable (90%),
- Cr, As, Zn and Cu were well measurable (60-90%),
- Hg was middling measurable (30-60%),
- Pb was poorly measurable (10-30%)

with this analytical method in 1996.

As for Lakanen-Erviö's method (NH₄-acetate+EDTA extraction), it can be stated that

- Cd was well measurable (60-90%),
- Cu and Zn were middling measurable (30-60%),
- Pb and As were poorly measurable (10-30%),
- Hg and Cr were hardly measurable (under 10%).

Cd can be well measured by both analytical methods, so Cd contamination of soil can be qualified even by NH₄-acetate+EDTA extraction.

Vertical movement of Cr(VI) in the soil profile was detected in the second year of the experiment (Table 3). Cr contamination expressed as total and extractable/available amounts in the 30-60 cm and in the 60-90 cm layers. Cr content in deeper layers was less than one-tenth of that in the ploughed (0-30 cm) layer. To check toward movement of Cr(VI), soil samples must be taken from deeper layers in the future.

As and Pb are basically left in the upper 0-30 cm layer in the second year. There was only slight contamination in the 30-60 cm layer. Dynamics of As and Pb leaching hasn't been evaluated yet. More examinations are needed in the future.

The elements Cd, Hg, Cu and Zn were fixed in the ploughed layer. Both total content and available fraction were detected in the upper 0-30 cm layer. These contaminants seem to be resistant to leaching.

Table 3: Effect of 270 kg·ha⁻¹ heavy metal load on the element composition of soil profile (Gyöngyös, 1996)

Element and depth of sampling (cm)		Total content, mg·kg ⁻¹		Available content, mg·kg ⁻¹	
		control soil	treated soil*	control soil	treated soil*
<i>As</i>	0-30	9	75	0	19,9
	30-60	9	12	0	0,3
	60-90	9	11	0	0,1
<i>Cd</i>	0-30	0,6	90	0,3	76,6
	30-60	0,6	0,6	0,2	0,2
	60-90	0,6	0,4	0,2	0,1
<i>Cr</i>	0-30	30	101	0	0,2
	30-60	26	36	0	0,4
	60-90	26	34	0	0,2
<i>Cu</i>	0-30	25	82	7	49,9
	30-60	22	22	5	5,1
	60-90	20	18	5	3,6
<i>Hg</i>	0-30	0	39	0	3,3
	30-60	0	0	0	0
	60-90	0	0	0	0
<i>Pb</i>	0-30	20	46	7	29,4
	30-60	20	21	6	9,4
	60-90	15	14	5	3,8
<i>Zn</i>	0-30	85	150	10	49,2
	30-60	85	82	7	6,9
	60-90	70	71	6	3,2

* averages of replications

Change of element content in crops

In the first year of the experiment considerable As accumulated in vegetative organs of wheat with increasing As load of the soil. The 270 kg·ha⁻¹ As load caused about a hundred times enrichment of As content in the green sprout and straw. As wasn't detectable in the grain even in case of the highest As load. In 1996 the As content of maize straw signed the load of the soil, but significant accumulation was measured only at the 270 kg·ha⁻¹ application rate. Corn was not contaminated with As. Higher As concentration could be measured in vegetative parts of sunflower compared with cereals, but it remained under the detectable level in the seeds (Table 4). Results were the same in case of the Hg.

Table 4: Effect of increasing As loads on the As content of crops, mg·kg⁻¹ (Gyöngyös)

Sampling date	part of crop	Treatment in the fall of 1994 mg·kg ⁻¹				LSD _{5%}	Average
		0	30	90	270		
Winter wheat, 1995							
05.05.	Shoot ¹	0,0	0,4	2,0	2,8	1,2	1,7
31.07.	Straw ⁴	0,0	0,1	1,1	5,2	0,9	1,6
31.07.	Grain ⁴	0,0	0,0	0,0	0,0	0,0	0,0
Maize, 1996							
07.06.	Shoot ²	0,0	0,0	0,0	1,0	0,5	0,2
17.07.	Leaf ³	0,0	0,0	0,0	0,0	0,0	0,0
08.10.	Straw ⁴	0,0	0,3	0,6	1,5	0,7	0,6
08.10.	Grain ⁴	0,0	0,0	0,0	0,0	0,0	0,0
Sunflower, 1997							
24.06.	Shoot ²	0,2	0,7	5,2	12,8	3,3	4,7
05.08.	Leaf ³	0,1	0,3	0,8	2,3	0,3	1,1
15.09.	Straw ⁴	0,0	0,4	1,3	3,3	1,1	1,2
15.09.	Seeds ⁴	0,0	0,0	0,0	0,0	0,0	0,0

¹- at shooting, ²- at 4-6 leaf stage,

³- at flowering, ⁴- at harvest

Cd accumulation was significant both in vegetative and generative parts of crops by increasing Cd loads of soil. 0,1-0,5 mg·kg⁻¹ Cd content of control crops suggests that the background contamination with Cd is rather high in soils of the Gyöngyös area. Each treatment resulted in wheat grain unsuitable for human consumption. The Hungarian Standard (8/1995. (X. 21.) EüM.) allows 0,1 mg·kg⁻¹ Cd in ground cereals and flour. Cd content was about 10-40 times higher in treated sunflower seeds than in the control, so the seeds were not usable for food. Cd remains mobile in the soil-plant system for a long time. It can accumulate in the generative tissue, so it is a real risk for the food chain (Table 5).

Table 5: Effect of increasing Cd loads on the Cd content of crops, mg·kg⁻¹ (Gyöngyös)

Sampling		Treatment in the fall of 1994, mg·kg ⁻¹				LSD _{5%}	Average
date	part of crop	0	30	90	270		
Winter wheat, 1995							
05. 05.	Shoot ¹	0,1	1,0	1,7	2,2	0,9	1,6
31. 07.	Straw ⁴	0,2	1,6	2,7	7,7	2,2	3,0
31. 07.	Grain ⁴	0,1	0,6	0,9	1,0	0,1	0,6
Maize, 1996							
07. 06.	Shoot ²	0,5	9,9	16,4	21,8	1,3	12,2
17. 07.	Leaf ³	0,3	5,4	8,8	12,2	0,6	6,7
08. 10.	Straw ⁴	0,4	5,7	9,0	11,6	0,6	6,7
08. 10.	Grain ⁴	0,1	0,6	0,9	0,9	0,2	0,6
Sunflower, 1997							
24. 06.	Shoot ²	0,3	14,7	26,3	38,6	8,0	21,2
05. 08.	Leaf ³	0,3	3,7	6,3	11,6	1,0	5,5
15. 09.	Straw ⁴	0,3	1,2	2,8	4,8	1,8	2,3
15. 09.	Seeds ⁴	0,3	3,8	6,4	12,8	4,2	5,8

¹- at shooting, ²- at 4-6 leaf stage³- at flowering, ⁴- at harvest

Although Pb showed only moderate enrichment in crops, it was near, or exceeded, the 0,5 mg·kg⁻¹ limit values of Hungarian Standard (8/1995. (X. 21.) EüM) in winter wheat grain. Effect of treatments couldn't be proved. Pb concentration in corn stayed at the same level, while sunflower grain wasn't contaminated, at all (Table 6). Pb proved to be immobile in the soil-plant system.

Table 6: Effect of increasing Pb loads on the Pb content of crops, mg·kg⁻¹ (Gyöngyös)

Sampling		Treatment in the fall of 1994, mg·kg ⁻¹				LSD _{5%}	Average
date	part of crops	0	30	90	270		
Winter wheat, 1995							
05. 05.	Shoot ¹	0,5	1,7	2,6	3,0	2,7	2,4
31. 07.	Straw ⁴	0,8	1,0	1,4	4,3	1,1	1,9
31. 07.	Grain ⁴	0,6	0,4	0,7	1,1	0,8	0,7
Maize, 1996							
07. 06.	Shoot ²	0,4	1,0	1,2	2,7	1,6	1,3
17. 07.	Leaf ³	0,1	0,1	0,6	0,9	0,9	0,4
08. 10.	Straw ⁴	1,1	2,1	2,6	2,0	1,0	2,0
08. 10.	Grain ⁴	0,1	0,2	0,3	0,2	0,4	0,3
Sunflower, 1997							
24. 06.	Shoot ²	0,4	0,9	1,4	1,2	0,8	1,0
05. 08.	Leaf ³	0,2	0,3	0,2	0,6	0,4	0,3
15. 09.	Straw ⁴	0,1	0,3	0,3	0,6	0,4	0,3
15. 09.	Seeds ⁴	0,0	0,0	0,0	0,0	-	0,0

¹- at shooting, ²- at 4-6 leaf stage³- at flowering, ⁴- at harvest

Zn content in winter wheat shoots wasn't affected considerably by Zn treatments. Only the 270 kg·ha⁻¹ load caused significant Zn enrichment in winter wheat straw. Moderate Zn enrichment

was observable in vegetative parts of maize and sunflower. Zn accumulation was expressed mostly in the grain by increasing doses. Zn content in the control wheat grain was higher than the limit values ($30 \text{ mg} \cdot \text{kg}^{-1}$). Corn indicated a moderate Zn accumulation, while treatments caused about twice as much Zn content in sunflower grain compared to the control (Table 7). Zn also proved to be a less mobile element in the soil-plant system, but its accumulation can be significant in the generative grain.

Table 7: Effect of increasing Zn loads on the Zn content of crops, $\text{mg} \cdot \text{kg}^{-1}$ (Gyöngyös)

Sampling		Treatment in the fall of 1994, mg·kg ⁻¹				LSD _{5%}	Average
date	part of crop	0	30	90	270		
Winter wheat, 1995							
05. 05.	Shoot ¹	31	34	38	39	8	35
31. 07.	Straw ⁴	16	16	22	40	8	24
31. 07.	Grain ⁴	38	42	46	54	7	45
Maize, 1996							
07. 06.	Shoot ²	37	49	74	80	20	60
17. 07.	Leaf ³	38	52	88	88	30	66
08. 10.	Straw ⁴	25	37	57	64	28	46
08. 10.	Grain ⁴	43	46	49	55	15	48
Sunflower, 1997							
24. 06.	Shoot ²	42	54	61	66	12	56
05. 08.	Leaf ³	45	52	69	70	17	59
15. 09.	Straw ⁴	7	11	26	31	5	19
15. 09.	Seeds ⁴	42	52	49	87	8	58

¹- at shooting, ²- at 4-6 leaf stage

³- at flowering, ⁴- at harvest

Conclusions

- The rates of transformation and fixation of toxic elements in the soil varies with the element. The mobile contaminants (Cd, Zn, Pb, Cu) separate from those that are transformed into insoluble/unavailable forms very quickly.
- Leaching of Cr, applied as Cr(VI) is a quick process on a slightly acid brown forest soil. Cr can be dangerous for the ground water, because of its quick vertical movement in the soil.
- There is no relation between the plant uptake and available/soluble element content of the soil. These are varied depending on microelements and crop plants.
- Cd remains mobile in the soil-plant system for a long time. Its accumulation can be observed both in vegetative and generative parts of plants without toxic symptoms and yield loss.
- Pb can enter the vegetative and generative plant organs, however its accumulation can't be increased by increasing loads of the soil. Pb has low mobility in the soil-plant system, its plant-uptake is impeded.
- As and Hg can't get into the grain still the very high load of the soil. Grain as a generative organ, proved to be protected against these micropollutants.

- Accumulation of Zn, which is an essential element, can be considerable in the grain.
- Environmentally dangerous elements (Cd, As, Hg, Cr, Pb) accumulate mostly in the vegetative straw. So, using right agrotechnics (plough of straw into the soil), their getting out of agronomic circle can be decreased.

References

- Kádár, I. (1995): A talaj-növény-állat-ember tápláléklánc szennyeződése kémiai elemekkel Magyarországon. KTM-MTA TAKI. Budapest, 388. p.
- Kádár, I. (1993): Talajaink mikroelem ellátottságának környezeti összefüggései. In: MTA Agrártudományok Osztályának tájékoztatója. 102-106. p.
- Németh, T. – Kádár, I. (1991): Macro- and micronutrients in Hungarian Soils. In: Proc. IGBP Symposium “Cicling of nutritive elements in the Geosphere and Biosphere”. (Ed.: Pais, I.) KÉE. Budapest. 19-52.
- Szabó, L. (1999): Heves megye agrárstruktúra és vidékfejlesztési stratégiai programja. Kézirat. GATE MFK, Gyöngyös, 132. p.
- Szalai, T. – Lehoczky, É. – Nyárai, F. – Holló, S. – Csathó, P. (2002): The available microelement content of soil in a long-term nutrient supply experiment. In: Communications in soil science and plant analysis. Vol. 33. Nos. 15-18. pp. 3251-3260.
- Simon, L. – Vágvölgyi, S. – Győri, Z. (1999): Kadmium akkumuláció napraforgóban. Agrokémia és Talajtan, 48. 1-2. 99-109. p.

USING OF MICRONUTRIENTS FOR LONG TIME PERIOD

R. Veitiene

Klaipeda University, E mail: rimaveit@takas.lt

Abstract

The paper discussed using of micronutrients for long time period to acidification process of soil of littoral region of Lithuania, it's causal relation-ships as well as impact for chemical indices of soil. Impact of meteorological conditions of sea-coast region on the acidification process of soil is accentuated.

Keywords: liming, acid soils, nutritious matter, micro-elements.

Introduction

The Lithuanian Centre of Agrochemistry was established in 1985 with the objective of working mainly on acid soils.. The soils with pH 5.5 or less occupies an area of around 80% in the East and South east Lithuania and around 50% in Western Lithuania [7]. The plants growing on acid soils experiences deficiencies of many elements. In acid soils the micro-biological activity as well as mineralization of nutrients are affected. Aluminium and manganese may become harmful to the plants. The yields of wheat, barley, clover and beet has been reported to be low in these soils as compared to normal soils. In Veizaiciai it has been established that after liming of soils the pH increased from 4.4 to 6.5, the yield of barley increased from 0.46 to 4.44 t/ha [4]. Decrease in acidity due to liming depends upon dose, kind and course of liming, physical properties of soil, amount of precipitation, amount and nature of mineral fertilisers [5]. Soil acidification was fixed after the second year of liming [4, 10]. Liming of the soil is recommended after every 5 to 7 years. The dose of repeating lime depends upon the time of previous liming. The ratio of mostly nutritious matter by the liming of soil and during acidification process of soil was disbalanced. Optimization of roots nutrition of plants is main condition of plant developing and productivity. It was established that content of potassium increased about two times, but content of phosphorus as well as of microelements in mostly cases decreased or not changed. Balanced fertilisation is the only way to bridge the gap between nutrient supply of the soil and crop uptake, in order to sustain productivity in modern farms without deteriorating of soil health.

The main objectives of the present study were:

- to observe the process of soil acidification

- to establish the influence of soil acidification on the amount of chemical elements in the soil.
- To establish the impact of long time using of micronutrients on the yield of crop rotation

Materials and Methods

Soil characteristics

The field trials were carried out in 1988 on the Gleyic Albeluvisols (Abg). The top soil chemical characteristics are presented in table 1.

The composition of the soil showed that original non-limed soil was more acidic. It contain less amount of bases. Amount of Al was near toxic limits. The soil have average amount of phosphorus and very high amounts of potassium. It contains low amounts of micro-elements. First year of liming decreased the acidity as well as aluminium content of soils. Amount of hydrolytic soil acidity decreased and that of bases increased after liming

Table 1: Chemical characteristics of soil

Agrochemical indices	1988	1989
pH _{KCl}	4.05 - 4.60	5.2 - 5.4
Hydrolytic soil acidity, m-ekv./kg	41.6 - 55.0	24.0 - 35.1
Amount of bases, m-ekv./kg	28.7 - 44.5	71.3 - 93.7
Exchangeable soil acidity, m-ekv./kg	3.6 - 8.7	0.3 - 0.7
Mobile aluminium, mg/kg	29.0 - 75.9	0.2 - 2.2
P ₂ O ₅ , mg/kg	105.0 - 125.0	127.0 - 152.0
K ₂ O, mg/kg	238.0 - 262.0	268.0 - 297.0
Total N, %	0.12 - 0.14	0.10 - 0.13
Humus, %	0.85 - 2.89	-
Ca, mg/kg	505 - 649	-
B, mg/kg	0.25 - 0.44	0.25 - 0.44
Cu, mg/kg	1.16 - 1.47	0.97 - 1.17
Zn, mg/kg	0.54 - 1.07	1.10 - 1.79

Methods of analyses

Soil pH was estimated by electrometer with glass electrode; hydrolytic soil acidity according to Kappen; exchangeable soil acidity and mobile aluminium according to Sokolov; amount of bases according to Kappen-Hilcovic; mobile potassium and phosphorus according to Al; total nitrogen by Kjeldal method; boron was extracted in hot water and estimated colorimetrically; copper in 1N HCl extract; zinc in 1 N KCl extract; calcium in ammonium acetate extract were estimated on atomic absorption spectrophotometer; humus was estimated according to Turin.

Climatic conditions

Climatic conditions, especially amount of precipitation, has great influence on the soil acidification and to the accessibility of nutrients to the plants. In the dry conditions the amount of accessible elements are considerably low than in humid conditions.

The data of many years (Table 2.) showed that amount of average precipitation was more than 800 mm. Higher rainfall was recorded in 1989, 1990, 1994 and 1998. The rainfall was below normal in 1988 and 1996. June of 1992 and July of 1994 were dry months when amount of precipitation was rather low. August of 1989, July of 1990, June of 1995 and May of 1996 were especially humid months with highest rainfall. Large amount of precipitation increases the possibility of leaching down of bases and nutrients to the subsoil and speeds up the acidification of soil.

Table 2: Amount of precipitation (mm)

Month	88	89	90	91	92	93	94	95	96	97	98	Average 1947-1998
January	-	37	122	59	70	106	111	106	19	31	105	64
February	-	72	51	47	79	65	33	74	43	67	76	44
March	-	92	75	35	65	46	124	63	10	36	59	46
April	-	46	11	62	94	15	72	42	18	68	41	45
May	-	21	50	48	49	39	35	48	147	76	44	46
June	-	79	96	66	7	74	49	108	35	68	87	62
July	134	73	109	53	41	88	0	56	91	51	80	86
August	58	198	72	74	69	101	80	53	41	18	168	91
September	82	32	163	83	88	92	118	120	37	134	71	95
October	43	109	130	90	87	57	134	70	85	201	198	93
November	107	99	179	171	146	22	73	93	84	47	63	91
December	112	85	58	84	58	106	102	55	85	78	57	80
Total	537	943	1117	872	844	810	931	888	695	875	1049	843

Results

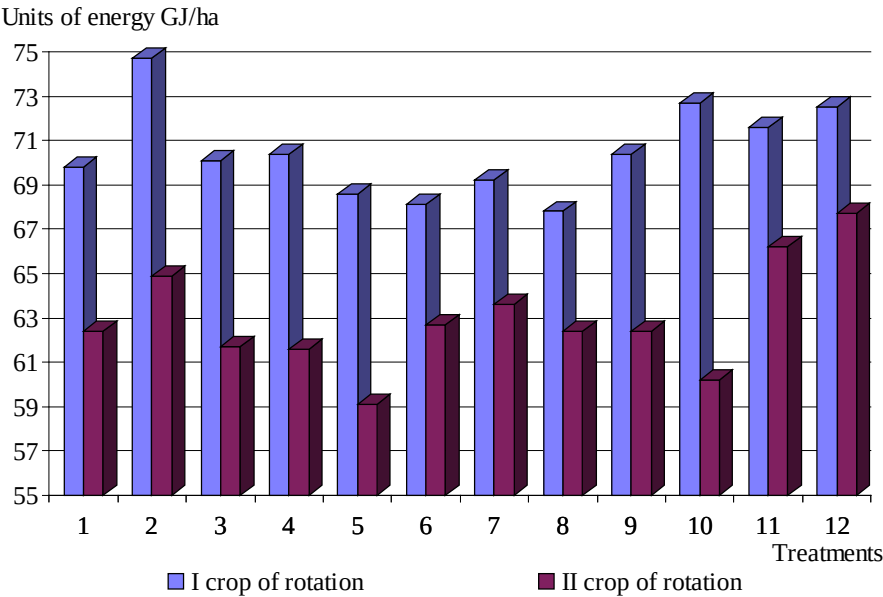
Impact of soil acidification on the crop yield

Results in Fig 1. depicts the effect of soil acidification on the accumulation of energy of crops and efficiency of micro-elements. Among the micro-nutrients applied the effect of boron and molybdenum on the yields of crops was more pronounced. Application of boron in the beginning of crop rotation has long time effect on the yield of fodder beets. Boron application increased the yield by 7.8 t/ha, which were 23% higher as compared to control.

Micro-elements, especially molybdenum and zinc, increased yield of perennial grasses in the both crop rotations. Use of micro-elements in the beginning of crop rotation gave 1.92 and 1.06 t/ha additional of hay yield. Use of micro-elements in every year increased the hay yield by 0.94

and 1.05 t/ha. Increase in soil acidity decreased the efficiency of micro-elements. There was no increase in the yield of fodder beets and corn by fertilising it with micro-elements.

Fertiliser use efficiency is also related to soil acidity. Increases amount of aluminium due to soil acidity decreased the amount of phosphorus in the soil. Total yield of second crop rotation decreased from 70.5 GJ/ha to 62.9 GJ/ha. Acidification of soil can be considered as one of the reason of chemical soil degradation. It changes the balance of nutrients in soil. Some of the elements such as Al may become toxic where as other elements such as Ca and P may become deficient.



Treatments:

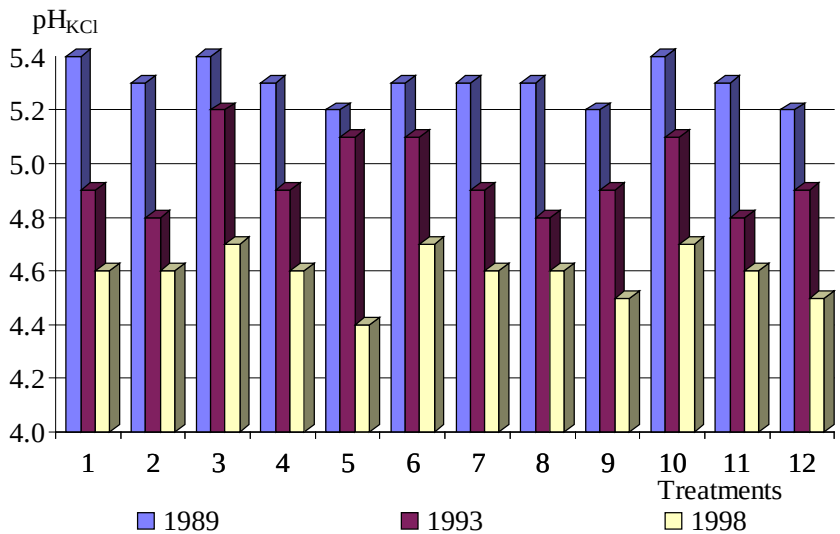
1. Without micro-elements	7. Cu every year into soil and onto plants
2. B once during rotation into soil	8. Zn once during rotation into soil
3. B every year onto plants	9. Zn every year onto plants
4. B every year into soil and onto plants	10. Zn every year into soil and onto plants
5. Cu once during rotation into soil	11. Mo once during rotation into soil
6. Cu every year onto plants	12. Mo every year onto plants.

Figure 1: Accumulation of units of energy in the crop rotation, GJ/ha
(Vezaiciai, 1989-1998)

Impact of soil acidification on the changes of chemical elements

The chemical analysis of soil showed that pH of the soil which was in the range of 5.2 to 5.4 after the liming of the soil in 1989 decreased to 4.5 to 4.7 after the period of ten years in 1998.

Acidification of soil in the first five year was not so intensive. The pH decreased about 0.2 units during 1989 to 1994. Acidification was more intensive during the last five-year period from 1994 to 1998 when the pH decreased by 0.4 to 0.6 units. This may probably be due to effectiveness of lime for the first four years and leaching down of the CaCO_3 into subsoil at later period when acidification of soil were noticeable again. The reaction of the soil seems to be sufficiently stable. The deviation of $\pm 0.12 - 0.16 \text{ pH}_{\text{KCl}}$ from the average data showed the diversity of field trial in respect of soil acidity is low.



Treatments:

1. Without micro-elements	7. Cu every year into soil and onto plants
2. B once during rotation into soil	8. Zn once during rotation into soil
3. B every year onto plants	9. Zn every year onto plants
4. B every year into soil and onto plants	10. Zn every year into soil and onto plants
5. Cu once during rotation into soil	11. Mo once during rotation into soil
6. Cu every year onto plants	12. Mo every year onto plants.

Figure 2: Changes of soil reaction (Vezaiciai, 1989-1998)

The data in figure 2. showed the use of micro-elements had not much influence on the soil reaction. The highest affect of soil acidification was observed by dressing with copper one time per crop rotation but the effect was not statistically significant.

Amount of mobile aluminium in the soil has a direct relation with the soil reaction (Table 3.).

As reported in the preceding section the Al content of non-limed soil varied from 29 - 76 mg/kg, which was decreased to 0.3 - 2.2 mg/kg after liming the soil. However over the period of 10

Table 3: Impact of soil acidification on the amount of mobile aluminium (mg/kg)

Treatments	Al ⁺⁺⁺ , $\bar{x} \pm Sx$		
	1989	1994	1998
Without micro-elements	0.9 ± 0.4	1.6 ± 0.6	15.9 ± 6.1
B once during rotation into soil	0.3 ± 2.7	8.9 ± 7.4	22.1 ± 10.1
B every year onto plants	0.3 ± 0.2	6.4 ± 3.7	19.9 ± 7.6
B every year into soil and onto plants	1.9 ± 1.8	5.1 ± 3.2	21.3 ± 10.1
Cu once during rotation into soil	1.4 ± 0.5	4.2 ± 1.6	33.8 ± 7.2
Cu every year onto plants	0.3 ± 0.2	4.9 ± 2.0	15.7 ± 7.8
Cu every year into soil and onto plants	1.4 ± 1.3	6.4 ± 2.5	17.2 ± 8.2
Zn once during rotation into soil	2.2 ± 0.8	12.0 ± 4.9	20.6 ± 9.9
Zn every year onto plants	0.8 ± 0.2	4.7 ± 2.1	25.8 ± 6.7
Zn every year into soil and onto plants	0.5 ± 0.2	3.3 ± 1.0	13.9 ± 6.2
Mo every year onto plants	1.0 ± 0.7	7.6 ± 2.3	18.8 ± 7.2
Mo every year into soil and onto plants	1.7 ± 1.0	5.5 ± 3.0	18.3 ± 8.0

$\bar{x}$ - average data

Sx - standard deviation

years as the acidity of the soil increased it was also increased to 14 - 34 mg/kg. A wide variation in deviation from average showed that aluminium was not a stable element.

Table 4: Impact of soil acidification on the amount of mobile phosphorus, mg/kg

Treatments	P ₂ O ₅ , $\bar{x} \pm Sx$		
	1989	1994	1998
Without micro-elements	152 ± 11	123 ± 12	105 ± 10
B once during rotation into soil	147 ± 10	127 ± 10	111 ± 6
B every year onto plants	137 ± 9	123 ± 3	112 ± 10
B every year into soil and onto plants	145 ± 7	122 ± 3	117 ± 8
Cu once during rotation into soil	129 ± 9	116 ± 5	110 ± 9
Cu every year onto plants	137 ± 11	129 ± 6	118 ± 6
Cu every year into soil and onto plants	140 ± 8	138 ± 2	106 ± 10
Zn once during rotation into soil	145 ± 12	126 ± 5	111 ± 9
Zn every year onto plants	130 ± 2	126 ± 8	112 ± 3
Zn every year into soil and onto plants	142 ± 6	126 ± 4	114 ± 9
Mo every year onto plants	145 ± 10	121 ± 5	116 ± 7
Mo every year into soil and onto plants	127 ± 6	132 ± 10	113 ± 8

$\bar{x}$ - average data

Sx - standard deviation

Amount of mobile phosphorus decreased with soil acidification over a period of time after liming the soil (Table 4). In spite of fertilisation of crop every year, the average decrease of

20% over the period from 1989 to 1998 showed that the soil acidification degraded the soil with respect to the available phosphorus. The deviations from average data were not large. It indicates that phosphorus is rather a stable element.

Amount of mobile potassium, contrary to phosphorus, increased by soil acidification over the period of time. The average increase was to the extent of 15% (Table 5.). In contrast to other chemical indices, the increase in potassium was quite noticeable after five years. After this period although the K content increased but the increase was not significant.

Table 5: Impact of soil acidification on the amount of potassium, mg/kg

Treatments	K ₂ O, $\bar{x} \pm S_x$		
	1989	1994	1998
Without micro-elements	296 $\pm$ 12	331 $\pm$ 16	343 $\pm$ 17
B once during rotation into soil	297 $\pm$ 22	326 $\pm$ 12	320 $\pm$ 7
B every year onto plants	286 $\pm$ 19	327 $\pm$ 5	319 $\pm$ 19
B every year into soil and onto plants	293 $\pm$ 12	334 $\pm$ 2	326 $\pm$ 8
Cu once during rotation into soil	270 $\pm$ 6	297 $\pm$ 10	323 $\pm$ 10
Cu every year onto plants	273 $\pm$ 15	361 $\pm$ 21	345 $\pm$ 8
Cu every year into soil and onto plants	278 $\pm$ 19	308 $\pm$ 21	341 $\pm$ 25
Zn once during rotation into soil	278 $\pm$ 14	335 $\pm$ 4	314 $\pm$ 5
Zn every year onto plants	279 $\pm$ 10	338 $\pm$ 10	312 $\pm$ 10
Zn every year into soil and onto plants	287 $\pm$ 16	349 $\pm$ 10	317 $\pm$ 20
Mo every year onto plants	268 $\pm$ 11	331 $\pm$ 10	342 $\pm$ 25
Mo every year into soil and onto plants	285 $\pm$ 14	363 $\pm$ 24	344 $\pm$ 15

$\bar{x}$ - average data

S_x - standard deviation

Change of soil reaction not influenced the amount of boron in the soil and variation of data was not considerable (Table 6).The data showed that boron is not sensitive to the soil reaction. These results are at variance from the results reported by some other workers [4, 7].

Amount of calcium contrary to boron, has rather wide data variation. It is directly related to soil reaction. Migration of calcium to sub soils due to soil acidification is rather fast.

Amount of copper in the acid soil increased by about 27% over the period of time and data variation in the acid soil was quite large as compared to limed soils (Table 7).

Zinc is considered to be active in the acid soil. There is quite a large variation in the content of zinc in soils (Table 7). Acidification of soil over the period of 10 years after liming decreased the zinc content by 50%. The decrease in mobile zinc in the acid soils is contradictory to earliest

studies [8]. The decrease in content of zinc in the present study may due to its removal by crops as the higher crop yields were obtained after liming of the soil.

Table 6: Impact of soil acidification on the amount of boron and calcium, mg/kg

Treatments	$\bar{x} \pm Sx$		
	boron		calcium
	1989	1994	1997
Without micro-elements	0.25 ± 0.02	0.19 ± 0.01	562 ± 72
B once during rotation into soil	0.25 ± 0.03	0.26 ± 0.01	569 ± 107
B every year onto plants	0.25 ± 0.04	0.25 ± 0.03	597 ± 58
B every year into soil and onto plants	0.31 ± 0.03	0.24 ± 0.04	508 ± 89
Cu once during rotation into soil	0.32 ± 0.05	0.18 ± 0.02	497 ± 72
Cu every year onto plants	0.27 ± 0.04	0.21 ± 0.01	555 ± 38
Cu every year into soil and onto plants	0.31 ± 0.01	0.20 ± 0.01	577 ± 61
Zn once during rotation into soil	0.42 ± 0.05	0.25 ± 0.02	566 ± 99
Zn every year onto plants	0.44 ± 0.05	0.23 ± 0.04	520 ± 77
Zn every year into soil and onto plants	0.38 ± 0.04	0.26 ± 0.04	606 ± 39
Mo every year onto plants	0.32 ± 0.06	0.26 ± 0.02	585 ± 67
Mo every year into soil and onto plants	0.28 ± 0.05	0.26 ± 0.03	558 ± 69

$\bar{x}$ - average data

Sx - standard deviation

Table 7: Impact of soil acidification on the amount of copper and zinc, mg/kg

Treatments	$\bar{x} \pm Sx$			
	copper		zinc	
	1989	1996	1989	1996
Without micro-elements	1.07 ± 0.11	1.27 ± 0.24	1.10 ± 0.08	1.00 ± 0.20
B once during rotation into soil	1.17 ± 0.08	1.77 ± 0.30	1.56 ± 0.04	0.80 ± 0.14
B every year onto plants	1.07 ± 0.08	1.47 ± 0.08	1.44 ± 0.17	1.12 ± 0.22
B every year into soil and onto plants	1.12 ± 0.07	1.67 ± 0.20	1.61 ± 0.10	0.70 ± 0.13
Cu once during rotation into soil	0.97 ± 0.02	1.40 ± 0.27	1.79 ± 0.41	0.65 ± 0.13
Cu every year onto plants	1.12 ± 0.11	1.37 ± 0.19	1.42 ± 0.27	0.65 ± 0.14
Cu every year into soil and onto plants	1.10 ± 0.20	1.50 ± 0.22	1.36 ± 0.16	0.67 ± 0.14
Zn once during rotation into soil	1.02 ± 0.08	1.57 ± 0.32	1.64 ± 0.10	0.55 ± 0.12
Zn every year onto plants	1.05 ± 0.05	1.35 ± 0.20	1.42 ± 0.22	0.90 ± 0.33
Zn every year into soil and onto plants	1.05 ± 0.05	1.50 ± 0.24	1.19 ± 0.19	0.77 ± 0.11
Mo every year onto plants	1.02 ± 0.02	1.40 ± 0.10	1.28 ± 0.07	0.60 ± 0.17
Mo every year into soil and onto plants	1.12 ± 0.13	1.12 ± 0.14	1.37 ± 0.21	0.67 ± 0.18

$\bar{x}$ - average data

Sx - standard deviation

Conclusions

1. Long time using of micronutrients the content of micro-elements not increased. Content of micronutrients depended from soil reaction.

2. Micronutrients are effective on yield of crop rotation in limed soil. Effectiveness of micronutrients after soil acidification decreased about 11%.
3. Acidity of soil while 10 years period increased about 1.0 pH_{KCl}.
4. While acidification of soil yield of crop rotation decreased from 70.5 to 62.9 GJ/ha.

Acknowledgements

Author is grateful to the Centre of Agrochemistry Researches and laboratory of Vezaiciai for the help at various stages for compiling this information and writing the paper.

References

- Antanaitis A., Mazvila J., (1984). Judriojo magnio ir kitu mikroelementu kiekis ir jo priklausomybe nuo dirvozemio savybiu. In: *Mikroelementu tyrimai ir naudojimas zemes ukyje*.
- Baginskas B., (1964). *Mikroelementai ir ju panaudojimas*. Vilnius.
- Ciuberkienė D., (1998). The dependence of barley yield and it's quality at the soil reaction. In: *The present and future at crop science and bee keeping*. Kaunas-Akademija.
- Ezerinskas V., (1998). Live powder efficiency and rates on the acid soils. In: *The present and future of crop science and bee keeping*. Kaunas-Akademija.
- Mazvila J., (1998). *Lietuvos dirvozemiu agrochemines savybes ir ju kaita*. Kaunas.
- Veitienė R., (1987). Kalkinimo ir tresimo itaka mikroelementu dinamikai dirvozemyje. In: *Jaunuju mokslininku konferencijos pranesimai*. Vilnius.
- Veitienė R., (1998). Micro-elements in crop rotation. In: *The present and future of crop science and bee keeping*. Kaunas-Akademija.
- Veitienė R., (1996). Usage of micro-elements in crop rotation. *Agriculture. Scientific Articles of the Lithuanian institute of agriculture*. 56: 43-53.

Section 6

Organic fertilizer management

SCREENING OF ORGANIC BIOLOGICAL WASTE PRODUCTS FOR THEIR POTENTIAL TO IMMOBILIZE NITROGEN RELEASED FROM CROP RESIDUES

B. Chaves¹, S. De Neve¹, G. Hofman¹, P. Boeckx² and O. Van Cleemput²

¹Department of Soil Management and Soil Care, Division of Soil Fertility and Nutrient Management, Ghent University, Coupure Links 653, B-9000 Gent, Belgium

²Department of Applied Analytical and Physical Chemistry, Laboratory of Applied Physical Chemistry_ISOIFYS, Ghent University, Coupure Links 653, B-9000 Gent, Belgium

Introduction

Intensive field vegetable production in Flanders (Belgium) is often characterized by an excessive use of N fertilization, resulting in large mineral N residues in the soil and large amounts of crop residues rich in N at harvest (De Neve and Hofman, 1998). The N in above ground residues can amount to over 200 kg N ha⁻¹ for a number of *Brassica* crops (Rahn et al., 1992). During mineralization of these crop residues, additional mineral N is released into the soil resulting in large nitrate residues in the soil during the autumn and winter and serious problems with respect to nitrate leaching. This specific situation of intensive field vegetable production in relation to crop residues makes it also very hard to comply with the nitrate standards, namely the European Nitrate Directive and the Belgian Manure Action Plan (MAP), stating that the nitrate residue in the 0 to 90 cm layer has to be less than 90 kg N ha⁻¹ during the period of October 1 till November 15 (Salomez and Hofman, 2003).

Alternative methods are required to reduce the nitrate residue in autumn. A possibility is manipulating the N mineralization of the crop residues by the use of on- and off-farm organic waste products. There are indications of possibilities for manipulating the N release of crop residues. Rahn et al. (1999) found that the N mineralization of sugar beet and Brussels sprouts leaves mixed with molasses doubled respectively after 56 and 112 days, while on the other hand when the leaves were mixed with straw and a green waste compost, the N mineralization showed a strong decrease. Gaona Sáez (2000) showed that next to straw and green waste compost, also polyphenols (tannic acid) can immobilize N from crop residues, and that the period of immobilization depends on the type of the added material.

The objective of this research was a screening of several organic waste products for their potential to immobilize N released from crop residues of vegetables.

Materials and Methods

Analytical methods

The crop residue and different organic waste products used in the experiment are presented in Table 1. Celery leaves were chosen as crop residue for their high N mineralization potential. Only the leaf blades were used in order to have a more homogenous N content. Cereal straw, two green waste composts (GCP1 and GCP2), saw dust and paper sludge were chosen for their wide C:N ratio, and tannic acid for its a high polyphenol content, since a wide C:N ratio or a high polyphenol content have proved to be indicators for a decreased N mineralization or N immobilization (Palm and Sanchez, 1991; Mueller et al., 1998). Tannic acid was used as a model compound for organic materials containing important amounts of water soluble polyphenols, but not with the intention to use this product in real field conditions.

Table 1: (Bio)chemical composition of the celery leaves and the organic waste products (GCP is green waste compost, FM is fresh matter, DM is dry matter, OM is organic matter, Total N is the total N content, N_{min} is the mineral N content, Total C is the total C content)

	Celery leaves	Cereal straw	GCP1*	GCP 2*	Saw dust	Tannic acid	Paper sludge
FM added to 283 g dry soil	6.00	1.00	3.00	3.00	1.00	1.00	4.00
DM (%)	13.2	91.4	52.5	55.5	95.0	94.0	29.0
OM (% DM)	76.5	93.5	43.6	42.2	99.6	100.0	61.9
Total N (% DM)	4.68	0.47	1.45	1.30	0.06	0.06	0.61
N _{min} (g/kg DM)	3.30	0.09	0.40	0.54	0.01	0.04	0.20
Total C (% DM)	36.1	46.7	27.8	24.3	51.8	52.6	30.9
C:N ratio	7.7	99.4	19.0	18.7	863.3	876.6	50.7
Fractions (%OM)							
Water soluble fraction	29.2	4.7	4.3	4.2	2.7	100.0	3.5
Hemicellulose fraction	42.7	38.8	25.7	22.2	27.4	0.0	26.6
Cellulose fraction	7.4	21.7	4.8	22.2	26.9	0.0	20.8
Lignin fraction	20.7	34.8	65.2	51.4	43.0	0.0	49.1
N content of fractions (% of total N)							
Water soluble fraction	28.0	2.5	17.1	31.9	36.8	100.0	13.1
Hemicellulose fraction	58.4	41.4	17.3	15.3	28.7	0.0	53.2
Cellulose fraction	5.9	41.3	27.5	19.5	14.9	0.0	11.7
Lignin fraction	7.7	14.8	38.1	33.3	19.6	0.0	22.0

* GCP 1 was one month older than GCP 2

Samples of the celery leaves and the waste products were dried at 55 °C until constant weight for the determination of the dry matter content, and were then ground for further chemical

analysis. The total C and N content of the products were determined by dry combustion using a CNS elemental analyser (ELEMENTAR, Germany). For the extraction of inorganic N of the celery leaves and wastes, 60 ml KCl (1M) was added to 5 g of fresh material (ratio 1:12). This solution was shaken for one hour, filtered, and analysed for NO_3^- -N and NH_4^+ -N with a continuous flow auto-analyser (Chemlab System 4, SKALAR, The Netherlands). The water soluble, hemicellulose (+ structural protein), cellulose (+ structural protein) and lignin (+ structural protein) fractions were determined by Stevenson fractionation as modified by De Neve and Hofman (1996). For each fraction obtained by the Stevenson fractionation, the N content (CNS elemental analyser) was determined. The biochemical characteristics of the celery leaves and the organic waste products are shown in Table 1.

Incubation conditions

The soil used in the incubations was the top layer (0 - 20 cm) of a sandy loam soil collected at Beitem (West-Flanders, Belgium) after the harvest of spinach. The soil contained 8.6% clay, 30.9% silt and 60.6% sand, had a pH_{KCl} of 5.45, a total N content of 0.11% and a C content of 1.52%. The soil was sampled at a moisture content of 20% (w/w), which was too high for the incubations. Therefore the soil was dried to a moisture content of 13% (w/w). During the drying period, visible impurities (e.g. stones, roots) were removed from the soil. The soil was not sieved and not air-dried in order to minimize the disturbance of the microbial activity.

Fresh soil (equivalent to 283 g dry soil) was mixed thoroughly with fresh chopped celery leave blades (equivalent to 36 ton fresh residue ha^{-1}) and a fresh organic waste product (equivalent to ca. 2.5 ton C ha^{-1}) and incubated in PVC tubes (diameter = 4.63 cm; filling height = 12 cm; bulk density = 1.4 g cm^{-3}). After filling the PVC tubes, distilled water was added to obtain a moisture content of 16.5% (w/w) (49% WFPS) and the tubes were covered with a single layer of gas permeable parafilm to minimize water loss. The tubes were incubated during 169 days at constant temperature (15°C). Next to the six treatments with organic waste products, also two control treatments were included: ‘only soil’ and ‘soil plus celery leaves’. The sampling was destructive by removing tubes in triplicate for each treatment at each sampling date. Samples were taken 1, 2, 4, 5, 7, 10, 14, 15, 16, 18, 22 and 24 weeks after the start of the incubation. The soil was removed from the tubes and mineral N (NO_3^- -N + NH_4^+ -N) was extracted by adding 60 ml of 1N KCl to 30 g of fresh soil (ratio KCl:soil 1:2) and this extract was analysed with a continuous flow auto-analyser (Chemlab System 4, SKALAR, The Netherlands).

Analysis of variance (One-way ANOVA in SPSS) was used to determine variances attributable to treatments at each sampling date.

Results

In order to evaluate the efficiency of the organic waste products as immobilisers, the amount of N released by the ‘soil plus celery leaves’ treatment was subtracted from the amount of N released from the treatments amended with a particular waste product. The net N mineralization patterns are presented in Figure 1.

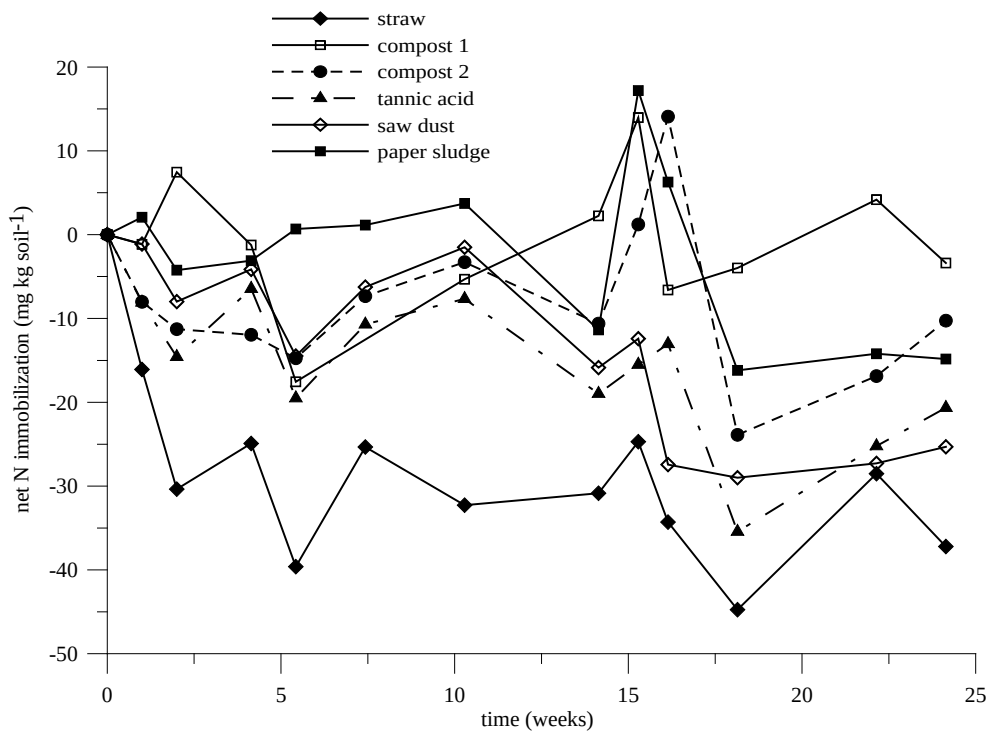


Figure 1: Net N immobilization of the organic waste products

The variability both between replicates at a given sampling time and between sampling times was very large, but this is typical when fresh organic material is incubated with soil (De Neve and Hofman, 1996). The standard deviations were not indicated in Figure 1 because they were largely overlapping, complicating the interpretation of the figure. The values of the standard deviations were more or less comparable amongst treatments and the average standard deviation across all sampling times and treatments was 7.6 mg N kg⁻¹ soil.

The addition of the organic waste products together with celery leaves caused a significant ($P < 0.01$) N immobilization at all sampling dates in only one treatment, namely upon addition of

straw. Compost 1, compost 2, tannic acid and saw dust caused significant ($P < 0.05$) N immobilization at respectively two, four, seven and five sampling dates. Nevertheless their net N release patterns showed a tendency towards N immobilization. The paper sludge treatment showed an evolution similar to that of the soil amended with only celery leaves, and did not immobilize the N released from the celery leaves.

Discussion

Apparently, the organic waste products showed differences in efficiency to immobilize N. Straw was the strongest immobiliser, followed by saw dust, tannic acid, compost 2 and compost 1. Paper sludge did not immobilize N.

The immobilizing action can be linked to two characteristics. The first one is the wide C:N ratio of the organic material and the second one is the high polyphenol content.

When organic materials with a wide C:N ratio are decomposing in the soil the amount of N in the material can be below the threshold of the microbial requirement for biosynthesis. Consequently, the inorganic N present in the soil will be immobilized within the microbial biomass during organic substrate breakdown. Also the composition of the C pool is important during decomposition, i.e. the water soluble, hemicellulose, cellulose and lignin content of the material. Organic materials rich in lignin will be more resistant to degradation by micro-organisms than materials rich in water soluble compounds, hemicellulose and cellulose. Although straw was the strongest immobiliser, saw dust had the widest C:N ratio. However, the lignin content of the saw dust was higher, which may have slowed down its decomposition, decreasing the N demand of the micro-organisms, and so, decreasing the N immobilization. The two green waste composts had a much lower C:N ratio and a higher lignin content than straw and saw dust, which explains the lower N immobilization. However, in spite of a wide C:N ratio, the paper sludge did not immobilize N.

The second characteristic, the polyphenol content, as found in tannic acid, had an influence which was very different from that of straw or compost. Polyphenolic compounds may influence the N mineralization-immobilization turnover in soils in two ways. There is a direct toxicity effect on the soil microbial biomass, including bacteria, fungi and microfauna involved in the process of N mineralization (Scalbert, 1991, Capasso et al., 1995, Hewlett et al., 1997). Polyphenols have also a strong protein binding capacity through their strong affinity for amide groups. The polyphenol effect on N availability therefore is not an immobilization of mineralized N, but an inhibition of N mineralization through the above mentioned effects.

There exists a large variety of other materials that could be used as immobilisers. These include a number of non-toxic agricultural waste products, which at present are still often landfilled or incinerated, but pressure is increasing to apply these waste products by landspreading on agricultural land (Gendebien et al., 2001). However great care should be taken that only those waste products that cause no risk with respect to environmental pollution because of toxic compounds are considered for this purpose.

Conclusion

The results of this study indicate that there is scope for manipulating the N release from crop residues rich in N by the addition of both on- and off-farm organic materials, in order to reduce the nitrate residues in soil during the autumn. This means also a reduced nitrate leaching risk, a better match between the crop N demand and the soil N supply, and an increase of the N use efficiency. Both the intensity of the immobilization and the time at which remineralization occurs seem to be manageable by the right choice of organic waste product.

Aknowledgements

The authors wish to express their thanks to the Belgian Ministry of Small Enterprises and Traders and Agriculture, Division Research and Development, for funding this research (project S-6059). We also thank M. Remue, V. Van De Vyvere, L. Bauwens and T. Coddens for their skilful technical assistance.

References

- Capasso, R., Evidente, A., Schivo, L., Orru, G., Marcialis, M.A., Cristinzo, G. 1995. Antibacterial polyphenols from olive oil mill waste waters. *Journal of Applied Bacteriology* 79, 393-398.
- De Neve, S., Hofman, G. 1996. Modelling N mineralization of crop residues during laboratory incubations. *Soil Biology and Biochemistry* 28, 1451-1457.
- De Neve, S., Hofman, G. 1998. N mineralization and nitrate leaching from vegetable crop residues under field conditions: a model evaluation. *Soil Biology and Biochemistry* 30, 2067-2075.
- Gendebien, A.H., Ferguson, R., Brink, J., Horth, H., Sullivan, M., Davies, R., Brunet, H., Dalimer, F., Landrea, B., Krack, D., Orsi, C. 2001. Survey of wastes spread on land – final report. European Commission Directorate General for Environment, Study Contract B4-3040/99/110194/MAR/E3.
- Gaona Sáez, S. 2000. Managing N release from N rich crop residues using on- and off-farm organic materials. MSc. Thesis, Ghent University, FLTBW, 112p.
- Hewlett, T.E., Hewlett, E.M., Dickson, D.W. 1997. Response of *Meloidogyne* spp., *Heterodora glycines*, and *Radopholus similis* to tannic acid. *Journal of Nematology* 29, 737-741.
- Mueller, T., Jensen, L.S., Nielsen, N.E., Magid, J. 1998. Turnover of carbon and nitrogen in a sandy loam soil following incorporation of chopped maize plants, barley straw and blue grass in the field. *Soil Biology and Biochemistry* 30, 561-571.
- Palm, C.A., Sanchez, P.A., 1991. Nitrogen release from the leaves of some tropical legumes as affected by their lignin and polyphenolic contents. *Soil Biology and Biochemistry* 23, 83-88.
- Rahn, C.R., Vaidyanathan, L.V., Paterson, C.D. 1992. Nitrogen residues from Brassica crops. *Aspects of Applied Biology* 30, 263-270.

- Rahn, C., Bending, G.D., Turner, M.K., Lillywhite, R. 1999. Use of carbonaceous amendments of contrasting lability for the management of nitrogen losses from high N content crop residues. BSSS Symposium, poster abstract (<http://www.sac.ac.uk/envsci/external/bsss/poster2.htm>).
- Salomez, J., Hofman, G. 2003. Residual nitrate nitrogen in autumn as an environmental quality indicator of N-fertilization practices. Proceedings of the 13th International Symposium of the International Scientific Centre of Fertilizers, June 10-13, 2002, Tokat, Turkey, in press.
- Scalbert, A. 1991. Antimicrobial properties of tannins. *Phytochemistry* 30, 3875-3883.

**POSSIBLE USE OF DRIED HOTAMIS LAKE SOILS
MIXED WITH FARM YARD MANURE AS A GROWTH MEDIUM
FOR WHITE CARNATION (*DIANTHUS CARYOPHYLLUS L.*) PRODUCTION**

M. R. Karaman¹, A. R. Brohi¹ and F. Er²

¹Gaziosmanpaşa Univ. Agricultural Faculty., Department of Soil Sci, Tokat, Turkey
e-mail: rkaraman @ gop.edu.tr

²Selcuk University, Department of Soil Sci., College of Profession, Cumra - Konya, Turkey

Abstract

Garden soil, farmyard manure, silt, sand or perlite is generally used as growing substrates at different ratios for flower production. However, other organic materials, having high water holding capacity, can also be used as growing substrate for planting. The main object of this study is to investigate the possible use of dried Hotamis Lake soils as a growth medium for White Carnation production. The dried Hotamis Lake area lies towards the South-East region of Konya closed basin in Turkey. The study area has remained under water lodged conditions for about twenty years. These organic soils may be used for potted plants, and for home flower as well as for commercial greenhouse flower production. For this aim, an experiment was carried out in a randomized block design with three replications using the soils obtained from this area. Seeds of White Carnation (*Dianthus caryophyllus L.*) were sown in plastic bags and grown in high plastic tunnels. Each plastic bag contained 500 grams of mixtures. The growth mixture consisted of two parts of garden soil and one part of perlite. This standard substrate was mixed with different ratios of soil obtained from dried Hotamis Lake and with farmyard manure. Plants were harvested after eight weeks. Some quality parameters were recorded, and nutrient status of the plants were determined.

Introduction

In recent years; flowers have been a very important part of the consumption of modern society. For example, clove growth have a big importance for Turkey, and it forms 60 % of annual flower production (Boztok et al. 1995). In flower production; garden soil, farmyard manure, silt, sand or perlite is generally used as growth substrates at different ratios.

Use of different materials so as to obtain different mixtures instead of the standard use of organic material or organic soils have drawn the attention of the research workers to get successful results for the cultivation of Gerbera plantation. The compost made from pinus bark and then mixed with sandy loam soil as suggested by Blomme and Dambre (1981) has given negative results when compared with the mixture of organic soil and perlite as suggested by Pivot (1988). Moltay et al. (1998) carried out an experiment to see effect of different growth mediums for gerbera plantation. They have used loam soil, farm yard manure, leaf residues, straw composte, sand, perlite and straphour to make about 18 mixtures in order to see the effect of these growth mixtures on the yield and quality of gerbera plant. The highest results were obtained with 3:1:1 ratio. Yılmaz and Korkut (1998) have also found a decrease in flowering

and flowering quality of Lily plant (*Lilium L.*) when the ratio of field soil in the mixture was increased. Sarısoy and Korkut (1998) found an increase in the flowering and flower quality of Violet plant (*Saintpaulia Ionantha L.*) when grown in the mixture of one part of soil, one part of farm yard manure and one part of perlite. As a result, the importance of organic matter additions to growth mediums is very clear and significant.

The alternative materials used instead of organic materials have been proved to be unsuccessful as a plant growth medium as has been tested by many workers (Blomme and Dambre,1981; Pivot,1988). However, other organic materials, having high water holding capacity can also be used as a growth substrate for planting. For example, peat had been used as a growth medium in Europe for a long time. Peat is known as decayed organic material formed in anaerobik conditions (Fitzpatrick 1971). It is not toxic for plants, and is an inactive chemical. The proper characteristics of the peat as a plant growth material is due to its high organic structure. Organic materials improve the physical, chemical and biological properties of the soil. A substrate should increase the water holding capacity and porosity of the soils, but also it should be economic. The main object of this study is to investigate the possible use of dried Hotamis Lake soils as a growth medium for White Carnation production. These organic soils may alternatively be used for potted plants, and for home flowering as well as for commercial greenhouse flower production.

Materials and Methods

A pot experiment was carried out on the greenhouse area of Konya Municipality with a randomized block design having three replications. Soils used for this study were obtained from the dried Hotamis Lake. The dried Hotamis Lake area lies towards the South-East region of Konya closed basin called Cumra in Turkey. The altitude of this region is 1013 m. It lies between 37 ° 35' (N) and 32 ° 42' (E). The study area has remained under water lodged conditions for about twenty years. It comprises 1000-1200 hectares with marsh plantation (Er, 1994). Three Seeds of White Carnation (*Dianthus caryophyllus L.*) for each replication (totally 135 plants) were sown in plastic bags, and left to be grown in high plastic tunnels. Each plastic bag contained 500 grams of mixtures. The standard growth mixture consisted of two parts of garden soil and one part of perlite. This standard substrate was mixed with different ratios of soil obtained from dried Hotamis Lake and farm yard manure. Five different rates of Hotamis organic materials and three different rates of highly fermented and sieved farm yard manure were added to the each standard mixture (two parts of garden soil and one part of perlite). The ratios of the mixture materials are given in Table 1.

Table 1: The ratios of different materials added to the standard mixture (two parts of garden soil and one part of perlite).

Mixture No.	Organic Material obtained from Dried Hotamis Lake (ratio)	Farm Yard Manure (ratio)
1	0:	0
2	0:	2
3	0:	4
4	1:	0
5	1:	2
6	1:	4
7	2:	0
8	2:	2
9	2:	4
10	3:	0
11	3:	2
12	3	4
13	4:	0
14	4:	2
15	4:	4

Plants were harvested after eight weeks. Some quality parameters were recorded. Stalk of flower, diameter of flower stalk, length of root and weight of flower stalk were determined in plants harvested very near to the ground level at the last blossoming period. Samples of stalks and roots of White Carnation were also collected to determine some nutrient status of the plant. The analysis in the wet ashing plant samples were done according to the routine methods. The field capacity, wilting point, total salt and pH of 15 different growth substrates were also determined according to the routine methods as suggested by Tüzüner (1990). Statistical evaluations were made using the MSTAT computer program.

Results and Discussions

Some physical and chemical properties of the mixtures used for this study have been determined. In general, total salt and pH values were statistically found at the same group. The lowest pH value was found at mixture no 1, whereas the lowest total salt value was found at

mixture no 13. The highest values of field capacity and wilting point were detected in mixture no. 3 (Table 2).

Table 2: Some physical and chemical properties of the mixtures

Mixture No.	Field capacity %	Wilting point %	Total salt %	pH (1:2)
1	32.6 c-e	28.7 bc	0.11 a	7.27 b
2	42.7 b	38.9 b	0.18 a	7.47 a
3	55.8 a	51.4 a	0.21 a	7.37 a
4	27.8 e	24.8 c	0.13 a	7.40 a
5	37.0 b-e	34.1 bc	0.13 a	7.47 a
6	27.0 e	24.6 c	0.16 a	7.47 a
7	31.4 de	27.3 c	0.16 a	7.40 a
8	28.3 e	24.7 c	0.17 a	7.43 a
9	33.1 b-e	28.3 bc	0.17 a	7.43 a
10	34.8 b-e	26.0 c	0.16 a	7.43 a
11	32.9 b-e	27.3 c	0.19 a	7.40 a
12	37.1 b-e	32.1 bc	0.15 a	7.50 a
13	38.7 b-d	33.3 bc	0.06 b	7.43 a
14	40.9 b-d	35.1 bc	0.18 a	7.43 a
15	41.3 bc	32.0 bc	0.15 a	7.50 a
LSD*	8.54	10.12	0.22	0.11

* P < 0.05 level

The productivity and quality values of the Carnations are given in Table 3. In general, the values of productivity and quality parameters were varied depending on different growing mixtures. As it is seen from Table 3, the highest length of stalk was obtained at mixture no.13, whereas the highest diameter of stalk was obtained at mixture no.12. The highest average length of root was found at mixture no.10, and the highest weight of the stalk was found at mixture no. 15.

Table 3: Effect of different growth mixtures on some productivity and quality values of White Carnation (average values).

Mixture No.	Length of flower stalk, cm	Diameter of flower stalk, cm	Length of root cm	Weight of stalk g
1	61.0 a-c	0.45	14.1	9.1 b-d
2	51.0 a-e	0.51	18.3	18.3 ab
3	21.3 e	0.40	11.3	6.7 cd
4	66.3 ab	0.37	14.3	11.8 a-d
5	32.7 c-e	0.43	14.3	12.1 a-d
6	25.3 de	0.35	6.7	7.2 cd
7	22.3 e	0.38	8.0	4.5 d
8	43.6 a-e	0.38	10.6	7.4 cd
9	42.3 a-e	0.43	18.0	15.5 a-c
10	55.3 a-e	0.47	22.3	16.1 a-c
11	55.7 a-d	0.43	21.0	19.5 ab
12	35.3 b-e	0.52	16.0	12.5 a-d
13	72.7 a	0.43	18.3	14.6 a-d
14	20.3 e	0.41	18.0	15.8 a-c
15	40.3 a-e	0.50	18.3	20.5 a
LSD*	28.36	N.S.	-	9.21

* $P < 0.05$ level

The statistical analysis of variance related to the plant nutrients in the Carnation stalk has also been done. As it is seen from Table 4; the highest values of N, Ca and Mg contents were determined at mixture no 14. The highest P content was found at mixture no.15, whereas the highest K content was found at mixture no.12. However non significant difference was observed among the mixtures no. 6, 3 and 12. The highest values of Fe, Zn and Mg were found at mixtures no. 5, 3 and 10, respectively. In the root parts of Carnations, nutrient status were also varied depending on different growing mixtures (Table 5). The highest average N, P and K contents in the root parts of carnation were found at mixtures no. 3, 2 and 12, whereas the highest average Fe, Zn and Mn contents were determined at mixtures no. 1.

As a result; addition of organic materials obtained from Dried Hotamis Lake and farm yard manure to the standard mixture of soil and perlite have improved the physical and chemical properties of the mixtures. These additions also increased the productivity, quality, and nutrition

status of plant. In the top and root parts of Carnations, nutrient status were varied depending on different growing mixtures. This study has also revealed that the organic material originated from Dried Hotamis Lake could be confidently used as a suitable growing material in Carnation production.

Table 4: Effect of different growing mixtures on some macro and micro nutrient status of White Carnation (in tops)

Mixture No.	N %	P %	K %	Ca %	Mg %	Fe ppm	Zn ppm	Mn ppm
1	1.86 c	0.18 a-c	0.83 d	2.56 a-c	0.25 ab	29.3 b	34.7 ab	81.4 bc
2	2.49 a-c	0.21 a-c	1.03 cd	2.48 b-d	0.27 ab	20.9 bc	30.5 a-c	105.0 ab
3	2.60 ab	0.21 a-c	3.02 a	1.90 cd	0.25 ab	25.9 bc	37.3 a	73.7 bc
4	2.25 a-c	0.12 c	0.80 d	1.81 d	0.25 ab	10.5 bc	33.7 ab	75.9 bc
5	2.21 bc	0.16 bc	1.03 b-d	2.76 ab	0.28 ab	70.3 a	34.7 ab	107.3 ab
6	2.06 bc	0.28 ab	2.90 a	2.47 b-d	0.28 ab	23.9 bc	23.2 a-c	72.0 bc
7	2.52 ab	0.21 a-c	0.80 d	2.35 b-d	0.29 ab	28.1 b	28.2 a-c	79.0 bc
8	2.58 ab	0.19 a-c	1.0 cd	2.62 ab	0.29 ab	26.7 bc	34.7 ab	52.9 c
9	2.47 a-c	0.22 a-c	2.35 ab	2.92 ab	0.30 ab	11.2 bc	17.5 c	84.2 a-c
10	2.12 bc	0.21 a-c	0.91 d	2.76 ab	0.28 ab	13.4 bc	15.1 c	127.1 a
11	2.64 ab	0.23 a-c	2.27 a-c	2.87 ab	0.29 ab	10.1 bc	16.6 c	86.3 a-c
12	2.50 ab	0.17 a-c	3.06 a	2.23 b-d	0.24 b	12.6 bc	20.9 bc	70.2 bc
13	2.22 a-c	0.15 bc	0.84 d	2.36 b-d	0.30 ab	8.3 b	14.4 c	63.2 bc
14	2.87 a	0.26 a-c	1.35 b-d	3.24 a	0.33 a	25.5 bc	21.4 a-c	100.1 ab
15	2.47 a-c	0.31 a	2.24 a-c	2.64 ab	0.29 ab	12.2 bc	17.7 c	72.1 bc
LSD*	0.55	0.12	1.19	0.62	0.07	16.8	14.0	39.8

* P < 0.05 level

Table 5. Effect of different growing mixtures on some macro and micro nutrient status of White Carnation (in roots)

Mixture	N	P	K	Ca	Mg	Fe	Zn	Mn
No.	%	%	%	%	%	ppm	ppm	ppm
1	1.60	0.21	0.62	2.08	0.27	188.8	55.3	52.7
2	2.34	0.39	0.83	2.28	0.30	35.1	44.7	36.8
3	2.48	0.15	0.89	1.97	0.22	55.2	33.5	36.8
4	1.52	0.27	0.70	2.99	0.32	29.6	56.6	38.6
5	2.45	0.26	0.86	2.72	0.28	42.7	23.7	13.2
6	1.61	0.11	0.69	1.39	0.24	22.1	25.8	24.6
7	0.83	0.14	0.50	2.55	0.29	27.2	14.7	28.1
8	1.35	0.10	0.60	2.58	0.28	32.1	20.9	7.9
9	1.81	0.23	0.81	1.71	0.17	44.3	44.7	32.4
10	1.98	0.20	0.82	1.87	0.21	42.2	34.4	35.6
11	2.12	0.32	0.78	1.43	0.18	38.3	38.4	27.3
12	2.27	0.34	0.92	1.72	0.20	25.7	36.3	40.2
13	2.20	0.27	0.74	2.20	0.25	18.3	32.3	35.7
14	2.45	0.30	0.86	2.98	0.32	18.4	40.5	28.9
15	2.00	0.20	0.84	1.62	0.22	20.5	29.3	28.1

Reference

- Blomme, R. and Dombre, R. 1981. Cultural substrate and fertilizer trials on gerberas. Hort. Abst. 62 (2).
- Boztok, Ş. Çokuysal, B. and Yıldırım, T. 1995. Effect of different growing mixtures on flowering and flowering quality of Carnation (*Dianthus Caryophyllus L.*) Ege University, Agricultural Faculty Press, Vol:32/3, 11-118. (In Turkish).
- Er, F. 1994. An investigation on some physical and chemical properties of Dried Hotamış Lake Soils laid in Konya Basin. MSc Thesis. Gaziosmanpaşa University, Agricultural Faculty, Tokat (In Turkish).
- Fitzpatrick, E.A. 1971. Pedology. A systematic Approach to Soil Science , Edinburg, Oliver and Boyd, 306.
- Kaplan, M. 1993. Effect of different growing mixtures on flowering and flowering quality of Carnation. Tr. J. of Agriculture and Forestry, 17, 987-996.
- Moltay, İ., Genç, Ç. and Gürsan, K. 1988. Determination of optimal growing mixture and fertilizer rate for Gerbera. I. Congress of National Ornament Plants, 119-127 p. 6-9 Ekim, Yalova (In Turkish).
- Munsuz, N. and Ünver, İ. 1980. Substrates used in agricultural production and properties of perlite. Seminar of perlite in Agriculture, İzmir, Turkey.
- Oral, N. and Açıköz, E. 1991. Garden Flowers. Environment Ltd. Press., Bursa, Turkey.
- Pivot, D. 1988. Sludge and bark compost mixed with or without peat or rockwol for the cultivation of potted gerberas. Hort. Abst. 58 (12).
- Sarısoy, S.Ç. and Korkut, A.B. 1998. Effect of different growing mixtures on flowering and flowering quality of Violet (*Saintpaulia Ionantha L.*). I. Congress of National Ornament Plants, 322-327 p. 6-9 Ekim, Yalova (In Turkish).
- Tüzüner, A. 1990. Handbook of Soil and Water Analysis. Turkish General Directorate of Rural Services Press.
- Usta, S. Sözüdoğru, S. And Çaycı, G. 1996. An investigation on properties of some peat materials in the Turkey and their humic and fulvic acid contents. Tr. J. of Agriculture and Forestry, 20, 27-33.
- Verdonc, O. and Gabriels, R. 1988. Substrate requirement for plant. Acta Horticultureae. 221:19-21
- Yılmaz, R. and Korkut, A.B. 1998. Effect of different growing mixtures on flowering and flowering quality of Lily (*Lilium L.*). I. Congress of National Ornament Plants, 113-118 p. 6-9 Ekim, Yalova (In Turkish).

POSSIBILITIES OF USING THE AQUATIC MACROPHYTE WATERHYACINTH (*EICHHORNIA CRASSIPES*) IN ORGANIC FERTILIZER PRODUCTION

S. A. Ahmed

Plant Protection Dept., Faculty of Agriculture, Assiut University, Assiut 71516, Egypt

Abstract

Waterhyacinth, widely spread aquatic weed in tropics and subtropics, has a unique capability for biomass production. Utilization is considered one of the most efficient measures beneficially contributing in its control. As this plant has a great potential in water pollution abatement through bioaccumulation of nutrients and heavy metals in its tissues, it is recommended in the treatment of domestic and industrial wastes, that usually include organic matter, inorganic nutrients, heavy metals and organic substances which lower water quality, contaminate soil and might be toxic to man and other organisms. It is also very powerful in reducing BOD, COD, TSS as well as nitrate and ammonium nitrogen, total and inorganic phosphorus, water alkalinity and hardness. It has been tested in many countries, i.e., USA, Japan, India, Malaysia, Sri-Lanka, Vietnam, Indonesia, China, Italy, France, Poland, Turkey, Brazil and Egypt, with focus on its role in encountering the contaminants in domestic sewage, livestock wastes, effluents of factories such as sugarcane production, palm oil mill, rubber, latex concentrate, olive oil, oxalic acid, tannery industry, petroleum refinery, paper industry, and its practical application such as sewage treatment and biogas production at Walt Disney World Resort, Orlando, Florida. The process of biogas production through anaerobic fermentation results in an organic fertilizer. This paper shed light in using the plant for this renewable and economic fuel and ready-to-use organic fertilizer and soil amendment. Possibilities and limitations of using this aquatic macrophyte for water purification and fertilizer production in countries not invaded by the plant, e.g., most European countries, are also discussed on the light of field visits carried out by the author to some European countries especially Hungary.

Introduction

The aquatic plant waterhyacinth (Order Liliales) (Fig. 1), native to the Amazon basin, threatens fresh water bodies, i.e., causes loss of substantial amounts of water through evapotranspiration, hinders the navigation, endangers fish populations through water oxygen depletion and fishing activity limitations, offering a suitable micro-environment for mosquito and disease-vectors snails.

The plant is widely spread in rivers, reservoirs, swamps, irrigation and drainage systems in tropic and subtropic countries (Fig. 2). In Europe, it only exists naturally in Portugal, due to the lethal effect of freezing on the plant. However, it can be found in other European countries, but in botanical gardens.

Many studies have been conducted, and some of them are in application, for the utilization of this plant. Among the utilization measures, using the plant material for soil amendment and

fertilization, exploitation for nutrient and heavy metal removal, producing organic fertilizer and biogas through anaerobic fermentation, have attracted a great concern.

Soil Amendment and Direct Fertilization

Studies indicated that covering the soil with plant material as mulch could contribute in weed control, soil water-loss prevention, increasing soil organic matter and crop yield, e.g., in banana (Kotoky and Bhattacharya, 1991), guava (Borthakur and Bhattacharyya, 1993), lemon (Nath and Sarma, 1992), tobacco (Tripathi *et al*, 1991b), potatoes (Rahman *et al*, 1992) and garlic (Baten *et al*, 1995).

In Indonesia, increased rates of waterhyacinth mulch suppressed weed population up to 73% and improved the soybean yield to 171% at 25 ton/ha fresh plant mulch (promising recommended rate). The yield increases were attributed to weed control and increasing pod formation and size of seeds (Lamid and Wahab, 1996).

In taro crop, in India, mulching with waterhyacinth gave cormel yields of 3.1 ton/ha compared with 5.57 ton without mulch and 2.91 ton with black polythene mulch (Mohankumar and Sadanandan, 1988).

Converting plant material into fertilizer is considered one of the best ways of utilization, e.g., mixing dried plant with soil, wood ash, manure, tree leaves and leaving them to ferment for ca. 3 months. The resulted fertilizer increased the yield of rice, okra and potatoes (Gopal and Sharma, 1981).

In Egypt, field trials indicated that application of waterhyacinth compost at 2.5 and 5 ton/ac could enhance the dry matter yield of groundnuts, maize and barely grown in sandy and calcareous soils, and increased the uptake of N, Fe, Mn and Zn (Rabie *et al*, 1995). Wheat crop yield and Mn, Cu, Cr uptake were increased with the addition of plant material at the rate of 40-80 ton/ac (Abou Zeid *et al*, 1992; Ahmed *et al*, 1992).

Water Purification

Waterhyacinth proved to have a great potential to remove and accumulate nutrients such as N, P, K; to reduce suspended solids (SS), soluble impurities, COD, BOD, turbidity, coliform bacteria and organic carbon in water (Dunigan *et al*, 1975). The plant can also accumulate heavy metals such as Hg, Se, Cd, Ni, Pb, Cu, Fe, Co, St and organic pollutants such as phenols, dyes, photography discharge pollutants and others in its tissues. This approach has been

investigated in many countries, of which USA, Japan, India, Malaysia, Sri-Lanka, Vietnam, Indonesia, China, Italy, France, Poland Turkey, Brazil and Egypt. The following represents some examples of this potential.

Early studies (Sheffield, 1967) on waterhyacinth potential for pollutant removal indicated 80 and 51% reduction in $\text{NH}_4\text{-N}$ and P, respectively, in sewage water drained in a pond covered with the plant in 10 days. Minerals are generally accumulate in the leaves of the plant more than roots and may differ in their occurrence in leaf parts, e.g., higher concentrations of K and P and low levels of Na were found in lamina than in petioles (Oke and Elmo, 1990). The plant also exhibited the highest rates of nutrient reduction in water (Triapathi *et al*, 1991a) and the concentration of $\text{NO}_3\text{-N}$, $\text{NH}_4\text{-N}$ and $\text{PO}_4\text{-P}$ in the water influenced the uptake rate of N and P of the plant (Petrucio and Edteves, 2000).

The plant could remove the following heavy metals: 0.16 kg Cd, 0.04 kg Pb, Hg, 0.15 kg Ni, Co, St/ac/day (Wolverton *et al*, 1976); could absorb 10 mg/lit of both Cu and Zn within 48 hrs that accumulated mostly in roots (Yahya, 1990); the absorption of heavy metals such as Pb has increased as the concentration in water increased (Ackin *et al*, 1994). In USA, Se has been removed by the plant at 30 ug/ gm dry weight within 2 weeks (Ornes *et al*, 1991).

The plant was tested in Italy for organic-biologic load removal from olive oil factories wastewater. Control of parameters such as COD, TSS, DO and pH gave an indication of the purifying efficiency, particularly reduction of TN and COD “ca. 60%” (Forgione *et al*, 1990).

In tannery effluent in India, the plant could remove Cr better than two other weeds; the roots accumulated higher amounts of this metal (Singram, 1994). In Indonesia, the plant proved to be potent as a natural filter for wastewater treatment (Moenandir and Murgito, 1994).

At paper industry factory, France, wastewater effluent in ponds was treated with waterhyacinth. Removal of SS was 40%, reducing BOD_5 was 35%, COD 17% /day. SS removal occurred mainly by rapid settling caused by overlapping plants. COD and BOD_5 reduction was related to both physical settling and plant absorption. Removal of N and P was 1.94 g and 0.239 g/m²/day, respectively, with a production of 659 dry weight/m²/day (Casabianca and Goma, 1991).

In Malaysia, the plant could be used efficiently and economically in the treatment of palm oil mill and rubber factory effluents (Abdulla, 1988) and could reduce pollutants in ponds of latex concentrate factories in Sri Lanka: 100% reduction on COD, >80% COD and TSS within 10 days (Krishanthi *et al*, 1996). In Vietnam, effluent from petroleum refinery wastes, a system containing waterhyacinth, *Chlorella* and reeds could purify the wastes from petroleum to 98%,

COD to 93% removal, and removed many minerals in 2 weeks (Triet *et al*, 1991). In Poland, a significant reduction in BOD₅ was observed for the plant (86.1%) (Daniszewski, 2000).

In Turkey, waterhyacinth was grown in solutions containing 10 ppm Cr, 35 ppm Cu, 14 ppm Ni. By 24 hr, the dry matter contents of these metals were up to 156, 1692, 980 ug/g, respectively. It was concluded that the plant could be used for removing heavy metals from industrial effluents under Turkish conditions (Saltabas and Akcin, 1994).

In industrial effluent from a battery factory in Brazil, the plant could correct acid pH to 7. After neutralization of effluent (4.45 mg/lit) lead concentration was removed with 99% efficiency (Santos and Lenzi, 2000).

In the US, pilot-plant studies with a treatment pod led to the development of system that could treat wastewater high in sulfate without development of odors or insect nuisances, the results have led of the design and construction of a 3,800 m³/day waterhyacinth treatment facility (Tchobanoglous *et al*, 1989).

Dense mats of the plant in one hectare could remove the N from annual sewage of 30-595 persons and P for 40-189 persons (Steward, 1970). In some areas of USA, one acre of dense mats could treat sewage of 2,000 persons (Wolverton and McDonald, 1979).

In India, trials on potentials of waterhyacinth ponds for degradation of raw domestic sewage indicated that wastewater from waterhyacinth ponds were 17% lower in BOD and TSS compared with an oxidation pond. An organic loading rate up to 220 kg BOD/ha/day was expected to give effluent BOD and TSS values of 30 mg/lit. The system appeared to have possible application for small rural communities (Kumar and Grade, 1989)

In the USA, the plant is used practically in some areas such as Walt Disney World Resort, Orlando, Florida, at which the plant is grown in channels containing secondary sewage effluent then harvested for biogas production using methane generator (Fig 4) (Wolverton, 1987). In Japan, within a year, the plant could remove 58% TN, 46% IN, 80% TP, 56% IP from a stabilization trench of domestic sewage in Okayama and was better than 10 other aquatic weeds (Oki, 1992).

Near a small Alabama town, NC, USA, waterhyacinth pilot scale treatment system was constructed to investigate the feasibility of using this type of process as a low-cost, easily implemented alternative for upgrading small community water treatment system. At system hydraulic rates of 1870 m³/ha/day of sewage, COD, BOD, TSS could be maintained under the level of 10 mg/lit, NH₄-N under 5 mg/lit (Mcanally and Benefield, 1992).

Biogas and Organic Fertilizer Production

It has been proved, with anaerobic fermentation, the possibility of converting plant material into biogas (containing ca. 75% methane and ca. 25% CO₂) that could be used in cooking, heating, lightening, electric power production, beside the production of ready-to-use organic fertilizer rich of different nutrients and could be used as a liquid or dried. According to studies of NASA, USA, one hectare of dense plant mat could produce ca. 70,000 m³ of biogas. This ability is now being applied in many countries (Figs 3, 4).

Methane results under the anaerobic conditions as a number of volatile fatty acids that result first which represent the source of gas production (Deshpande *et al*, 1979). The rate of this production increases with the addition of livestock dung or sewage (Guha *et al*, 1976).

In China, the plant was shown to be satisfactory as a raw material for the production of biogas using fermentation method (Huang and Fang, 2000).

Possibilities of Organic Fertilizer Production Outside Natural Habitats

In most European countries, in which waterhyacinth is not naturally existing, it seems a possibility to use the plant for sewage and factories discharge treatments in warm and hot seasons (spring-autumn) and could be possibly maintained in winter in warm water as that of hot springs, to enable the plant to stand the winter low-temperature. If there are no hazardous pollutants in the treated water, such as toxic heavy metals, the plant can be possibly used for biogas and fertilizer production through fermentation process. Personal contacts of the author with some Hungarian scientists in Kesthely years ago confirmed this possible approach to benefit from the advantages of this aquatic weed in pollution abatement and producing materials of high value, i.e., fuel and fertilizer, and the excess of biomass can be used in direct fertilization.

References

- Abdullah, M.Y. 1988. Status of waterhyacinth infestation and management in Malaysia. In: Drylands, wetlands, croplands: turning liabilities into assets. Nairobi, Kenya. United Nations Environment Program, INFOTERRA Program Activity Center (1988) 53-61.
- Abu-Zeid, M.I., M.A. El-Desoky and S.A. Ahmed. 1992. Contents of some heavy metals in wheat plants grown in soils treated by waterhyacinth. Proc. National Symposium on Waterhyacinth. Assiut University (25-26 Feb.): 25-40.
- Ahmed, S.A., M.A. El-Desouky and M.A. Gameh. 1992. Utilization of waterhyacinth as a soil amendment: growth and contents of N, P, K of wheat. Proc. National Symposium on Waterhyacinth, Assiut University (25-26 Feb.): 11-24.
- Akcin, G., O. Saltabas and H. Afsar. 1994. Removal of lead by waterhyacinth (*Eichhornia crassipes*). Journal of Environmental Science and Health. Part A, Environmental Science and Engineering 29 (10): 2177-2183.

- Baten, M.A., B.S. Nahar, S.C. Sarker, M.A.H. Khan. 1995. Effect of different mulches on the growth and yield of late planted garlic (*Allium sativum* L.). Pakistan Journal of Scientific and Industrial Research 38 (3/4) 138-141.
- Borthakur, P.K. and R.K. Bhattacharyya. 1993. Effect of mulches on controlling weeds in guava orchards. Proc. Indian Society of Weed Science International Symposium, Hisa, India, 18-20 Nov. 1993.
- Casabianca, C.M. and G. Goma. 1991. Treatment of paper industry effluents with *Eichhornia crassipes*: first results (Tartas factory, Landes, France). Comptes Rendus de l'Academie des Sciences Series 3, 312 (11): 579-585.
- Daniszewski, P. 2000. Effectiveness of decreasing BOD₅ quality by *Pistia stratiotes*, *Eichhornia crassipes* and *Stratiotes aloides* roots from water-vegetation from imperf wastes. Folia Universitatis Agriculturae Stetinensis, Agricultura No.84: 87-90.
- Deshpande, P., S. Sarnaik, S.H. Godbole and P.M. Wagle. 1979. Use of waterhyacinth as an additive in biogas production. Curr. Sci. 48: 490-492.
- Dunigan, E.P., R.A. Phelan and Z.H. Shamsddin. 1975. Use of waterhyacinth to remove nitrogen and phosphorus from eutrophic water. Hyacinth Control J. 13: 59-61.
- Forgione, P., L. Ferrara and O. Schettino. 1990. Comparison of the efficacy of some hydrophytes used for the depuration of olive oil factories water. Industrie Alimentari 29: 362-364.
- Gopal, B. and K.P. Sharma. 1981. Waterhyacinth : most troublesome weed of the world. Hindsai, Newdelhi, 128pp.
- Guha, B.R., T.K. Bandopadhyaya and R.K. Choudhury. 1976. Fuel gas and compost manure from waterhyacinth. Khadi Gramodyog 22 (11): 483.
- Huang H. and R. Fang. 2000. Study on anaerobic treatment of effluent obtained from SCR processing and water hyacinth. J. Rubber Research 3 (3): 157-163.
- Kotoky, U. and R.K. Bhattacharya. 1991. Bunch weight and yield of banana as influenced by organic mulches. Indian Journal of Horticulture 48 (2): 121-123.
- Krishanthi, A., P.A.J. Yapa and A. Kanthi. 1996. Laboratory studies on the use of *Eichhornia crassipes* in treatment systems for skim latex serum. Journal of the National Science Council of Sri Lanka 24: (2) 51-62.
- Kumar, P. and R.J. Garde. 1989. Potentials of waterhyacinth for sewage treatment. Research Journal of the Water Pollution Control Federation 61 (11/12): 1702-1706.
- Lamid, Z. and R. Wahab. 1996. Utilization of waterhyacinth as fresh mulch for controlling soybean weeds grown on dryland soil. Biotrop Special Publication No. 58: 21-28.
- Mcanally, A.S. and L.D. Benefield. 1992. Use of constructed waterhyacinth treatment systems to upgrade small flow municipal wastewater treatment facilities. Journal of Environmental Science and Health. Part 1, Environmental Science and Engineering A27 (3): 903-927.
- Moenandir, J., Murgito. 1994. Heavy metal absorption by aquatic weeds. Agrivita 17 (2): 61-64.
- Mohankumar, C.R. and N. Sadanandan. 1988. Effect of sources of planting material and mulching on the growth and yield of taro (*Colocasia esculenta* L.). J. Root Crops 14 (2): 55-57.
- Nath, J.C. and R. Sarma. 1992. Effect of organic mulches on growth and yield of Assam lemon (*Citrus limon* Burm). Horticultural Research Journal 5 (1): 19-23.
- Oke, O.A. and B.O. Elmo. 1990. Elemental analysis of waterhyacinth (*Eichhornia crassipes*) growing in the Badagry lagoon of Lagos state, Nigeria. Nigerian Journal of Weed Science 3: 67-70.
- Oki, Y. 1992. Effects of aquatic weeds on nutrient removal from domestic sewage. Proc. 1st International Weed Control Congress. Melbourne, Australia. Weed Science Society of Victoria, Vol. 2, 365-371.
- Ornes, W.H., K.S. Sajwan, M.G. Dosskey and D.C. Adriano. 1991. Bio- accumulation of selenium by floating aquatic plants. Water, Air and Soil Pollution 57-58: 53-57.
- Petrucio, M.M. and F.A. Edteves. 2000. Uptake rates of nitrogen and phosphorus in the water by *Eichhornia crassipes* and *Salvinia auriculata*. Revista Brasileira de Biologia 60 (2): 229-236.
- Rabie, M.H., A.M. El-saadani, M.F. Abdel-Sabour and I.A. Mousa. 1995. The use of water hyacinth (*Eichhornia crassipes*) as an organic manure to amend soils. Egyptian Journal of Soil Science 35 (1): 105-116.
- Rahman, M.M., M.A. Rahman and M.R. Islam. 1992. Agro-economic productivity of panikachu and potato intercropping in shallow ditches. Annals of Bangladesh Agriculture 2 (1): 53-58.
- Saltabas, O. and C. Akcin. 1994. Removal of chromium, copper and nickel by waterhyacinth (*Eichhornia crassipes*). Toxicol. Environ. Chem. 41 (3-4): 131-134.
- Santos, M. and E. Lenzi. 2000. The use of aquatic macrophyte *Eichhornia crassipes* as a biological filter in the treatment of lead contaminated effluents. Environmental Technology 21 (6): 615-622.
- Sheffield, C.W. 1967. Waterhyacinth for nutrient removal. Hyacinth Control J. 6: 27-30.
- Singaram, P. 1994. Removal of chromium from tannery effluent by using waterweeds. Indian Journal of Environmental Health 36 (3): 197-199.
- Steward, K.K. 1970. Nutrient removal potentials of various aquatic plants. Hyacinth Control J. 8 (2): 34-35.
- Tchobanoglous, G., F. Maitiski, K. Thompson and T.H. Chadwick. 1989. Evolution and performance of city of San Diego pilot-scale aquatic wastewater treatment system using waterhyacinth. Research Journal of the Water Pollution Control Federation 61 (11/12): 1625-1635.
- Triet, L.M., N.T. Viet, T.V. Thinh, H.D. Cuong, and J.C. Buren. 1991. Application of three-step biological pond with the use of aquatic plant for post treatment of petroleum wastewater in Vietnam. Water Science and Technology 23 (7-9): 1503-1507.
- Tripathi, B.D., J. Srivastava and K. Misra. 1991. Nitrogen and phosphorus removal capacity of four chosen aquatic macrophytes in tropical freshwater ponds. Environmental Conservation 18 (2): 143-147.

- Tripathi, S.N., B.L. Singh and P.G. Ghosh. 1991. Influence of mulching, topping and intercropping on Motihari tobacco (*N. rustica* L.). *Indian J. Agronomy* 36 (2): 194-196.
- Wolverton, B.C. 1987. Aquatic plants for wastewater treatment: an overview. In: *Aquatic plants for water treatment and resource recovery* (ed. Reddy & W.H. Smith), P. 3-15, Magnolia Publ. Orlando, Florida.
- Wolverton, B.C. and R.C. McDonald. 1979. Upgrading facultative wastewater lagoons with vascular aquatic plants. *J. Water Poll. Cont. Fed.* 51: 305-313.
- Wolverton, B.C., R.M. Barlow and R.C. McDonald. 1976. Application of vascular aquatic plants for pollution removal, energy and food production in a biological system. P. 141-149, in: J. Tourbier and R.W. Pierson, Jr (ed.). *Biological Control of Water Pollution*. Univ. Pennsylv. Press.
- Yahya, M.N. 1990. The absorption of metal ions by *Eichhornia crassipes*. *Chemical Speciation and Bioavailability* 2 (2): 82-91.



Figure 1: Waterhyacinth's flower (left); a small plant showing leaf blade, floats and roots



Figure 2: Infestation of waterhyacinth at Lake Biwa, Japan (left); at Assiut, Egypt (right)



Figure 3: Waterhyacinth mats accumulation; biogas and fertilizer production unit, Egypt

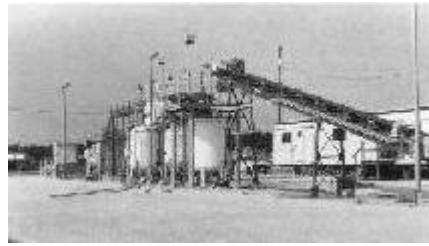
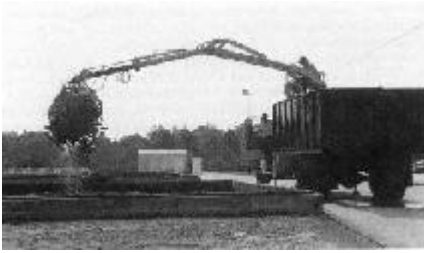


Figure 4: Waterhyacinth in channels containing secondary sewage effluent : harvested for biogas production (left); methane generator utilizing waterhyacinth (right), at Walt Disney World Resort, Orlando, Florida, USA.

USE OF ORGANIC-BIOLOGICAL WASTES TO INCREASE SOIL ORGANIC CARBON STOCKS

S. Sleutel, M. R. Prat Roibas, S. De Neve, B. Chaves Daguiar and G. Hofman

Department of Soil Management and Soil Care, Coupure Links 653, 9000 Gent, Belgium

Introduction

Adding organic matter to mineral soils can improve their physical properties (infiltration, water holding capacity, structure, etc.) and chemical properties (cation exchange capacity, fertility, etc.). Stringent nutrient legislation, the replacement of farmyard manure by slurry and the increasing harvesting indices of common grown crops are considerably affecting the soil organic carbon balance of Western-European cropland soils. Also in the light of climatic change there is a growing interest in the potential of agricultural soils to act as a carbon sink. In this context, we conducted a research concerning the potential value of several agricultural industry wastes for increasing the soil organic carbon (SOC) content. Through agricultural utilization of organic wastes, producers can benefit (and possibly derive marketing potential) from these waste materials that otherwise may be placed into landfills or incinerated and as such present environmental pollution problems.

Methodology

A range of 14 organic wastes originating from different industries (food industry, wood and paper processing,...) were mixed with a sandy loam soil ($\pm 2 \text{ mg C g}^{-1} \text{ soil}$). All products were characterized chemically using a modified Stevenson fractionation method and by determining their total C, N and P content. Table 1 gives the C, N and P content of the added materials along with their dry matter content and their C/N ratio.

The experiment consisted of laboratory incubations in large glass jars, which contained small soil columns. The CO_2 respired by the soil micro-organisms was captured in 15ml 1M NaOH, in small glass vials which were placed together with the soil columns in the measuring jars. For 12 weeks, periodic titrations of the NaOH with 1M HCl to pH 8.3 in the presence of BaCl_2 were carried out to measure the evolution of the C-mineralization of the different organic wastes. A constant temperature ($15 \pm 1^\circ \text{C}$) and soil moisture content (15 g g^{-1}) were maintained throughout the experiment. At the end of the incubation, all jars were sampled to determine total C and N (with a CN analyser) and soil microbial C contents (according to the fumigation-extraction method). The soil used was a field surface (0-20cm) sandy loam cropland soil (0.76 % OC), which was not dried to air dry in order to minimize disturbance of the activity of micro

organisms. The samples were incubated in triplicate including three control soils without any addition of wastes, to determine CO₂ evolved from untreated soil. A blank treatment was established in order to account for the CO₂ present in the air.

Table 2: Chemical charecteristics of the organic wastes

Product	abbreviation	% Dry Matter	Total C (% of DM)	Total N (% of DM)	Total P (% of DM)	C/N ratio
Wood Chips	WCH	87.22	47.18	0.072	0.02	655.3
Sawdust Compressed	SCO	86.77	48.28	0.067	0.02	720.6
Sawmeal	SAW	88.07	47.73	0.070	0.02	681.9
Tobacco	TOB	91.02	40.00	2.780	0.26	14.4
Cacao	CAC	89.11	43.68	2.640	0.35	16.6
Vinasse	VIN	30.66	27.95	4.069	-	6.9
Dairy Industry Sludge	DAI	9.08	45.30	5.35	0.24	8.47
Dry Sludge of Feather Meal	SFM	97.33	54.67	6.841	1.10	8.0
Feather Meal	FEM	98.71	51.69	13.045	1.20	4.0
Gelatin	GEL	44.52	21.29	1.937	1.11	11.0
Paper Industry Sludge	PAP	29.3	30.62	0.590	0.32	51.9
Malt	MAL	10.11	25.01	3.026	1.20	8.3
Hair Meal	HAI	94.82	49.66	14.890	0.18	3.3
Straw	STR	91.4	42.44	0.661	0.04	64.2

Results and Discussion

The organic products were very different with respect to their patterns of C mineralisation (Figures 1, 2 and 3). In most cases, and according to the results of some authors (Trinsoutrot *et al.*, 1994; De Neve, *et al.*, 1996), the C mineralisation occurred in two distinct phases which are a first rapid phase (corresponding to the decomposition of the most labile products by the microorganisms) and a second, slower phase, during which more recalcitrant organic products started to mineralize.

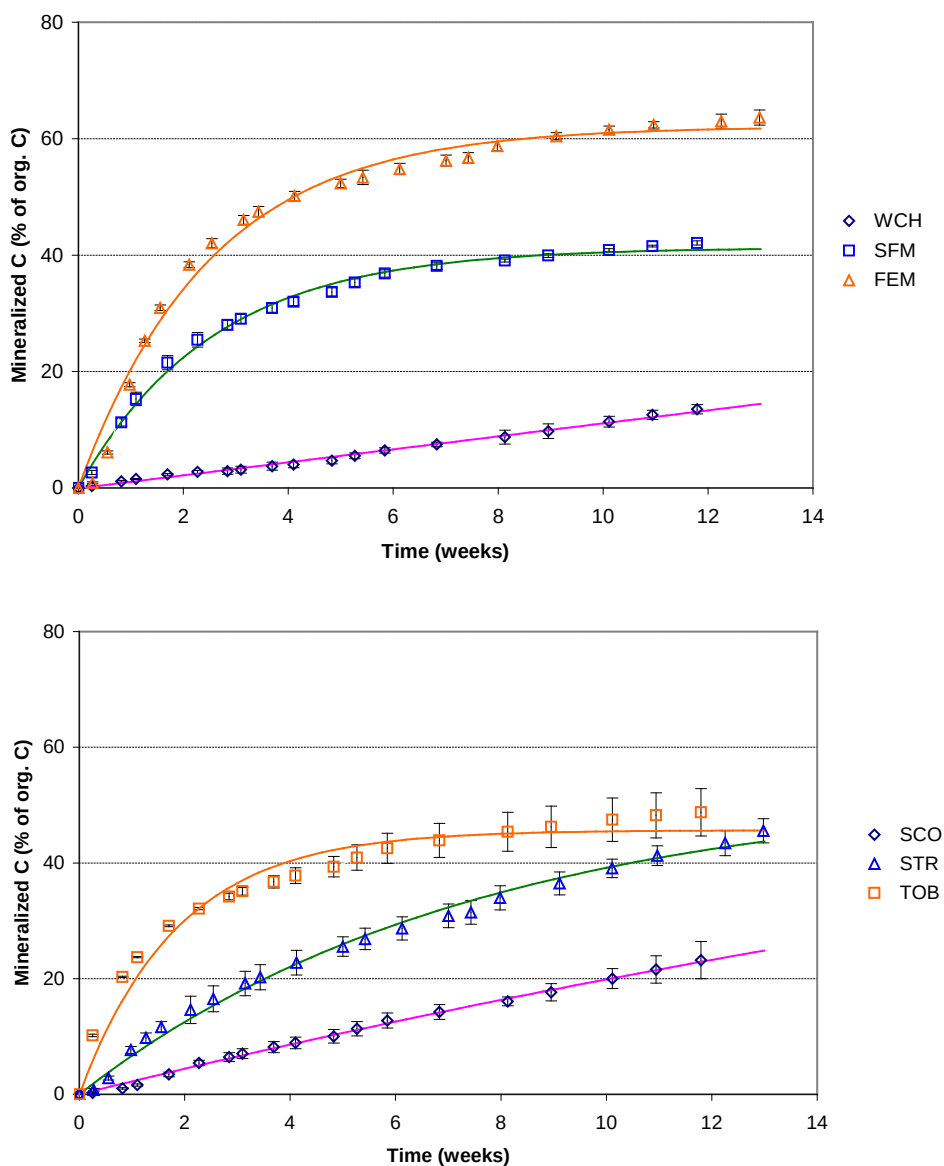


Figure 1: C mineralized during aerobic incubation of Wood Chips (WCH), Sludge of Feather Meal (SFM), Feather Meal (FEM), Sawdust Compressed (SCO), Straw (STR), and Tobacco (TOB), with the first order or the linear model (solid line) fitted to the data. Bars represent $\pm$ standard deviation

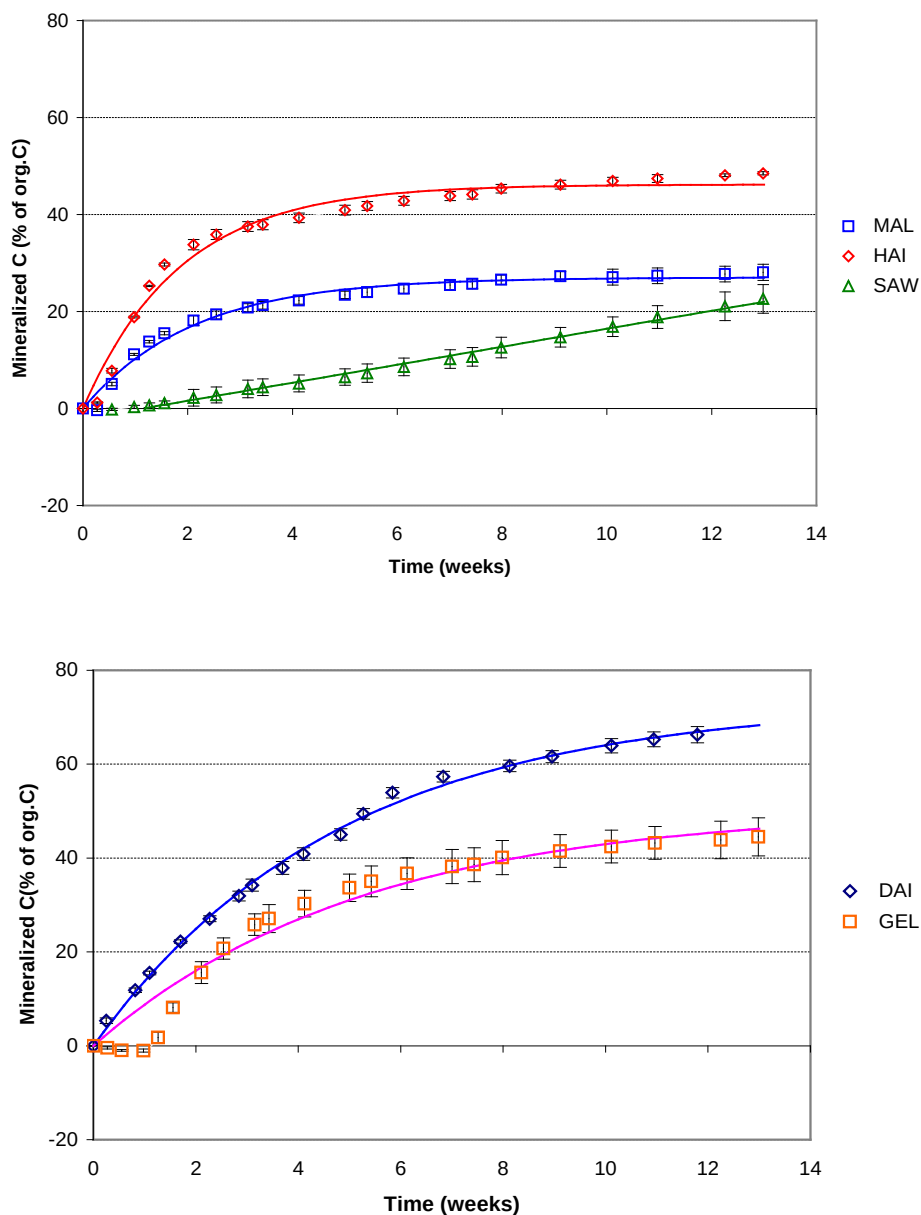


Figure 2: C mineralized during aerobic incubation of Brewery (MAL), Hair Meal (HAI), Sawmeal (SAW), Dairy Sludge (DAI) and Gelatin (GEL), with the first order and a linear model (solid line) fitted to the data. Bars represent $\pm$ standard deviation

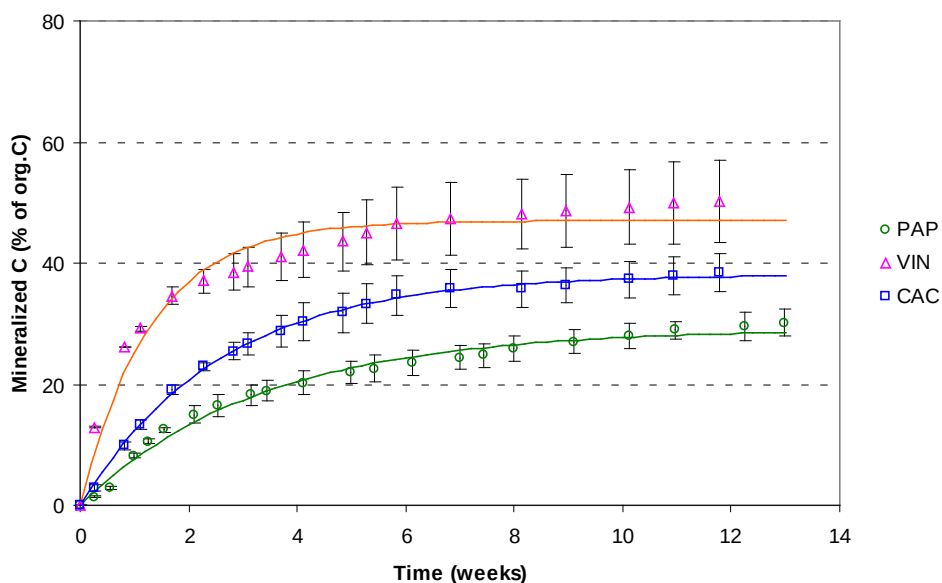


Figure 3: C mineralized during aerobic incubation of Paper Sludge (PAP), Vinasse (VIN) and Cacao (CAC), with the first order model (solid line) fitted to the data. Bars represent $\pm$ standard deviation.

The woody materials namely WCH, SAW, and SCO showed a linear behavior together with the lowest percentages of C mineralized at the end of the incubation period. The other products were in general less stable. DAI and FEM mineralized very fast, 65 and 62 % of the total added C mineralized by the end of incubation respectively. HAI, SFM, TOB, and VIN had similar percentages of C being mineralized at the end of the incubation, all between a range of 40-50 %, and similar curve shapes, with a clear stabilization around the 8th week. With respect to VIN, the fact that it has a high mineralisation rate suggests the presence of a readily pool of mineralizable C, which can be due to the high sugar content present in this product. TOB had the highest C mineralisation rate and the highest amount of the added C mineralized at the end of the incubation of these four products. GEL had an irregular behavior during the first week of incubation, with negative net C mineralisation values during this period. A possible explanation for this lag period is the extremely high pH measured, namely 12.5, by which the microbial activity was depressed. At the start of the incubations, MAL and PAP showed very similar patterns of mineralisation with nearly 30 % mineralized at the end of the incubation; amongst these two products, the higher mineralisation rate corresponded to MAL. The STR mineralisation curve did not have the characteristic asymptotic shape, indicating that important

additional C mineralisation could be expected if the incubation was to be continued for a longer period.

A first **order exponential model** was fitted to the net C mineralisation data:

$$C_{\min}(t) = OC_A (1 - e^{-kt})$$

where $C_{\min}(t)$ is the organic C mineralized in the soil-waste mixture at specific time t , k is the first-order mineralisation rate, and OC_A is the amount of mineralizable C expressed as percentage of total added organic C. The values of OC_A are given in Table 2. Based on the model kinetics the hypothetical amount of stable organic C in the wastes was calculated as the amount of C that would not be mineralised within one year under field conditions (Hénin & Dupuis, 1945). The calculation of the approximate length of an incubation carried out at 16 °C that would be equivalent to one year under field conditions was based on the long-term yearly average temperature in Ukkel (Belgium), which is 9.7°C. An S-shaped function was used to calculate the incubation period equivalent to one year under field conditions (De Neve *et al.*, 1996):

$$k(T) = k_{\text{opt}} e^{-\kappa (1 - T / T_{\text{opt}})}$$

$k(T)$ is the rate constant as a function of temperature, k_{opt} the maximum rate constant, T_{opt} the optimum temperature (in °C), and κ a rate parameter reflecting the temperature sensitivity of k . The optimum temperature was set at 37 °C (according to De Neve *et al.*, (1996), C mineralisation is maximal between 25 and 45 °C). κ was set as 2.55, as calculated by De Neve *et al.*, (1996).

By introducing $k(16\text{ °C})$ in the equation, k_{opt} could be calculated. Substitution of k_{opt} in the equation then yielded the C mineralisation rate at 9.7 °C (average yearly temperature). From this, the time needed to reach a C mineralisation (at 16 °C) equivalent to the C mineralisation after 52 weeks at 9.7 °C (one year under field conditions) could be derived and was equal to 30 weeks. The amount of organic C, OC_{30} , that would mineralize over a 30 weeks incubation period (equivalent to one year under field conditions) according to the first order model was then calculated. The difference **100 - OC_{30}** can be considered as a measure for the **amount of stable organic C** in the organic wastes Table 2.

Table 2: C mineralized at the end of incubation (OC₁₃), C mineralisation parameters of the first order model $OC(t) = OC_A (1 - e^{-kt})$ and amounts of stable organic C (100-OC₃₀) in the wastes. Bracketed values are standard errors of the parameter estimates

Product	OC13 (% of added Corg)	OCA (% of added Corg)	k (week ⁻¹)	100 – OC30 (% of added Corg)
PAP	30.099	29.104 (0.56)	0.303 (0.016)	70.900
FEM	63.632	62.084 (1.06)	0.399 (0.022)	37.917
GEL	44.494	50.437 (3.75)	0.191 (0.031)	49.743
MAL	28.074	27.016 (0.45)	0.478 (0.029)	72.984
SAW*	22.009	~	1.855	49.239
STR	45.549	52.854 (1.94)	0.135 (0.009)	48.131
HAI	48.494	46.191 (0.78)	0.540 (0.035)	53.809
WCH*	14.449	~	1.117	67.120
VIN	50.226	47.006 (0.91)	0.768 (0.068)	52.994
SFM	42.085	41.284 (0.43)	0.391 (0.013)	58.716
SCO	23.189	83.981 (16.38)	0.027 (0.006)	53.886
CAC	38.451	38.121 (0.24)	0.390 (0.008)	61.879
TOB	48.745	45.655 (1.01)	0.768 (0.044)	54.345
DAI	66.277	73.190 (1.10)	0.208 (0.007)	26.968

*: Zero order kinetics ($OC(t) = k \cdot t$) were used for describing the behavior of these products, as the first order model could not be fitted. k is expressed as %C · week⁻¹

According to these results, the products with more **C sequestration potential** would be those with the highest 100 - OC₃₀ value, because they would leave the greatest amount of C in the soil. MAL had the highest value, followed by PAP and the woody products.

Correlation analysis was performed between the model parameters, the chemical composition of the wastes and of the soil at the end of the incubation. The calculated amount of stable organic carbon could best be explained by the total N-content of the wastes and their C/N ratio (high correlation between C/N-ratio and 100-OC₁₃, whereas the results of the fractionation had little predictive power. There was however a significant correlation between 100-OC₁₃ and the % of water soluble compounds (P= 0.01) and also with the % cellulose in the products. The organic carbon left in the soil at the end of the incubation alone did not allow us to estimate the

stable organic carbon in the wastes. Also, no linear correlation could be found between the chemical composition of the products and the microbial biomass.

Environmental restrictions related to the N and P content of the products were also investigated by measuring these parameters and by determining the NO_3^- -N and the NH_4^+ -N content of the soil at the end of the incubation. These application rates and soil residual contents were then compared to the current Flemish nutrient legislation (for discussion see conclusions).

Conclusions

Based on this research, paper sludge, malt and wood chips appeared to be the most suitable for increasing the soils OC content (approximately 70% of their OC is stable). Regarding N addition, the most convenient products would be those with the lowest N and P content, mainly all the woody materials, as well as STR and PAP. Products which are already being used as commercial fertilizers by farmers (hair meal, tobacco, vinasse and feather meal sludge) can also contribute to an enhancement of the soil OC content as between 50 and 60% of their OC was stable (40% for Feather Meal). When taking into account the nutrient supply by these materials, the use of dairy processing sludge, malt, hair meal, feather meal and gelatine production sludge is restricted because at normal application rates they imported excessive amounts of N or P to the soil.

References

- De Neve, S., Pannier, J., and Hofman, G., 1996. Plant & Soil 181:25-30
Hénin S & Dupuis M., 1945. Ann. Agron. 15: 17-29.
Trinsoutrot I., Bentz B., Chèneby D., Linères M., Nicolardot B., and Recous S., 2000. Soil Sci. Soc. Am. J. 64:918-926.

Section 7

Foliar fertilization

ROLE OF THE FOLIAR FERTILIZERS IN SUSTAINABLE AGRICULTURE

A. Dorneanu¹, Z. Borlan¹, E. Dorneanu¹, Tr. Cioroianu² and T. Prodan³

¹Research Institute for Soil Science and Agrochemistry, Bucharest, Romania

²CHIMENERG, Craiova

³Research-Development Station for Crops on Sandy Soils, Dăbuleni, Dolj

Abstract

The foliar fertilizers are foliar complex solutions containing macro- and microelements essential for plant nutrition with specific properties, which permit the assimilation by leaves.

The experiment achievements concerning the foliar fertilizers (FOLPLANT, BIODOR, ECOFERT) presented in this paper reveal the important yield increases obtained with these fertilizers, ranging from 21.0 to 30.4 % with wheat and from 20.2 to 25.5 % with maize grown on irrigated sandy soil

A series of data emphasizes the important effects of foliar fertilizers in improving the yield quality, especially the increase of protein substances.

The obtained results lead to the conclusion that the foliar fertilizers are indicated for supplementary fertilization. Their role in the sustainable agriculture is to partially reduce the fertilization rate of the classical fertilizers without diminishing the yield as well as technologically interfering during the plant growing season. The reason is to supplement the nutrition elements, which are at a low level, and to mitigate the stress effects due to the unsuitable vegetation factors.

Keywords: foliar fertilizers, supplementary fertilization, ecological protection

Introduction

The supplementary foliar fertilization during the plant growing season with complex solutions of nutrients is a main measure of the sustainable agriculture to ameliorate the plant nutrition under ecological protection conditions.

The recent investigations carried out the different climatic conditions clearly prove that without fertilizers it is not possible to obtain a high and constant vegetal yield. Having in view that the classical fertilizers have also some negative polluting effect on the crop environment, in many countries there are serious concerns to promote some systems to improve fertilization by applying some new fertilizer types and to modernize the application methods. Within these categories the foliar complex fertilizers are also included.

The foliar complex solutions with macro- and microelements essential for plant nutrition (N, P, K, Ca, Mg, Fe, Mn, Cu, Zn, S, B, Mo, Co). Also, they contain organic substances which chelate a series of elements and diminish the surface tension with positive influence on adhesion and

absorption in leaves. Some of fertilizers contain amino-acids enzymes, different vegetal hormones, which stimulate the metabolism and plant growth (Dorneanu et al.1999).

The penetration of elements and organic substances in leaves takes place as ions and molecules, by diffusion, through the pores of cuticle in the interstices between the epidermis cells and subjacent strata, which the free space of leaves (Borlan et al., 1995).

The research results presented in this report have in view to emphasize the qualities of set of foliar fertilizers as means to fertilize under the ecological protection conditions in sustainable agriculture.

Material and Method

A set six of foliar fertilizers with different compositions and properties was studied. The test was carried out by their application on winter wheat and maize cultivated on sandy soil (Psammosols) characterized by the following agrochemical indexes by the following agrochemical indices: sand (87 %), silt (7.4 %), clay (7.4 %), humus (0.065 %), total nitrogen (0.016 %) and phosphorus (0.028 %), Ca (45 ppm), Cu (5 ppm), Zn (21.5 ppm), Fe (3750 ppm) and Mn (162 ppm)..

The application of fertilizers was carried out by their administration in the early vegetation phases by spraying the plants with 500 litre/ha solutions with a concentration ranging from 0.3 to 1.0 per cent.

The efficiency of each fertilizer was assessed according to the quantitative and qualitative yield increase.

Results and Discussion

The ions adsorbed in leaf cells are immediately metabolised in physiologically active organic compounds that in the processes developed in the palisadic tissues of leaves as well as by their integration in the circuit of the liber vessels in the whole plant, stimulate the synthesis of the amino-acids and chlorophyllic pigments, and intensify the different metabolic processes with important consequences on plant growth and development, yield quality improvement, respectively (Chamel, 1990, Franke, 1967).

While the plant may assimilate by leaves low quantities of 3-5 %, rarely 7-8 %, of the total quantity of elements assimilated in a vegetal cycle, the efficiency of these fertilizers is very high (Dorneanu et al., 1976).

Table 1 presents the compositions of the tested foliar fertilizers, considered as the most efficient fertilizers produced in Romania. Their composition includes macro- and microelements essential for plant nutrition. They are differentiated by the rapport of the NPK elements. The FOLPLANT are classical foliar fertilizers, but with an improved composition, and the BIODOR and ECOFERT types have been recently created, their composition including amino-acids, and different organic compounds, vegetal hormones which stimulate the plant growth. By their rich content of nutrients they have an universal character, being used to fertilize all the agricultural crops.

The field experiment results obtained with the presented above fertilizers applied to winter wheat (Table 2) and maize (Table 3) emphasize their efficiency in obtaining important yield increases due to their positive influence on the plant nutrition. In the case of winter wheat, the yield increases were between 670 and 972 kg/ha (21.0-30.4 %) and in the case of maize between 832 and 1055 kg/ha (20.2-25.5 %).

All the foliar fertilizers determine with the both crops significant increases of nitrogen and protein substances in the grains (kernels, respectively) as compared to the control – without foliar fertilization. These increases are partially explained due to the stimulation of the amino-acids synthesis.

The data also emphasize the fact that both the yield increases and the protein content in grains differ according to the composition of the foliar fertilizers, being significantly higher with the foliar fertilizers containing organic components (amino-acids) and other organic compounds with stimulating effects on the metabolic process and plant growth.

Comparing the consumption of nutrients with the yield increases and the input of nutrients by applied foliar fertilizers reveals very high output (input) ratios on account of the yield output (Table 4). These ratios reveal the complex influence of the foliar fertilizers both on the plant nutrition by their elements and as the stimulators of the radicular assimilation with positive consequences with regard to the assimilation degree of elements in soil and the ecological protection in the applied fertilization systems.

Conclusions

The field experiments with foliar fertilizers applied to winter wheat and maize ensured higher yield increases with 20.2-30.4 %, and also higher significant contents of protein substances in the grains (kernels, respectively). The obtained data confirm the theories regarding the metabolization of the absorbed ions in physiologically active compounds that stimulate the

synthesis of amino-acids, chlorophyllic pigments and other processes with positive consequences on plant growth and development, improvement of yield quality, respectively.

- Comparison between the quantity of elements removed by yield and the input of elements supplied by the applied foliar fertilizers reveals a substantial increase of the plant root capacity to assimilate the elements in soil reserve by complex effects produced in the metabolic process by the ions and molecules assimilated by leaves;

- Because the foliar fertilizers applied in low quantities (5-10 litres/ha) and directly on the plants, and, by their action, they determine also the stimulation of the plant growth capacity and the assimilation of some higher quantities of elements in soil reserve, it may be considered that the foliar fertilization represents an important means to increase the vegetal production under the conditions of an ecological production;

- Economic efficiency of foliar fertilizers is fully ensured having in view the low quantities used for fertilization and the costs between 1.5 and 2.2 EURO/litre.

- Foliar fertilizers are intended to supplementary fertilization, their role in the sustainable agriculture is aiming at the partial decrease of the fertilization level with classical fertilizers without yield decrease as well as the facility of technological intervention during the growing season in order to supplement the deficient nutrients in soil and to mitigate the stress effects caused by the unsuitable factors of plant growth.

References

- Borlan Z. și col. 1995 - Îngrășăminte simple și complexe foliare. Ed. Ceres.
- Chamel A., 1990 - Quelques aspects de l'absorption des oligoéléments par voie foliare. C.R. de L'Acad., D'Agric. France, 76, 2, 31-41
- Cioroianu Tr., Dorneanu A., Farfara S., Guță Elena, Dorneanu Emilia, 1999 - Sortimentul de îngrășăminte foliare FOLPLANT, mijloc modern de fertilizare a culturilor agricole. A 25-a Sesiune Națională de Chimie, Rm. Vâlcea.
- Dorneanu A., Dorneanu Emilia, 1976 - Îngrășăminte foliare în: Dirijarea fertilității solului. Ed. Ceres, 417-421.
- Dorneanu A., Cioroianu Tr., Farfara S., Dorneanu Emilia și col., 2000- Utilizarea îngrășămintelor complexe foliare, mijloc modern de fertilizare în condiții de protecție ecologică. A 26-a Simpozion Național de Chimie, Rm. Vâlcea.
- Franke W, 1967 – Mechanism of foliar penetration of solutions. Ann. Rev. Plant. Physiol. 18, 281-300.

Table 1: Composition of assortment of foliar fertilizers produced by SC CHIMENERG SA Craiova

No	Item	UM	Types of foliar fertilizers					
			FOLPLANT		BIODOR		ECOFERT	
			411	231	2311	2312	1	2
1	Nitrogen (N)	g/l	180	80	70	60	75	35
2	Phosphorus (P ₂ O ₅)	g/l	35	130	110	95	2	20
3	Potassium (K ₂ O)	g/l	40	40	35	30	60	45
4	Magnesium (Mg)	g/l	-	-	0.1	0,09	0.09	0.02
5	Iron (Fe)	g/l	0.2	0.2	0.17	0.15	1.20	0.5
6	Manganese (Mn)	g/l	0.2	0.2	1.8	3.55	1.50	0.5
7	Zinc (Zn)	g/l	0.04	0.04	0.5	0.95	0.9	0.45
8	Copper (Cu)	g/l	0.04	0.04	0.5	0.95	0.7	0.30
9	Cobalt (Co)	g/l	0.008	0.008	0.007	0.006	0.1	0.04
10	Boron (B)	g/l	0.1	0.1	0.08	0.075	0.1	0.40
11	Molybdenum (Mo)	g/l	0.008	0.008	0.007	0.006	0.1	0.04
12	Sulfur (S)	g/l	0.1	0.1	0.08	0.075	-	-
13	Calcium (Ca)	g/l	-	-	-	-	0.15	0.05
14	Amino acids and different organic compounds with effects of plant growing stimulation	%	-	-	8.0	16	140	75
15	pH	-	6.5-7.0	6.5-7.0	6.0-6.5	6.0-6.5	5.5-6.5	6.0-7.0
16	Density	g/cm ³	1.18	1.18	1.75	1.15	1.20	1.10

Table 2: Efficiency of different types of foliar fertilizers applied with winter wheat F-4 cultivated on sandy soil (Psammosol) at the Research Development Station for Plant Growing on Sandy Soils, Dābuleni-Dolj under classical soil fertilization and irrigation conditions

- Soil fertilization: N-80, P₂O₅-80, K₂O-80 kg/ha (K-16-16-16)
- Foliar fertilization: 2 treatments by plant sprinkling (500 litres fertilizer solution/ha to each treatment with concentration indicated in table)

No	Fertilizer type	Solution Conc. %	Total applied foliar fertilizer litre/ ha	Average yield (4 years) kg/ha	Yield increase			Content in grain	
					kg/ha	%	kg grain/litre of foliar fertilizer	N	Protein substances
								%	%
1	Control (under classical soil fertilization and irrigation condition)	-	-	3190	-	100.0	-	2.31	14.43
2	FOLPLANT 411	1.0	10.0	3900	710	122.2	71.0	2.41	15.06
3	FOLPLANT 231	1.0	10.0	3860	670	121.0	67.0	2.38	14.87
4	BIODOR 2311	0.5	5.0	4046	856	126.8	171.2	2.41	15.06
5	BIODOR 2312	0.5	5.0	4162	972	130.4	194.4	2.43	15.18
6	ECOFERT 1	0.5	5.0	4090	900	128.2	180.0	2.46	15.37
7	ECOFERT 2	0.5	5.0	4070	880	127.5	176.0	2.53	15.81
LSD 5 %					298			0.06	
1 %					415			0.84	
0.1 %					570			1.16	

Table 3: Efficiency of different types of foliar fertilizers applied with maize HF-420 cultivated on sandy soil (Psammosol) at Research Development Station for Plant Growing on Sandy Soils, Däbuleni-Dolj under classical soil fertilization and irrigation conditions

- Soil fertilization: N-100, P₂O₅-100, K₂O-100 kg/ha
- Foliar fertilization: 2 treatments by plant sprinkling (500 litres fertilizer solution/ha to each treatment with concentration indicated in table)

No	Fertilizer type	Solution Conc. %	Total applied foliar fertilizer litre/ ha	Average yield (3 years) kg/ha	Yield increase			Content in grain	
					kg/ha	%	kg grain/litre of foliar fertilizer	N %	Protein substances %
1	Control (under classical soil fertilization and irrigation condition)	-	-	4130	-	100.0	-	1.52	9.50
2	FOLPLANT 411	1.0	10.0	4977	847	120.5	84.7	1.69	10.56
3	FOLPLANT 231	1.0	10.0	4962	832	120.2	83.2	1.60	10.00
4	BIODOR 2311	0.5	5.0	5083	953	123.5	190.6	1.72	10.75
5	BIODOR 2312	0.5	5.0	5185	1055	125.5	211.0	1.77	11.06
6	ECOFERT 1	0.5	5.0	5020	890	121.5	178.0	1.74	10.87
7	ECOFERT 2	0.5	5.0	5123	1023	124.8	204.6	1.78	11.12

LSD 5 %

1 %

0.1 %

545

760

1055

0.11

0.15

0.21

Table 4: Ratios between the removed nutritive elements by yield increases and the contribution of nutritive elements supplied by foliar fertilizers applied with maize HF-420 cultivated on sandy soil (Psammosol) at the Research Development Station for Plant Growing on Sandy Soils, Dăbuleni-Dolj

Fertilizer type	Average yield increase (3 years) kg/ha	Average consumption of nutrients at harvest (kg/ha) *			Contribution of foliar fertilizers**			Ratios		
								N _{rem} /N _{in}	P _{rem} /P _{in}	K _{rem} /K _{in}
		N	P	K	N	P	K			
FOLPLANT 411	847	23.29	4.61	11.39	1.80	0.35	0.40	12.9	13.8	28.5
FOLPLANT 231	832	22.88	4.53	11.19	0.80	1.30	0.40	28.6	3.48	27.9
BIODOR 2311	953	26.20	5.45	12.81	0.35	0.55	0.18	74.8	9.90	71.2
BIODOR 2312	1055	29.01	15.74	14.18	0.30	0.48	0.15	96.7	11.90	94.5
ECOFERT 2	1023	28.13	5.57	13.75	0.43	0.10	0.23	65.4	55.70	59.8

*) Specific consumption calculated taking into account the quantity: NPK/ton grain + 1.6 ton stalks (N-27.5 kg; P-5.45 kg; K -13.45 kg

**) Quantities of elements in 1000 litres solution /ha (2 applications x 500 litres/ha) taking into account the composition of fertilizers and concentration of solutions indicated in table 3

rem - removed by yield

in - input by fertilization

INVESTIGATION ON THE SEASONAL VARIATIONS OF MINERAL NUTRIENTS IN THE LEAVES OF WASHINGTON NAVEL ORANGES GROWN IN ANTALYA REGION

N. Ari, C. F. Özkan, T. Ateş and A. E. Arpacioğlu

Citrus and Greenhouse Crops Research Institute, Antalya-Turkey

Abstract

This study was carried out to investigate the seasonal variations of nutrient element contents of leaves to determine the stable periods and to determine the most suitable sampling time for leaves of Washington navel orange.

For the above purpose, orange leaves selected from 5 orchards were taken for 13 months starting from May 1995, and nutrient contents were analysed. According to the variance analysis of data, the effect of leaf age on seasonal variation of elements was found significant at 1% for N, P, K, Ca and Mg and at 5 % for Mn. The seasonal variation of each nutrient element has shown different pattern. Four stable periods for N, Ca, Mg and Fe, three stable periods for P, Mn and 5 stable periods for K were determined.

In conclusion, the period of September-October (when the leaves were 5-6 month-old) was determined to be common stable period in which the variation of nutrient element was minimum. According to these results, the most suitable leaf sampling time for Washington navel oranges was determined to be the period of September-October in Antalya region.

Keywords. Washington navel, seasonal variations of nutrient elements, leaf sampling technique

Introduction

Leaf analysis is an effective way to determine nutrition conditions of culture plant. Various physiological processes during the vegetation period cause important seasonal changes in plant nutrient levels. It is thought that these seasonal changes in nutrient levels should be taken into consideration an important criteria for leaf sampling and for evaluating data of leaf analysis. Smith et al. (1950), indicates that leaf nutrient composition is depended on the leaf age and position of leaf on the citrus plant. Thus, stabilised periods of nutrients in citrus during the vegetation period is seen as an important criteria for effective leaf sampling and effective fertilisation.

The objective of this experiment was to investigate the seasonal variations and stable periods of nutrient element contents and to determine the most suitable sampling time for leaves of Washington navel orange which is constituted 63 % of total citrus growing area in Antalya region (Akkaya and Çelikyurt,1992).

Material and Methods

In this study, five Washington navel orchards were selected in Antalya region (one orchard in Serik, two orchard in Kumluca and two orchard in Finike). Total 15 soil samples were taken from 0-30 cm, 30-60 cm and 60-90 cm soil dept in this orchards. The soil samples were air-dried and passed through a 2 mm sieve. In soil samples, CaCO_3 was determined by calcimeter method (Nelson 1982), pH was determined by pH meter (McLean, 1982), total soluble salt was determined by Rhoades (1982), the texture of the soil samples was determined by the hydrometer method (Day, 1982), organic matter was determined by the Walkley-Black procedure (Nelson, 1982), available P was determined by Olsen and Sommers (1982), exchangeable K, Ca and Mg determined by 1 N NH_4OAc extraction (Jackson, 1962). The P, content in the extracts was determined by spectrophotometer, K by flame photometry, and Ca, Mg by atomic absorption spectrophotometer (Table 1).

Leaf samples were taken at the every last week of each month, and studies continued for 13 months starting from May 1995. Leaves on the tree were sampled by taking from the same labelled branch during sampling time. After preparing samples properly, leaf analysis was performed on 260 samples. The leaf samples were immediately transported to the laboratory in closed polyethylene bags. In order to eliminate surface contamination, the leaves were carefully washed with liquid soap (Teepol, 0.1 %), rinsed in tap water, and finally in deionised water. For nutrient analysis, the leaf samples were dried in a forced-air oven at 70 °C for 72 hours. The dried leaf samples were then ground in a stainless steel Wiley mill. The total N content of dried leaf samples were analysed by the Kjeldahl digestion procedure. Dried leaf samples were wet digested in a mixture of $\text{HNO}_3\text{-HClO}_4$. Total P was determined by spectrofotometrically, K by flame photometrically, and Ca, Mg, Fe, Mn and Zn by atomic absorption spectrophotometrically (Kacar, 1972).

Table 1: Some Physical and Chemical Characteristics of Experimental Orchard Soils

	Soil Depth, cm		
	0-30	30-60	60-90
PH 1:2.5 soil/water suspension	7.8-8.2*	8.0-8.2	8.0-8.3
Salts, %	0.006-0.015	0.007-0.018	0.006-0.014
CaCO_3 , %	4.4-15.1	8.5-19.8	8.9-24.8
Texture	Clay loam	Clay loam	Sandy clay loam
Organic Matter, %	1.0-1.3	0.4-1.1	0.3-1.0
P, mg/kg	5-42	3-12	3-9
K, mg/kg	165-345	115-310	90-230
Ca, mg/kg	2400-3175	2100-2700	2000-2700
Mg, mg/kg	410-1000	440-1000	525-1000

* Average values obtained from five orchards show minimum and maximum levels respectively

Results

Leaf analysis showed that N, P, K, Ca, Mg, Fe and Mn contents of orange leaves depend on the leaf age were found statistically important ($P<0.01$ and $P<0.05$).

Experimental results can be evaluated as below.

1. Nitrogen Contents of Orange Leaves

Nitrogen contents of leaves were decreased till the end of season, and stabilised at four periods. Nitrogen contents were ranged between at 1.8 % in the oldest leaves and 2.83 % in 5-month-old leaves. In this period, 2.78 % and 2.83 % of nitrogen contents of leaves were found over the critical nitrogen levels suggested for citrus nutrition (Figure 1)(Table 2).

2. Phosphorus Contents of Orange Leaves

Phosphorus contents of leaves were decreased at the end of season at 69 % rate. Similar findings were reported by Köseoğlu (1980). P contents were ranged 0.09 % at April-May period and 0.16 % at June-July period. Phosphorus contents were stabilised at four periods. After the end of October phosphorus contents were began to decreasing trend. However, before September-October period, 0.15 % P content was found over the critical P levels (0.12-0.16 %) (Figure 2) (Table 2).

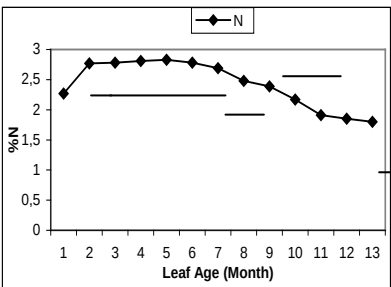


Figure 1 N contents of leaves
* stable period —

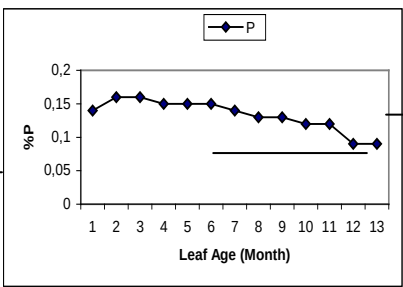


Figure 2 P contents of leaves

3. Potassium Contents of Orange Leaves

Potassium contents of leaves were decreased till the end of season. K contents were ranged 0.36 % in March and 1.28 % in June. Stabilised K contents of leaves were determined at 5 periods. After November month, K contents of leaves were decreased to critical K concentrations (Figure 3) (Table 2).

4. Calcium Contents of Orange Leaves

Calcium contents were determined between 2.34 % in the youngest leaves in May and 4.48 % in 12 months aged leaves. Lower calcium contents at the beginning of season become to increase till the end of season. The rate of differences in calcium contents between end of season and at the beginning of season were found at 176 %. These findings were in accordance with the findings of Köseoğlu (1980). Stabilised calcium contents of leaves were determined at 4 periods. Calcium contents in all periods were determined over the critical calcium levels (Figure 4) (Table 2).

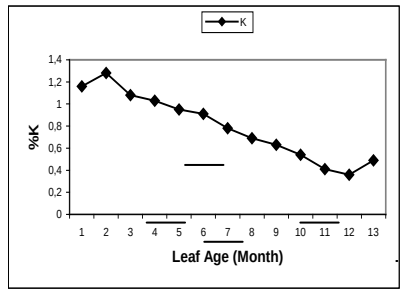


Figure 3 K contents of leaves
* stable period ____

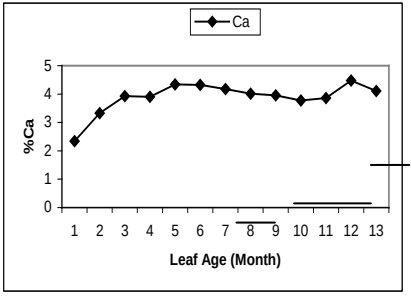


Figure 4 Ca contents of leaves

5. Magnesium Contents of Orange Leaves

Magnesium contents were determined between 0.23 % at May and 0.32 % at July-August periods. Lower magnesium contents at the beginning of season were increased June-September period. After this period it become to decreased, and stabilised in 9-13 months aged leaves. Stabilised Mg contents of leaves were determined at 4 periods. Mg contents in all periods were found over the critical concentrations (Figure 5) (Table 2).

6. Iron Contents of Orange Leaves

Iron contents of leaves were increased by increasing leaf age. Iron contents of leaves were determined between 44.7 mg/kg in June and 89.4 mg/kg in the oldest leaves in May, and these iron concentrations were below the critical concentration until the January. Iron contents stabilised at four periods. June and December month-period were the longest iron stabilised period. High pH and CaCO₃ contents of experimental soil, may be thought an important reason for iron deficiency (Figure 6) (Table 2).

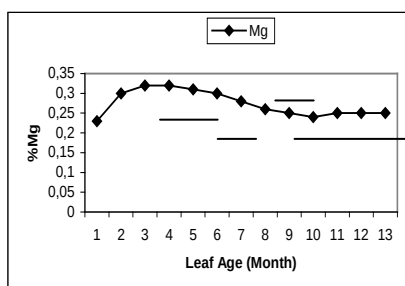


Figure 5 Mg contents of leaves

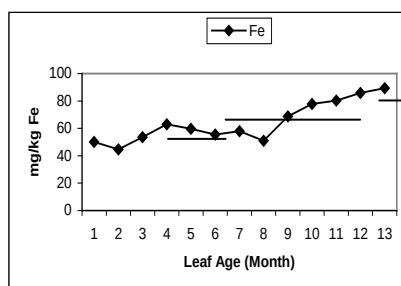


Figure 6 Fe contents of leaves

* stable period ____

7. Manganese Contents of Orange Leaves

Manganese contents were determined between 22.8 mg/kg at January and 40.3 mg/kg at June. Manganese contents of leaves at the beginning of season were similar to at the end of season. Because of Mn fertilisation in the middle of season, Mn contents were found above the critical Mn concentrations. Exceptionally, in December, January, April and May months Mn concentrations were found below the critical concentrations. Stabilised Mn contents were classified at 3 periods (Figure 7) (Table 2).

8. Zinc Contents of Orange Leaves

Zinc contents were ranged between 22.3 mg/kg and 42.5 mg/kg. Zinc contents of leaves at the end of season were found higher than that of the beginning of season. Due to Zn fertilisation at the beginning of season Zn content has begun to increase. This trend has chanced vice verse in December and January months, and then increased again. Zn contents were generally above the critical Zn levels. No relations between leaf age and Zn content were found (Figure 8) (Table 2).

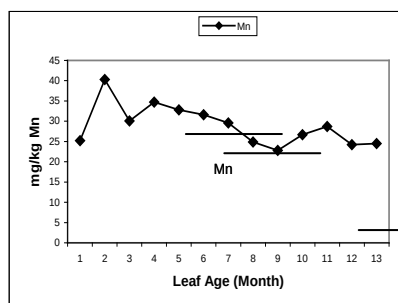


Figure 7 Mn contents of leaves

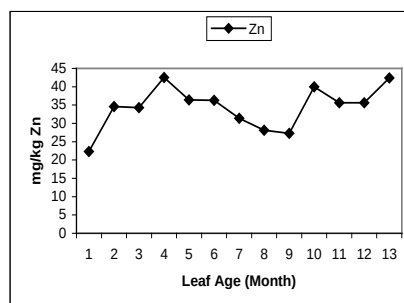


Figure 8 Zn contents of leaves

* stable period ____

Discussion

Results showed that seasonal variation of each element was different (Table 2). Based on the experimental results, September-October period (when the leaves were 5-6 month-old) was determined to be common stable period. In this period, variation of nutrients was determined minimum. In this period, N, P, K, Ca, Mg, Mn, Zn except Fe contents were found above on the critical concentrations suggested for citrus. Thus, no nutrition problems of these elements were found. It is thought that high pH and CaCO_3 content of experimental soils might frequently cause problems on Fe, Zn and Mn nutrition. Also, sharply decrease in N, P and K contents in aged leaves in March, April and May months, may be related by the mobilisation of these elements to newly developing shoots.

According to these result, the most suitable leaf sampling time for Washington Navel oranges was determined as the period of September-October in Antalya region. These results are also in confirmation with the findings of Jones and Embleton (1969).

Table 2: Nutrient Composition of 1 to 13 month-old Washington navel Orange Leaves in Different Months

Month of Sample Collection	%						mg/kg	
	N	P	K	Ca	Mg	Fe	Mn	Zn
1- May	2.27	0.14	1.16	2.34	0.23	50.1	25.2	22.3
2-June	2.77	0.16	1.28	3.33	0.30	44.7	40.3	34.6
3-July	2.78	0.16	1.08	3.93	0.32	53.6	30.1	34.3
4-August	2.81	0.15	1.03	3.90	0.32	63.0	34.7	42.5
5-Septem.	2.83	0.15	0.95	4.34	0.31	59.7	32.8	36.4
6-October	2.78	0.15	0.91	4.33	0.30	55.5	31.6	36.3
7-Novem.	2.69	0.14	0.78	4.18	0.28	57.9	29.6	31.4
8-Decem..	2.48	0.13	0.69	4.01	0.26	51.0	24.9	28.1
9-January	2.39	0.13	0.63	3.95	0.25	68.7	22.8	27.3
10-Febru.	2.17	0.12	0.54	3.77	0.24	77.8	26.7	40.0
11-March	1.91	0.11	0.41	3.86	0.25	80.3	28.7	35.6
12-April	1.85	0.09	0.36	4.48	0.25	85.8	24.2	35.6
13-May	1.80	0.09	0.49	4.11	0.25	89.4	24.5	42.4

References

- Akkaya, F., M. A. Çelikyurt, 1992. Antalya İli Turunçgil İşletmelerinde Ekonomik Faaliyetlerin Değerlendirilmesi Üzerinde Bir Araştırma. Narenciye Araştırma Enstitüsü-Antalya.
- Day, P.R. 1982. Particle Fractionation and Particle-Size Analysis, pp. 545-567 IN: A.L. Page, R.H.Miller, and D.R.Keeney (eds.)Methods of Soil of Analysis, Part 2, Chemical and Microbiological properties. Soil Science Society ofAmerica, Inc., Madison, WI.
- Jackson, M. L., 1962. Soil Chemical Analysis. Prentice-hall, Inc 183: 219-284
- Jones, W., Embleton, 1969. Development And Current Status Of Citrus Leaf Analysis As A Guide To Fertilization In California. Proceedings First International Citrus Symposium, Vol. III.
- Kacar, B., 1972. Bitki ve Toprağın Kimyasal Analizleri II. Bitki Analizleri. A.Ü.Z.F. Yayınları No: 453.
- Köseoğlu, A. T., 1980. İzmir Bölgesi Satsuma Mandarinini Yapraklarındaki Mineral Besin Maddelerinin Mevsimsel Değişiminin İncelenmesi. Doktora Tezi, E. Ü. Z. F. Bornova-İzmir.
- McLean, E.O.1982. Soil pH and Lime Requirement, pp 199-224. IN: A.L. Page, R.H.Miller, and D.R.Keeney (eds.) Methods of Soil of Analysis, Part 2, Chemical and Microbiological properties. Soil Science Society ofAmerica, Inc., Madison, WI.
- Nelson, R.E. 1982. Carbonate and of Gypsum, pp. 181-197. IN: A.L. Page, R.H.Miller, and D.R.Keeney (eds.) Methods of Soil of Analysis, Part 2, Chemical and Microbiological properties. Soil Science Society ofAmerica, Inc., Madison, WI.
- Olsen, S.R. and L.E. Sommers.1982. Phosphorus, pp.403-430. IN: A.L. Page, R.H.Miller, and D.R.Keeney (eds.) Methods of Soil of Analysis, Part 2, Chemical and Microbiological properties. Soil Science Society ofAmerica, Inc., Madison, WI.
- Rhoades, J.D.1982. Soluble Salt, pp.167-179. IN: A.L. Page, R.H.Miller, and D.R.Keeney (eds.) Methods of Soil of Analysis, Part 2, Chemical and Microbiological properties. Soil Science Society ofAmerica, Inc., Madison, WI.
- Smith, P. T., W. Reuther, And A. W. Specht, 1950. Mineral Composition Of Chlorotic Orange Leaves And Some Observations On The Relations Of Sample Preparation Technique The Interpretation Of Result. Plant Physiology 25: 496-506.

Posters

EFFECT OF PHOSPHORUS FERTILIZATION ON PHOSPHORUS AND ZINC CONTENTS IN SOIL AND PLANT

D. Bogdanović^{1,2}, M. Cuvardic^{1,2}, F. Miladinovic²

¹ Faculty of Agriculture, Trg Dositeja Obradovica 8, 21000 Novi Sad, Serbia and Montenegro

² Institute of Field and Vegetable Crops, Maksima Gorkog 15, 21000 Novi Sad, Serbia and Montenegro

Introduction

Numerous studies of P and Zn interactions have been conducted but have produced conflicting results. It is common knowledge that high P content in soil reduces Zn availability to plants (Norvel et. al, 1987; Mandal and Mandal, 1990; Bogdanović et al., 1999). According to Sataya (1976), Zn deficiency symptoms became evident on corn plants when fertilized with 75 mg P kg⁻¹ of soil. Conversely, Elnaïm (1983) found that high P doses did not reduced available Zn in the chernozem soil under corn. The P by Zn interactions are affected by other factors as well (soil pH, organic matter, CaCO₃ content, clay content, structure).

High P levels can affect soil properties such as (I) a shift in pH due to the dissolution of the fertiliser in soil solution due to reaction to both the phosphate and the associated cation with soil components and (II) changes in surface charge due to the adsorption of phosphate on the soil colloids (Shuman, 1988). Various hypotheses have been suggested to explain this phenomenon, including (I) a simple dilution effect on Zn concentration in the tops owing to the growth response of P (Olsen, 1972); and (II) a metabolic disorder within plant cells related to an imbalance between P and Zn, or an excessive concentration of P interferes with the metabolic function of Zn at certain sites in the cell (Haldar and Mandal, 1981).

Materials and Methods

In order to monitor the effects of increasing P-fertilizer rates on the readily available soil phosphorus content and the P/Zn relationship in plants and soil, the following was done:

Two trials with Mitscherlich pots were established according to a randomized block design (5x8). The pots were filled with a chernozem soil taken from an extensive two-field crop rotation trial (maize-wheat, no fertilization, started in 1946/47 at Rimski Šančevi) and sand in the proportion of 2:1. The same fertilization treatments were used in the trials with and without plants:

1. Ø – no fertilization

2. 29.5 mg TCP per pot, which is equivalent to 50 kg P_2O_5 ha⁻¹ and 6.56 mg $ZnSO_4$ per pot, or 10 kg Zn ha⁻¹
3. 59 mg TCP per pot, 100 kg P_2O_5 ha⁻¹ +10 kg Zn ha⁻¹
4. 295 mg TCP per pot, 500 kg P_2O_5 ha⁻¹ +10 kg Zn ha⁻¹
5. 590 mg TCP per pot, 1000 kg P_2O_5 ha⁻¹ +10 kg Zn ha⁻¹

Five maize grains (NS SC 444 hybrid) were sown into each pot. After emergence, four maize plants at the 5-7-leaves stage were left in each pot and soil and plant samples were taken from both trials.

Readily available P in the soil samples was determined after drying and grinding using the AL method of Egner and Riehman (1958). Available Zn in the soil was determined using 0.01M Na_2EDTA and KCl extract (2:1) for two hours, followed by filtering reading performed on an AAS.

The total P content of dry plant mass was determined by sample extraction with HNO_3 and ammonium-molybdate-vanadate. The P content was determined spectrophotometrically. The total plant Zn level was measured by digesting 0.5 g of finely ground plant materials with a mixture of HNO_3 and $HClO_4$ for three hours (Ganje and Page, 1974). After cooling, the samples were filtered and then diluted with distilled water to 50 ml. The concentration of Zn was measured on an AAS.

Results and Discussion

The average initial readily available phosphorus content of the soil taken from the long-term field trial (extensive two-field crop rotation) with which Mitcherlich's pots were filled before the incorporation of P fertilizer was 5.8 mg P_2O_5 100⁻¹ g soil. However, the phosphorus content of soil samples from the trial with no plants and that with maize plants at the 5-7-leaves stage according to the P-fertilization treatment was significantly increased (Table 1). Table 1 shows that the average readily available P content in the pots with no plants increased from 5.8 mg P_2O_5 100⁻¹ g soil up to 30.4 mg P_2O_5 100⁻¹ g soil depending on the P-fertilization treatment. The coefficient of correlation between the amount of P-fertilizer added and the measured soil P content suggests high positive interdependence ($r=0.989$). In the soil sown with maize plants, the readily available phosphorus content ranged from 5.48 (unfertilized control) to 35.8 mg P_2O_5 100⁻¹ g soil depending on the fertilization treatment. The coefficient of correlation between the soil phosphorus and phosphorus incorporated with P-fertilizers was very high

($r=0.994$). No statistically significant differences in readily available phosphorus levels were found between the trial without plants and the one with plants up to $100 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$. With the treatments with 500 and $1,000 \text{ P}_2\text{O}_5 \text{ ha}^{-1}$, however, the trial with plants had a significantly higher readily available phosphorus content. In both trials, increases of the readily available phosphorus content caused by the lower P-fertilizer rates (50 and $100 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$) were smaller than those resulting from the higher rates (500 and $1000 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$) (Table 1). This can be explained by pronounced chemisorption in a phosphorus-poor soil ($5.84 \text{ mg P}_2\text{O}_5 100^{-1} \text{ g}$ measured in the control), where the bulk of the P-fertilizer added formed poorly soluble compounds in the soil.

Table 1: Readily available P content of soil in trials with and without plants where P-fertilizer was added

Treatments P_2O_5 kg ha^{-1}	Trial with no plants			Trial with plants		
	P_2O_5 $\text{mg } 100^{-1} \text{ g}$ soil	Difference relative to control $\text{mg P}_2\text{O}_5 100^{-1} \text{ g}$ soil	Increase of $\text{mg P}_2\text{O}_5 100^{-1} \text{ g}$ soil by $1 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$	P_2O_5 $\text{mg } 100^{-1} \text{ g}$ soil	Difference relative to control $\text{mg P}_2\text{O}_5$ 100^{-1} g soil	Increase of $\text{mg P}_2\text{O}_5 100^{-1} \text{ g}$ soil by $1 \text{ kg P}_2\text{O}_5$ ha^{-1}
Control	5.98	-	-	5.48	-	-
50	6.51	0.63	0.013	6.43	0.95	0.019
100	7.91	2.03	0.020	7.26	1.78	0.18
500	14.42	8.54	0.017	17.25	11.77	0.024
1000	30.36	24.48	0.025	35.83	30.35	0.030

Table 2 shows how much triple superphosphate (nutrient) has to be incorporated when using increasing P-fertilizer rates in order to raise the readily available phosphorus content by $1 \text{ mg } 100^{-1} \text{ g}$ soil in chernozem with low initial levels of this element ($5.8 \text{ mg P}_2\text{O}_5 100^{-1} \text{ g}$).

Table 2: Effect of increasing P-fertilizer rates on increasing readily available phosphorus content per $1 \text{ mg P}_2\text{O}_5 100^{-1} \text{ g}$ zemljišta

Amount of $\text{kg P}_2\text{O}_5 \cdot \text{ha}^{-1}$ added	Amount of $\text{kg P}_2\text{O}_5 \text{ ha}^{-1}$ needed for $1 \text{ mg P}_2\text{O}_5 100^{-1} \text{ g}$ soil increase	
	Trial without plants	Trial with plants
50	78.7	52.6
100	49.3	56.2
500	58.8	42.5
1000	41.7	32.9

The results of this trial indicate that the effects of applying increasing P-fertilizer rates for a 1mg P_2O_5 100⁻¹ g increase will differ in different soil types with different properties and different supplies of readily available phosphorus.

Analyses of plant materials for P content have shown large interdependence of the amount of P added to the soil and plant phosphorus content ($r=0.960$) (Figure 1).

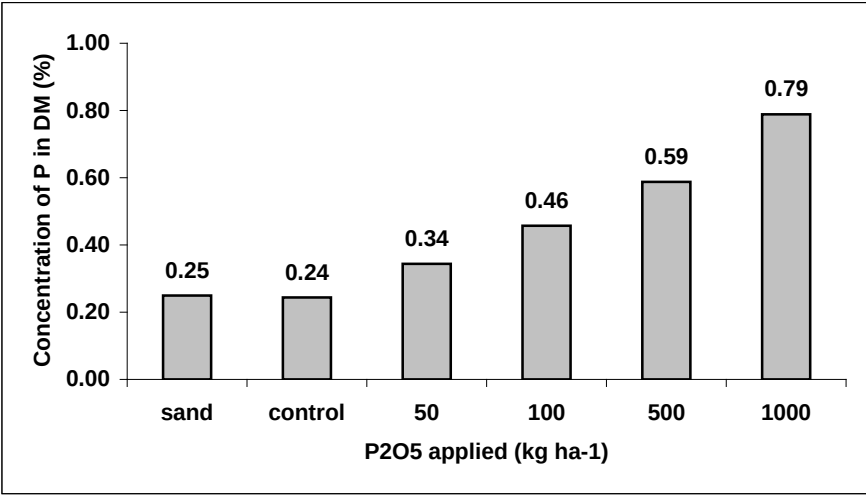


Figure 1: Percentage contribution of phosphorus to dry maize matter according to phosphorus treatment

The dry matter P content of plants fertilized with up to 100 kg P_2O_5 /ha was 0.2-0.46% P, which agrees with data found in the literature (Kastori, 1983). When extremely high phosphorus rates were added to the soil (1,000 kg P_2O_5 /ha), the contribution of this element to maize plants' dry mass was 0.8%, which is also supported by the literature data (Green; Warder, 1973). The T-test between phosphorus incorporated in the soil and plant phosphorus content revealed highly significant differences among all the fertilization treatments both relative to the control and relative to each other.

In order to determine phosphorus effects on soil and zinc content in the trial with maize plants fertilized with increasing phosphorus and flat zinc rates, we determined the readily available soil Zn content and total plant Zn content. A negative correlation was found between the readily available soil Zn content and phosphorus introduced by fertilizer ($r= -0.807$) Figure 2. An antagonistic relationship between Zn and P manifested itself already at 100 kg P_2O_5 /ha, and the soil levels of readily available Zn dropped significantly with increasing P-fertilizer rates.

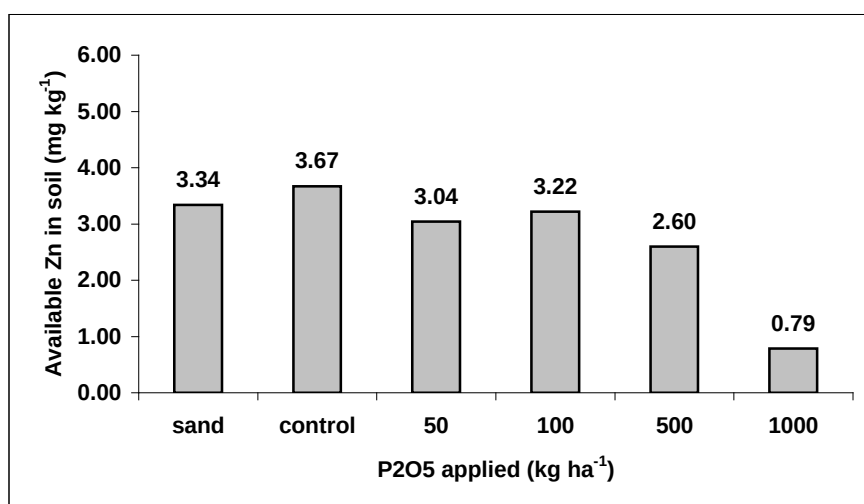


Figure 2: Readily available soil Zn content when using increasing P-fertilizer rates

The negative correlation between the readily available Zn content and increasing P-fertilizer rates can be explained by the formation of poorly soluble zinc phosphates in the soil as well as zinc carbonates (because of the calcareous soil). Besides CaCO₃, the P and Zn interaction was also affected by organic matter, pH, clay content, soil structure, and so on.

High P levels can affect soil properties such as (I) a shift in pH due to the dissolution of the fertilizer in soil solution or due to reaction of both the phosphate and the associated cation with soil components and (II) changes in surface charge due to the adsorption of phosphate on the soil colloids (Shuman, 1988). Such changes in soil properties may influence the transformation of both native and applied Zn in soil in different forms and hence their availability to plants.

The present study's results for Zn content of maize plants are lower than those from the literature (20-100 mg·kg⁻¹, Kastori 1983). However, the results shown in Table 3 fully agree with those reported by Lott (1973), where in a study similar to this one the average maize plant Zn content was 12-17 mg·kg⁻¹. Bogdanović et al.. (1999) also report similar Zn levels (22-10.6 mg kg⁻¹) found in maize leaves and stems after the application of increasing P-fertilizer rates in a long-term field trial.

Table 3: Contribution of P and Zn to dry maize mass and P/Zn ratio

Amount of kg P ₂ O ₅ ha ⁻¹ added	Contribution of P to dry plant mass mg g ⁻¹	Contribution of Zn to dry plant mass µg g ⁻¹	P/Zn ratio
0	2.44	17.12	142.5
50	3.44	16.35	210.3
100	4.57	16.52	276.0
500	5.88	15.12	388.8
1000	7.89	12.51	630.6

Conclusion

The following conclusions have been made:

Use of increasing P-fertilizer rates increased the readily available phosphorus content from 5.8 in the check treatment to 30.4 mg P₂O₅ 100⁻¹ g soil in the trial without plants and from 5.48 to 35.8 mg P₂O₅ 100⁻¹ g soil in the trial with plants.

The increase of readily available phosphorus caused by the addition of 1 kg P-nutrient ranged from 0.013 to 0.025 mg P₂O₅ 100⁻¹ g soil in the trial without plants and from 0.019 to 0.030 mg P₂O₅ 100⁻¹ g soil in the trial with plants. Use of lower rates of P-fertilizer requires higher amounts to obtain a 1 mg P₂O₅ 100⁻¹ g increase relative to extremely high rates where smaller amounts are needed for the same result.

A highly positive interdependence was found between the phosphorus introduced by fertilizer and the P content of the maize plants (r=0.969)

A negative correlation was found between readily available soil Zn and the P-fertilizer added (r=-0.807). With higher P-fertilizer rates (500 and 1000 kg/ha), the readily available Zn content was significantly lower.

A significantly lower Zn content was found in plants fertilized with very high rates of P-fertilizer relative to that of plants fertilized with the usual (smaller) rates, meaning that extremely high P-fertilizer rates result in P/Zn antagonism.

References

- Bogdanović Darinka, Ubavić M., Čuvardić Maja (1999): Effect of phosphorus fertilization on Zn and Cd contents in soil and corn plants. *Nutrient Cycling in Agroecosystems* 54: 49-56.
- Elnaim Abd.M., (1983): Zinc adsorption in soil with different part of CaCO_3 and increasing phosphorus doses. 41: 335-362.
- Green,D.G., Warder, F.G., (1973): Accumulation of damaging concentrations of phosphorus by leaves of Selkirk wheat. *Plant and Soil*, 38: 567-572.
- Haldar, M., Mandal, LN (1981): Effect of phosphorus and zinc on the growth and phosphorus, zinc, iron, and manganese nutrition of rice. *Plant and Soil* 59: 415-425.
- Kastori, R;(1983): Role of elements in plant nutrition. Departman of Natural Sciences, Editor Mihaljev 1-350, Novi Sad, Yugoslavia.
- Mandal L., Haldar M., (1980): Influence of phosphorus and zinc application on the availability of zinc, copper, iron, manganese and phosphorus in water logged rice soils. *Soil Sci* 130, 251-257.
- Mandal B., Mandal LN., (1990): Effect of phosphorus application on transformation on zinc fraction in soil and on the zinc nutrition of lowland rice. *Plant and Soil*: 121, 115-123.
- Norvell, WA, Dabkowska-Naskret H., Cary EE., (1987): Effect of phosphorus and zinc fertilization on the solubility of Zn^{2+} in two alkaline soils. *Soil Sci.Soc.Am.J.* 51: 584-588.
- Olsen, S.R., (1972): Micronutrient interactions. In: Mortvedt JJ et al. (eds) *Micronutrients in Agriculture*, pp 243-264. Soil Science Society of America, Madison WI
- Shuman,L.M., (1988): Effect of phosphorus level on extractable micronutrients and their distribution among soil fractions. *Soil Sci.Soc.Am J.*52:136-141.
- Sataya, NM.,(1976): Phosphorus-zinc interaction in relation to absorption rates of phosphorus, zinc, copper, manganese and iron in corn. *Soil Sci.Soc.Am.J* 40 (5): 719-722.

PRODUCTIONAL AND ECOLOGICAL ASPECTS OF NUTRIENT BALANCE ON FARM LEVEL

R. Bujnovský

Soil Science and Conservation Research Institute, Gagarinova 10, 827 13 Bratislava,
Slovak Republic; bujnovsky@vupu.sk

Abstract

Results of soil surface nutrient balance are presented on set of selected Slovakian mixed farms in years 1999 and 2000. Soil surface nutrient balance results is possible to consider as basic information about nutrient management within a farm.

Average values of nitrogen balance in selected farms exceeded the OECD provisional limit value $+50 \text{ kg N.ha}^{-1}$ in 31 % of cases. In 19 % of cases was noted even negative nitrogen balance that from view of long-term yield stabilization cannot be accepted.

From comparison of phosphorus or potassium balance with P or K available supply in the soil (expressed by fertilization coefficients) follows that in 37 % phosphorus balance indicated insufficient P inputs and in 6 % was observed excessive input of given nutrient. In the case of potassium balance indicated insufficient K inputs in 12 % and excessive fertilization in 19 % of cases.

Animal manures and fertilizers represent important source of nutrients. In average per set of farms within two years animal manures covered 29.1 % of N inputs, 72.1 % P inputs and 82.2 % of K ones. Fertilizer share on nutrient inputs was 38.7 % N, 22.3 % P and 16.1 % K.

Use of animal manures is limited as by Nitrate Directive limit, as well as their compound nature and great nutrient content variability. From view of satisfying the different crop demands on nitrogen the fertilizer are more appropriate than animal manures. Average loading of agricultural soil by nitrogen from animal manures, generally considered as important source of water resources pollution, was in all farms deep under the Nitrate Directive limit.

Because within phosphorus and potassium inputs dominate animal manures, on field level is not possible to secure consistent considering the different P and K fertility classes and avoid their excessive or insufficient input that is possible to consider as some "tax" for recycling/maintenance of these nutrients within a farm.

Introduction

In coherence with principles of sustainable development philosophy constitutive parameter of next mankind existence is as sufficient food production (in quantity, nutritional quality and safety) as well as natural resources preservation. Last decade is characterized by great decrease of fertilizers and animal manures consumption in all countries of Central and Eastern Europe, when the most radical decrease is observed in the case of phosphorus and potassium fertilizers (e.g. Igras et al., 2001; Klír, 2001; OECD, 2001; Torma, 2001). Besides the inputs quantity there is also necessary to pay attention to they effective use and reducing ineffective losses, especially in the case of nitrogen. As follows from many papers (e.g. Collective, 2000; Crouzet

et al., 1999; Schrama, 1998), agricultural sector is considered as an area that significantly contributes to water issues pollution, especially by nitrogen.

Balanced nutrient inputs and outputs are considered as factor that contributes to sustain as agricultural production as well as environment quality (Laegreid et al., 1999). Besides Nitrate Directive limit for loading of agricultural soil by nitrogen from animal manures (Anonymous, 1991), nitrogen balance is considered as next indicator of potential pollution of water resources (OECD, 1998, 2001). As introduces Oenema (1999), analysis of nutrient balance data as well as N, P, K nutrient efficiency may help not only to describe the current status in nutrient structure but also to discover some causal reasons that may help to improve the nutrient management with regard to farm economy and environment.

Material and Methods

Submitted paper is concerned on evaluation of nutrient balance on farm level with respect to evaluation the efficiency of nutrient inputs related to maintenance of soil fertility and potential of environment pollution.

Soil surface nutrient balance was calculated on set of selected farms in Trnava province (Agrobio Hubice j.s.c., co-operative farms in Bucany, Kocin, Madunice, Novy Zivot, Piestany, Velke Blahovo and Vrakun) for years 1999 and 2000. Balance calculation was going out from principles of OECD balance (OECD, 1998). On input side of balance calculation following nutrient sources were taken into the account: animal manures, purchased organic manures, fertilizers, biological N fixation, atmospheric N deposition, seeds and tubers. Input data were obtained directly from farm record keeping. On output side was assumed nutrient amount in yield product transported from field. In the case of atmospheric deposition was assumed only nitrogen in amount $20 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$ that is in correspondence with published data (Bielek, 1998).

In the case of phosphorus and potassium balance, soil fertility was also taken into account and expressed indirectly through P, K fertilization coefficients. They were obtained as sum of products of relative share of individual nutrient fertility classes and correction coefficients (by 2.0 at very low nutrient supply, 1.5 at low, 1.0 at medium, 0.5 at good and 0 at high and very high category of nutrient supply).

Results

Nutrient balances per individual farm are introduced in Table 1 and 2. Average values of nitrogen balance per set of selected farms were $+23.2 \text{ kg N.ha}^{-1}$ in 1999 and $+44.9 \text{ kg N.ha}^{-1}$ in 2000 with range from -27.8 to $+90.6 \text{ kg N.ha}^{-1}$ of farm agricultural soil. OECD provisional limit value $+50 \text{ kg N.ha}^{-1}$ was exceeded in 31 % of cases. In 19 % of cases was noted even negative nitrogen balance that from view of crop productivity maintenance can not be accepted. Average loading of agricultural soil by nitrogen from animal manures per set of selected farms was $35.1 \text{ kg N.ha}^{-1}$ that is deep under the Nitrate Directive limit (Anonymous, 1991).

Table 1: Nitrogen balance and nitrogen use efficiency on selected farms

Farm	Farm area (ha)		Loading of agricultural soil by N from animal manures (kg.ha^{-1})		Nitrogen balance (kg.ha^{-1})	
	1999	2000	1999	2000	1999	2000
Bucany	876.6	871.6	23.3	23.1	-27.8	-13.0
Hubice	4072.0	4097.0	33.4	30.9	45.4	74.5
Kocin	1273.6	1272.6	53.6	46.3	70.5	90.6
Madunice	560.0	560.0	27.7	27.1	-11.7	36.6
Novy Zivot	1184.0	1121.0	42.4	35.7	10.6	17.7
Piestany	831.7	838.8	39.2	35.1	16.9	34.4
Velke Blahovo	922.0	827.0	35.9	36.0	19.6	71.6
Vrakun	1431.6	1648.0	37.8	33.8	61.9	46.9
Average	-	-	36.7	33.5	23.2	44.9

Phosphorus balance per hectare of agricultural soil was ranging between -13.9 and $+4.5$ with average values $-5.4 \text{ kg P.ha}^{-1}$ in 1999 and $-4.8 \text{ kg P.ha}^{-1}$ in 2000. Average values of potassium balance were $-13.9 \text{ kg K.ha}^{-1}$ in 1999 and $+4.1 \text{ kg K.ha}^{-1}$ in 2000 with range from -27.3 to $+25.1 \text{ K.ha}^{-1}$ of farm agricultural soil. From comparison of phosphorus or potassium balance with P or K available supply in the soil (expressed by fertilization coefficients) follows that in 37 % phosphorus balance indicated insufficient P inputs and in 6% was observed excessive input of given nutrient. In the case of potassium balance indicated insufficient K inputs in 12 % and excessive fertilization in 19 % of cases.

Table 2: Nutrient balance (kg.ha⁻¹) and P, K balance coefficient on selected farms

Farm	Nutrient balance				Fertilization coefficient	
	1999		2000			
	P	K	N	P	P	K
Bucany	-12.0	-27.3	-9.1	-19.4	1.35	0.53
Hubice	-13.9	-21.9	-5.9	1.2	0.54	0.32
Kocin	-8.6	-12.1	4.5	25.1	0.59	0.68
Madunice	-11.6	-14.7	-2.7	9.8	1.35	1.50
Novy Zivot	-5.8	-14.2	-8.1	-24.0	0.68	0.80
Piestany	-8.9	-8.6	-6.6	22.6	0.84	1.05
Velke Blahovo	-7.1	-0.6	-2.3	24.3	1.11	0.69
Vrakun	-7.6	-11.7	-8.1	-7.0	0.42	0.61
Average	-5.4	-13.9	-4.8	4.1	-	-

Relative shares of individual nutrient source inputs illustrate Table 3 and 4. As follows from introduced data animal manures and fertilizers were dominant nutrient sources. In average for two years, fertilizers covered 38.7 % (0.0 to 53.2 %) of nitrogen inputs, 22.3 % (from 0.0 to 52.9%) of phosphorus inputs and 16.1% (0.0 to 46.5 %) of total potassium inputs. Animal manures covered 29.2 % (21.6 to 37.3 %) of nitrogen inputs, 72.1 % (from 42.2 to 95.7 %) of phosphorus inputs and 82.2 % (from 52.6 to 99.2 %) of total K inputs.

Table 3: Relative share of fertilizers, animal manures and purchased organic manures on total N, P, K inputs (%)

Farm	Fertilizers			Animal manures			Purchased organic manures		
	N	P	K	N	P	K	N	P	K
Bucany	2.4	0.0	0.0	36.3	90.0	97.4	0.0	0.0	0.0
Hubice	52.6	0.9	0.3	22.0	92.3	98.5	0.0	0.0	0.0
Kocin	44.5	22.4	9.4	29.2	70.3	85.9	1.6	4.0	4.0
Madunice	32.2	37.1	12.8	31.9	57.7	86.1	0.0	0.0	0.0
Novy Zivot	39.5	36.1	20.1	30.2	59.3	78.4	0.0	0.0	0.0
Piestany	39.6	21.1	40.7	30.6	74.5	58.4	0.0	0.0	0.0
Velke Blahovo	49.0	39.8	28.5	27.4	57.2	70.7	0.0	0.0	0.0
Vrakun	49.9	20.8	17.0	25.4	75.4	82.2	0.0	0.0	0.0
Average	38.7	22.3	16.1	29.1	72.1	82.2	0.2	0.5	0.5

Table 4: Relative share of biological N fixation, atmospheric deposition and seeds and tubers on total N, P, K inputs (%)

Farm	Biological N fixation			Atmospheric N deposition			Seeds and tubers		
	N	P	K	N	P	K	N	P	K
Bucany	26.0	-	-	31.4	-	-	3.9	10.0	2.6
Hubice	10.2	-	-	13.8	-	-	1.4	6.8	1.2
Kocin	12.0	-	-	11.5	-	-	1.2	3.3	0.7
Madunice	10.6	-	-	23.2	-	-	2.1	5.2	1.1
Novy Život	12.4	-	-	15.6	-	-	2.3	4.6	1.5
Piestany	11.4	-	-	16.6	-	-	1.8	4.4	0.9
Velke Blahovo	7.0	-	-	15.2	-	-	1.4	3.0	0.8
Vrakun	9.2	-	-	14.3	-	-	1.2	3.8	0.8
Average	12.4	-	-	17.7	-	-	1.9	5.1	1.2

There was observed greater share of nitrogen in fertilizers than in animal manures. To satisfy the changing crop demands on nitrogen the fertilizer are more appropriate than animal manures. The fact that within phosphorus and potassium sources dominate animal manures indicate lower manageability of these P, K-sources with regard to different soil fertility classes of these nutrients when even single nutrient fertilizer are advised.

Discussion and Conclusions

As follows from OECD report (OECD, 2001) soil surface nitrogen balance as well as nitrogen efficiency belong to the basic two environmental indicators for agriculture related to nutrient use. In agreement with Parris (1998) and Crouzet (2000) it is necessary to mention, nutrient excess or deficit in short period may only potentially indicate the soil depletion, harmful environmental or resource impact due to agricultural activities what is relevant to presented and evaluated data. Ground water pollution is in relation to all the positive surpluses over a longer period where time of year and thus yearly nitrogen surplus does not play crucial role.

In connection with nutrient balance interpretation most attention is paid to the nitrogen and rather to its excess than insufficiency. Proposed baseline $+50 \text{ kg N.ha}^{-1}$ per year (Eckert et al., 1999 cit. in OECD, 2001) for evaluation of the risk of possible nitrate leaching has very relative validity when variation of N-reference value significantly depends on soil and climatic factors (Cameron, Trenouth, 1999 cit. in OECD, 2001). Undoubtedly, negative nitrogen balance may be beneficial at preservation of water resources against pollution but from viewpoint of crop

productivity maintenance can not be accepted. In coherence with literary knowledge (OECD, 2001) and our opinion, even more extensive agricultural production with nitrogen balance up to 50 kg.ha⁻¹ seems not to be satisfactory guaranty against water pollution by nitrogen.

According to Johnston (1986), negative potassium balance not always negatively influences the yield of following crops even in long-term insufficient input of potassium. The similar situation is also in the case of phosphorus. Positive balance of P and K is possible to assess as the long-term investments into soil fertility, especially when soils with very low to medium available nutrients supply are improved. On soils with high available phosphorus and potassium supply positive balance of these nutrients indicates rather their ineffective input, especially with regard to crop production economy.

At interpretation of nutrient balance results there is essential also information about the yield level, because equalized nutrient balance is rather indicator of environmental acceptance than farm prosperity and thus necessity to fertilization.

Organic manures (sewage sludge, manure imports) and nitrogen in seeds and tubers play usually only minor role as N inputs (EECD, 2001). At more extensive form of agriculture farms tend to have a higher share of total N inputs provided from atmospheric deposition and biological N fixation. From Table 3 follows that when share of nutrient in fertilizer is lower than from animal manures (especially phosphorus and potassium) farms tend to have even high share of this nutrient in seeds and tubers.

Respecting the Nitrate Directive limit (170 kg N.ha⁻¹ from farm manure) is necessary to consider as preventive and help measure to prevent water pollution by nitrogen. Average loading 1 ha of agricultural soil by nitrogen represents only provisional values. As results from existing knowledge agricultural subjects in Slovak Republic do not use the agricultural soil equally intensively. Application of fertilizers as well as farm manures is more concentrated on market crops on arable land. In generally, permanent grasslands are loaded by nutrients the least. Within farm FYM application is managed by crop demands (crops cropped in first, second and third sequence). The demand of uniform liquid manure distribution within agricultural soil of farm remains actual problem as from effective utilization of applied nutrient as well as from view of frequent locally high loading of soil by nutrients.

Animal manures and fertilizers belong to the dominant sources of nitrogen, but fertilizers, due to better manageability, are more appropriate than animal manures at covering crop demands on nitrogen that follows also from literary issues (Bumb, Baanate, 1996; Isherwood, 2000).

As follows from many sources (Burt et al., 1993; Powlson, 1997; Goulding, 2000), the decisive moment at preservation of water resources against pollution from agriculture consists in substantial improvement of management and harmonization of cropping demands with need of sustaining/improving the water resources quality. So, implementation of abovementioned directive assumes improvement not only manure and fertilizer management, but also all cropping measures introduced in codes of good agricultural practice. For better understanding and solving the problem of water pollution by nitrogen from agriculture there is necessary to take into account also indicators related to management of manure/fertilizer, soil and crop management, while nitrate content in water resources is better to consider as indicator of the cropping measures efficiency from long-term view.

References

- Anonymous, 1991: Council directive concerning the protection of water against pollution caused by nitrates from agricultural sources (91/676/EEC). Official J. Eur. Commun. No L 375, 1-8
- Bielek, P., 1998: Nitrogen in agricultural soils of Slovakia. VÚPÚ, Bratislava, 255 p. (in Slovak)
- Bumb, B.L., Baanante, C.A., 1996: The role of fertilizer in sustaining food security and protecting the environment. Food, Agriculture and the Environment Discussion Paper 17. Int. Food Policy Res. Inst., Washington, 54 p.
- Burt, T.P., Heathwaite, A.L., Trudgill, S.T. (eds.), 1993: Nitrate, patterns and management. J. Wiley and Sons, Chichester, 444 p.
- Collective, 2000: Proposal of national strategy of sustainable development in Slovak Republic. REC Slovakia, Bratislava, 351 p. (in Slovak)
- Crouzet, P., 2000: Calculation of nutrient surpluses from agricultural sources. Technical Report No. 51. EEA Copenhagen, 62 p.
- Crouzet, P., Leonard, J., Nixon, S., Rees, Y., Parr, W., Laffon, L., Boegestrand, J., Kristensen, P., Lallana, C., Izzo, G., Bokn, T., Bak, J., Lack, T.J., 1999: Nutrients in European ecosystems. Env. Assessment Report No 4. EEA, Copenhagen, 156 p.
- Goulding, K., 2000: Nitrate leaching from arable and horticultural land. Soil Use and Management 16, 145-151
- Igras, J., Kopinski, J., Gosek, S., 2001: Regional diversity of nutrient balance in polish agriculture. In: Balanced fertilization for crop yield and quality. Proc. of Int. Workshop, VÚRV Praha-Ruzne, 41-49
- Isherwood, K.F., 2000: Fertilizer use and the environment. Int. Fert. Industry Associon, Paris, 51 p.
- Johnston, A.E., 1986: Potassium fertilization to maintain a K-balance under various farming systems. In: Nutrient balances and the need for potassium. 13th Congress IPI, Basel, 199-226
- Klír, J., 2001: Fertilization intensity and nutrient balance in Czech agriculture. In: Balanced fertilization for crop yield and quality. Proc. of Int. Workshop, VÚRV Praha-Ruzne, 27-33
- Laegreid, M., Bockman, O.C., Kaarstad, E.O., 1999: Agriculture, fertilizers and the environment. CABI Publishing, Wallingford, 294 p.
- OECD, 1998: Towards sustainable development. Environmental indicators. OECD, Paris, 129 p.
- OECD, 2001: Environmental indicators for agriculture. Vol. 3. Methods and results. OECD, Paris, 398 p.
- Oenema, O., 1999: Nitrogen cycling and loses in agricultural systems; identification of sustainability indicators. In Nitrogen cycle and balance in Polish agriculture. Institute for Land Reclamation and Grassland Farming, Falenty, 25-43
- Parris, K., 1998: Agricultural nutrient balances as agri-environmental indicators: an OECD perspective. In: Van der Hoek, K.W., Erisman, J.W., Smeulders, S., Wisniewski, J.R., Wisniewski, J. (eds): Nitrogen, the confer-N-s. First Int. Nitrogen Conference, Amsterdam, 219-225
- Powlson, D.S., 1997: Integrating agricultural nutrient management with environmental objectives - current state and future prospects. Proc. The Fertiliser Soc. No. 402, London, 42 p.
- Schrama, G.J.I. (ed.), 1998: Drinking water supply and agricultural pollution. Preventive action by the water supply sector in the European Union and the United States. Kluwer Acad. Publ. Dordrecht, 378 p.
- Torma, S., 2001: Crop production and nutrients balance in the Slovak Republic. In: Balanced fertilization for crop yield and quality. Proc. of Int.. Workshop, VÚRV Praha-Ruzne, 2001, 35-40

SUSTAINABILITY OF DIFFERENT FERTILIZATION SYSTEMS ON CHERNOZEM SOIL

M. Cuvaradic¹, D. Bogdanovic¹, M. Ubavic¹, M. Malesevic²

¹ Faculty of Agriculture, Trg D. Obradovica 8, 21000 Novi Sad, Serbia and Montenegro

² Institute of Field and Vegetable Crops, M. Gorkog 30, 21000 Novi Sad, Serbia and Montenegro

Abstract

In order to investigate effect of different fertilization systems on sustainability of wheat production on chernozem soil, three long-term field trials established on chernozem soil were chosen with following treatments:

1. The trial established in 1964/65 (Permanent trial), fertilized only with mineral fertilizers (unfertilized; $N_{100}P_{100}K_{100}$; $N_{150}P_{150}K_{150}$)
2. The trial established in 1983/84 (IOSDV), fertilized with harvest residues and liquid manure (HR + LM; HR + LM + N_{100} ; HR + LM + N_{200})
3. The trial established in 1971/72 (ISDV), fertilized with mineral fertilizers and harvest residues (unfertilized; N_{90} ; N_{90} + HR).

Unfertilization for a long-term, even on the chernozem, high productivity soil type, led to a decrease in soil fertility, especially in SOM. Soil fertility detriment, as a consequence caused a decrease in yield.

Long-term only mineral fertilizers application is enough to sustain SOM at sufficient level, but plowing under harvest residues had a better effect.

The application of liquid manure ($60 \text{ m}^3 \text{ ha}^{-1}$) positively affected SOM, but LM with higher doses of N fertilizers (LM + N_{200}) left non permitted concentration of nitrate in soil profile after the wheat harvest.

Keywords: long-term field trial, wheat, yield, soil properties, SOM, NO_3 content

Introduction

In the middle of the last century, the industrial model of agriculture made it possible for many countries to become self-sufficient in agricultural production, but negative effects such as huge energy consumption, pesticide and nutrients accumulation in underground and ground water, huge piles of organic waste and empty areas of deteriorating soils, appeared. It has become obvious that agricultural production will have to follow the principles of sustainable development in order to be able to satisfy the demand for food of the present and future human population and preserve natural resources and protect the environment (Lang, 1994). An important factor in this regard will be the maintenance and improvement of soil fertility by application of nutrients. This way the nutrients removed from the soil by yield will be compensated for and the fertility of naturally poor or exhausted soils will increase.

A decline in soil fertility due to continuous nutrient removal by yields of cultivated crops without proper compensation may lead to a degradation that is just as dangerous as any other form of environmental degradation. On the other hand, unrational nitrogen fertilization led to nitrate leaching and therefore possible contamination and eutrofication of underground water, rivers and lakes as well.

Therefore, the purpose of our research was to investigate changes in sustainability of different fertilization on chernozem soil. As sustainable agriculture can be defined as an agricultural system maintaining the soil fertility as well as avoiding environmental pollution in a long-term perspective (Körschens, 1998), long-term agricultural experiments are essential to provide the empirical data necessary to evaluate sustainability of agricultural systems (Lal and Stewart, 1995). In this study, we have investigated the effects of different fertilization systems on wheat production in a three long-term experiments in Novi Sad, located in the south part of the Pannonian valley.

Materials and methods

Experimental fields

In order to investigate the effects of different fertilization systems on sustainability of wheat production on chernozem soil, three long-term field trials established on chernozem soil were chosen with following treatments:

The trial established in 1964/65 (Permanent trial), fertilized only with mineral fertilizers (unfertilized; $N_{100}P_{100}K_{100}$; $N_{150}P_{150}K_{150}$) in rotation winter wheat, sugar beet, maize and sunflower

The trial established in 1983/84 (IOSDV), fertilized with harvest residues and liquid manure (HR + LM; HR + LM + N_{100} ; HR + LM + N_{200}) in rotation sugar beet, maize, maize and winter wheat

The trial established in 1971/72 (ISDV), fertilized with mineral fertilizers and harvest residues (unfertilized; N_{90} ; N_{90} + HR) in rotation maize, spring barley and winter wheat

Table 1. shows chemical properties of soils at the beginning of the experimental period.

Table 1: Chemical properties of soils at the beginning of the experiments

	pH in H ₂ O	CaCO ₃ %	SOM %	P ₂ O ₅ mg 100 ⁻¹ g	K ₂ O mg 100 ⁻¹ g
1. Permanent trial established in 1964/65	7.6	1.3	3.51	19	26
2. IOSDV established in 1983/84	7.7	2.8	2.62	173*	60
3. ISDV established in 1971/72	8.1	2.0	2.30	26	30

**Extremely high P-AL content was caused by cemetery, which had previously been at the site of the trial*

Soil analysis

The soil samples were taken from two different depths (0-30 and 30-60 cm) after wheat harvest. Soil samples were air-dried, mildly crushed to pass a 2 mm sieve. Soil pH, content of total C and N, and extractable P and K were determined.

Soil pH was measured in a soil-water suspension (1:2.5). Soil organic matter (SOM) was determined by bichromate method. The plant available P and K were extracted with AL solution (0.1 M ammonium lactate and 0.4 M acetic acid, pH 3.75) at a soil to solution ratio of 1:20 (w/v) (Egnér et al., 1960). The concentration of P was measured by spectrophotometer, while concentrations of K were measured by flame photometry.

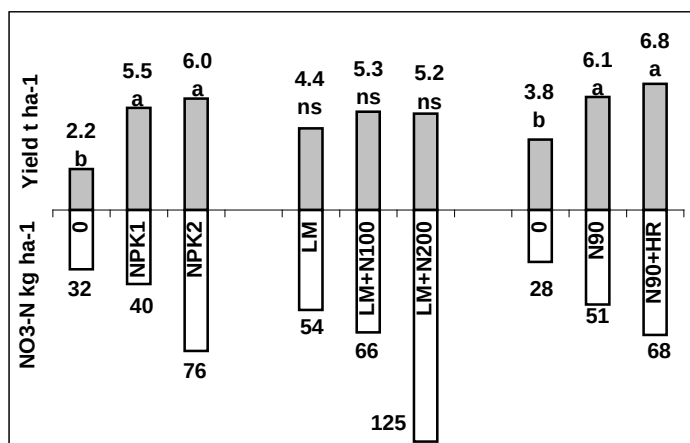
Results and Discussion

Effect of different fertilization systems on yield of wheat

The long-term application of different fertilization systems has a significant effect on the wheat yield (Figure 1). Compared to unfertilized plots, all systems applied (mineral fertilizers, liquid manure and harvest residue) increased the wheat yield, but higher doses of mineral fertilizers (N₁₅₀P₁₅₀K₁₅₀ and N₂₀₀ + LM) did not have economical justification for wheat.

Plowing under harvest residues has positive effect on wheat yield.

Application of liquid manure with higher doses of N fertilizers (LM + N₂₀₀), not only had the minor effect on the yield, but also left the highest concentration of nitrates in soil profile after the wheat harvest (Figure 1).



Whitin the same trial bars followed by the same letter are not significantly different at $p < 0.05$

Figure 1: Effect of mineral fertilizers, liquid manure and plowing under harvest residues on wheat yield (t ha^{-1}) and concentration of nitrates (kg ha^{-1}) in soil profile (0-90 cm) after wheat harvest

Effect of different fertilization systems on soil properties

The long-term fertilization affected not only the wheat yield, but also most of soil properties (Figure 2-4). Because of high buffer capacity and carbonate content of chernozem, the fertilization systems did not affect soil pH in topsoil (0-30 cm), but the impact of liquid manure on pH could be recognised (not shown). A higher pH value (from +0.1 to +0.2) was found in treatments with liquid manure, than in other treatments. Similar effects were also noticed in five long-term trials in the Czech Republic (Baier et al., 2001), where the use of manure (40 t FYM ha^{-1} ones in four years) during 17 years slightly improved the pH (+0.07).

As expected, the soil organic matter (SOM) was influenced by fertilization. Figure 2 presents differences in SOM content between the content in the year when the trial was established and after long-term application of fertilizers. It was obvious that omitting fertilization led to decrease in SOM content in the topsoil. Many long-term experiments have affirmed that SOM is increased by the application of both mineral fertilizer and manure (Kubat et al., 2001; Walther et al., 2001), but in our research, only fertilizer application did not affect SOM content positively.

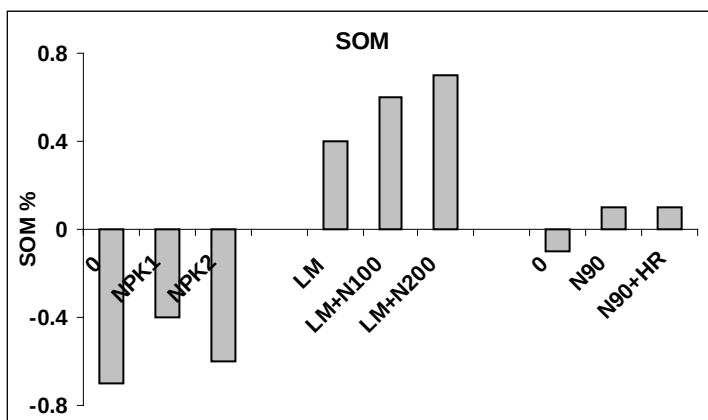


Figure 2: Differences in SOM content (%) in the topsoil (0-30 cm) between the content in the year when the trial was established and after long-term application of mineral fertilizers (NPK), liquid manure (LM) and plowing under harvest residues (HR)

In contrast to that, the liquid manure application increased SOM content significantly. Albert (2001) also found that FYM increased SOM to a higher level when compared to mineral fertilizer. Besides supplying nutrients, FYM and LM is also a source of organic C, and therefore adding manure is considered more effective in increasing SOM content than inorganic fertilizers (Singh et al., 1997; Uhlen, 1991).

The P-AL and K-AL were increased by fertilization (Figure 3 and 4), but in the trial with liquid manure the omission of P and K fertilization led to a decrease in P-AL and K-AL concentration.

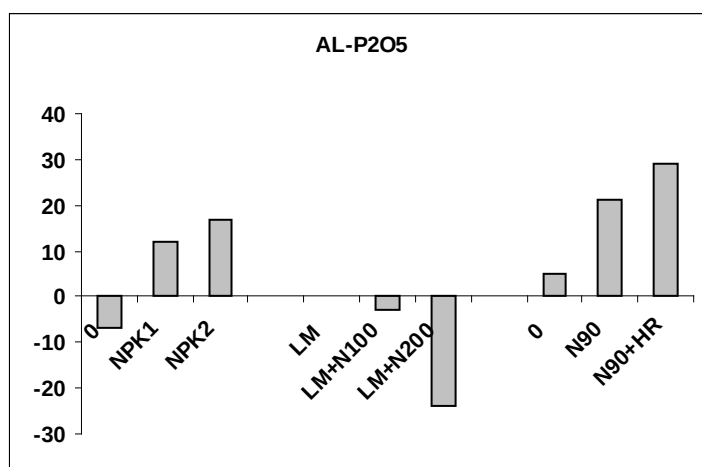


Figure 3: Differences in P-AL content (mg 100⁻¹ g) in the topsoil (0-30 cm) between the content in the year when the trial was established and after long-term application of mineral fertilizers (NPK), liquid manure (LM) and plowing under harvest residues (HR)

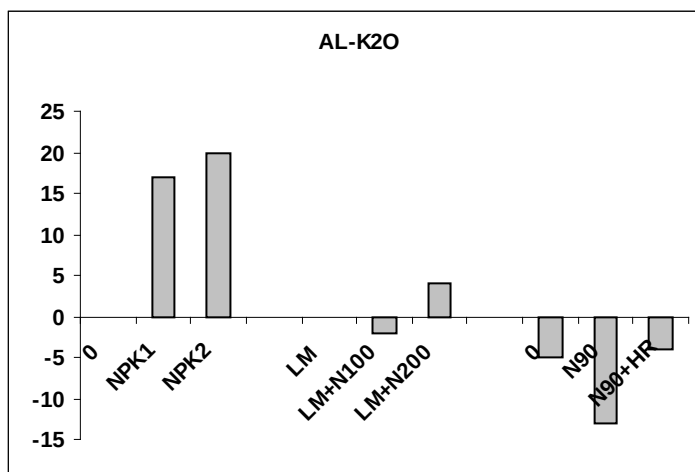


Figure 4: Differences in K-AL content (mg 100⁻¹ g) in the topsoil (0-30 cm) between the content in the year when the trial was established and after long-term application of mineral fertilizers (NPK), liquid manure (LM) and plowing under harvest residues (HR)

Conclusion

Unfertilization for a long-term, even on the chernozem, a high productivity soil type, led to a decrease in soil fertility, especially in SOM. Soil fertility detriment, as a consequence caused a decrease in yield.

Long-term only mineral fertilizers application is enough to sustain of SOM at the sufficient level, but plowing under harvest residues had better effect.

The application of liquid manure (60 m³ ha⁻¹) positively affected SOM, but liquid manure with higher doses of N fertilizers (LM + N₂₀₀) left non-permitted concentration of nitrates in soil profiles after wheat harvest.

References

- Albert E (2001) Effect of long-term different mineral and organic fertilization on yields, humus content, net N-mineralization and N-balance. Arch Acker- Pfl Boden, 46: 197-214
- Egner H, Riehm H & Domingo WR (1960) Untersuchungen über die chemische Bodenanalyse als Grundlage für die Beurteilung des Nährstoffzustandes der Böden. II Chemische Extraktionsmethoden zur Phosphor- und Kaliumbestimmung. Kungl Lantbr Högsk Ann 26: 199-215
- Körschens M (1998) Soil Organic Matter and Sustainable Land Use. Advances in GeoEcology 31: 423-430
- Kubát J, Klir J & Cerhanová D (2001) Quantification of the carbon and nitrogen cycles in long-term field experiments in Prague. Arch Acker- Pfl Boden, 46: 297-312.
- Lal R & Stewart BA (1995) Managing soils for enhancing and sustaining agricultural production. In: Lal R, Stewart BA (Eds), Soil Management: Experimental Basis for Sustainability and Environmental Quality, Lewis Publishers, Boca Raton, pp 1-9
- Láng I (1994) Nutrient cycling and sustainability. Fertilizers and environment, edited by C. Rodriguez-Barrueco. Kluwer Academic Publishers. Development in plant and soil sciences, Vol. 66: 83-87.

- Singh BR, Borresen T, Uhlen G & Ekeberg E (1997) Long-Term Effect of Crop Rotation, Cultivation Practices, and Fertilizers on C Sequestration in Soils in Norway. Chap. 14 In: Lal R, Kimble J, Follet R & Stewart B (ed.), Management of C Sequestration in Soil. pp 195-208, CRC Press, New York
- Uhlen G (1991) Long-term Effect of Fertilizers, Manure, Straw and Crop Rotation on Total-N and Total-C in Soil. Acta Agric Sca 41: 119-127
- Walther U, Weisskopf P, Oberhoizer HR & Knecht K (2001) 50 years of organic and mineral fertilization: humus content, n-utilization and N-balances. Arch Acker- Pfl Boden, 46: 265-280.

EFFECT OF DIFFERENT P SOURCES AND SOIL PROPERTIES ON TRACE ELEMENT UPTAKE OF SPRING BARLEY IN A POT EXPERIMENT

E. Osztoics¹, P. Csathó^{1*}, M. Magyar¹, T. Németh¹ and A. Osztoics²

¹ Research Institute for Soil Science and Agricultural Chemistry, H-1022 Budapest, Herman O. út 15, Hungary, E-mail: csatho@rissac.hu

² Budapest University of Technics and Economics, Dept. Of Sanitary and Environmental Engineering, H-1111 Budapest, Műegyetem rakpart 3.

Abstract

Rock phosphates contain different quantities and qualities of heavy metals and other potentially toxic elements according to their deposit. Varying proportions of these contaminants in rock phosphates can be transferred to P fertilizers, depending on the manufacturing process. Results of studies have shown that these heavy metals and potentially toxic contaminants in different P sources may accumulate in soil with repeated P fertilizer applications and may be available to plants. In addition to this different forms and rates of P-fertilization may change the soils' original pH, thus affect the availability of various elements and their transport to the crop plants.

The impact of various rates of single superphosphate (produced from Russian magmatic Kola rock phosphate) and directly applied, ground, reactive, sedimental Algerian rock phosphate on soil pH and on the trace element concentration of spring barley were studied in a pot experiment carried out on several acid soils, originating mainly from the Carpathian Basin.

The Cd and Cr content of the applied rock phosphate was higher than the permitted Hungarian threshold level. Superphosphate has high Sr content. Changes in soil pH affected mainly the Mn concentrations in the plant. This is why we focused on Cd, Cr, Sr and Mn uptake of spring barley.

The experiment was set up with equal doses (50, 100, 400 mg P₂O₅ kg⁻¹) of the two P forms. Besides this, extra high rock phosphate doses were also applied in the pot trial.

At increasing P application rates, soil pH decreased when superphosphate was added, but increased when the P was given in the form of rock phosphate. The differences among soil properties (original pH, soil texture) and those differences in soil pH, affected by the different P forms, or rates, were reflected in the Cd, Cr, and Mn concentrations of spring barley. Plant concentrations of these elements were smaller on the slightly acidic than on the strongly and extremely strongly acidic soils. Cd and Sr uptake also depended on their amount given with P-fertilizers. The Mn content of the undeveloped plants grown on extremely acidic soils was many-times higher than that of healthy plants. Elemental concentrations in the vegetative parts were generally higher than those in the grains.

Introduction

Rock phosphates contain heavy metals and other potentially toxic elements. Concentrations of these elements vary considerably with element and with region (Syers et al., 1986; Kponblekou & Tabatabai, 1994; Mortvedt & Beaton, 1995; Van Kauwenbergh, 1997). Varying proportions of these contaminants in rock phosphates can be transferred to P fertilizers, depending on the manufacturing process (Mortvedt & Beaton, 1995; Mortvedt, 1996; Syers & Cisse, 2000).

Results of studies have shown that these heavy metals and potentially toxic contaminants in different P sources may accumulate in soil with repeated P fertilizer applications and may be available to plants (Rothbaum et al., 1986; Sauerbeck, 1992; Györi et al., 1994; McLaughlin et al., 1996; Gavi et al., 1997).

The microelement and heavy metal uptake by plants from soil is mainly influenced by the pH, organic matter content, redox potential, cation exchange capacity, clay content, Fe-oxide content of the soil, hydrological conditions, temperature and the plant species. Soil pH has greatly influence the uptake of nutrient elements and pollutants. Generally the mobility of microelements and heavy metals increases with soil acidity. In addition to this different forms and rates of P-fertilization may change the original pH of the soils, thus affect the availability of various elements and their transport to the crop plants.

In the study presented here, the impact of various rates of single superphosphate (produced from Russian magmatic Kola rock phosphate) and directly applied, ground, reactive, sedimental Algerian rock phosphate on soil pH and plant uptake of Cd, Cr, Sr and Mn by spring barley were studied in a pot experiment on 6 different types of acidic soils.

Materials and Methods

The soils used in the experiment originated from Hungary, Romania, Slovakia and Algeria (Table 1.). Total Cd, Cr, Sr and Mn content in the soils and in the P-sources were determined by inductively coupled plasma emission spectrometry (ICP) after digesting the samples with a mixture of cc. HNO_3 and H_2O_2 (Table 1.).

Table 1: Characteristics and content of Cd ,Cr, Sr, Mn of the soils and fertilizers used in the pot experiment

	Super-phosphate	Rock phosphate	Soils					
			1.	2.	3.	4.	5.	6.
pH-H ₂ O			5.59	6.50	4.38	3.62	5.24	6.02
pH-KCl			4.25	5.56	3.71	3.40	4.03	5.55
hydrolytic acidity			13.3	9.3	19.5	26.5	21.6	7.7
humus, %			1.67	3.81	1.06	1.54	2.7	1.53
CEC, meq 100 g ⁻¹			9.31	30.1	8.5	8.1	11.0	4.9
base sat., meq100 g ⁻¹			8.7	29.4	4.2	0.74	3.7	4.4
total P, mg kg ⁻¹			801	525	493	688	211	198
water sol.-P, mg P kg ⁻¹			5.1	6.9	5.4	2.4	2.1	6.9
Cd, total, mg kg ⁻¹	0.9	18.3	0.30	0.22	0.16	ND	0.38	ND
Cr, total , mg kg ⁻¹	1.9	191	28.4	25.3	15.1	14.5	12.6	12.6
Sr, total, mg kg ⁻¹	13200	1769	33.9	25.9	5.1	2.9	3.6	6.8
Mn, total, mg kg ⁻¹	136	32	941	904	368	668	1177	64

Hungarian soils: **1. moderately acidic** pseudogley brown forest soil (Szentgyörgyvölgy) **2. slightly acidic** chernozem brown forest soil (Kompolt) **3. extremely acidic** sandy brown forest soil with thin interstratified layers of colloid and sesquioxide accumulation (Nagykorpád) *Rumanian soil* **4. extremely acidic** podzol soil (Livada) *Slovakian soil:* **5. strongly acidic** typical podzol soil (Lucenec) *Algerian soil:* **6. slightly acidic** sandy soil

Limit of detection by ICP: Cd:0.135; Cr:0.305; Sr:0.02; Mn:0.50 mg kg⁻¹.

ND: non detectable.

The experiment was set up with equal doses (50, 100, 400 mg P₂O₅ kg⁻¹) of the two P forms. Besides this, extra high rock phosphate doses were also applied in the pot trial. Soil pH was assessed also after fertilizer application. Spring barley was cut at 11 week stage. Elemental composition of the air-dried and ground plant parts was determined by ICP after wet digestion of the samples in cc. HNO₃+H₂O₂.

Results

In each of the soils, at increasing P application rates (with addition of the same amount of NK), the original soil pH decreased by 0.1-0.7 units when superphosphate was applied but increased by 0.3-1.0 units when P was given in the form of rock phosphate (Fig.1). The extent of these changes was different for the 6 soils, depending on original pH and texture.

The Cd and Cr contents of the applied Algerian rock phosphate were higher values than the permitted Hungarian threshold level (allowing 8 mg Cd kg⁻¹ rock above 20% P₂O₅ content and 100 mg Cr kg⁻¹ rock). Superphosphate has a high Sr content, because igneous apatites are commonly substituted with strontium and rare earth elements. Changes in soil pH affected

mainly the Mn concentrations in the plant. This is why we focused on Cd, Cr, Sr and Mn uptake of spring barley.

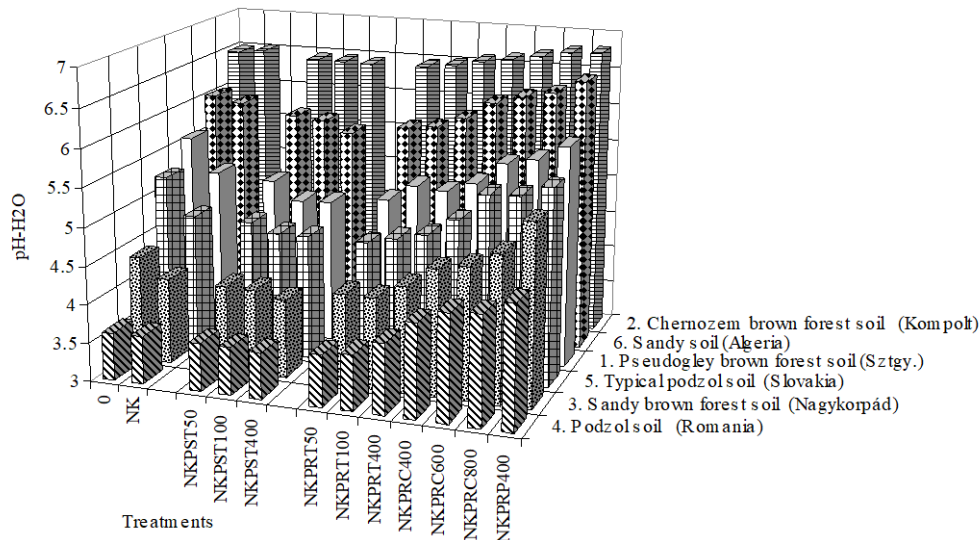


Figure 1: Treatments of the experiment, and their effect on soil pH

PS = superphosphate PR = rock phosphate; 50, 100, 400...= Active P ingredients, mg P_2O_5 kg^{-1} soil calculation of active ingredient based on: mineral acid-soluble- P_2O_5 content (PST and PRT); 2 % citric acid-soluble- P_2O_5 content (PRC) and alkaline NH_4 -citrate- soluble- P_2O_5 content according to Petermann (PRp)

These elements in the spring barley were present in different concentrations. In the grain Mn contents were the highest (ranged from 15 to 60 mg kg^{-1}), Sr concentrations were between 0.7-12 mg kg^{-1} , Cr and Cd contents were below the detectable limit. In the by-products (vegetative parts of the shoot) Mn contents also were the highest (ranged from 40 to 2200 mg kg^{-1}), Sr concentrations were between 20-700 mg kg^{-1} , Cd contents were between the detectable limit and 1 mg kg^{-1} , Cr contents were below the detectable limit except in the plants grown on the extremely acidic Rumanian soil. (On the most acidic Rumanian podzol soil ($pH-H_2O < 4.0$) in the control and PS treatments, as well as in lower PR treatments in the spring barley no grains developed. In these treatments plants were undeveloped).

Cd concentration of by-products was affected by both the soil properties and rock phosphates levels. Extreme rock phosphate doses increased by-products Cd content, except for the Rumanian soil. Both the undeveloped plants and the healthy ones grown on extremely acid Rumanian soil, showed similar by-product Cd concentrations (Figure 2).

Cr in spring barley by-products was in detectable concentration only in plants grown on the strongly acid Nagykorpad soil and in the control pots of Algerian sandy soil (2, and 0.6 mg kg⁻¹, resp.). Cr was also detectable (>1 mg kg⁻¹) in the undeveloped plants grown on the extremely acid Rumanian soil, but was not in the healthy plants, grown in the same soil.

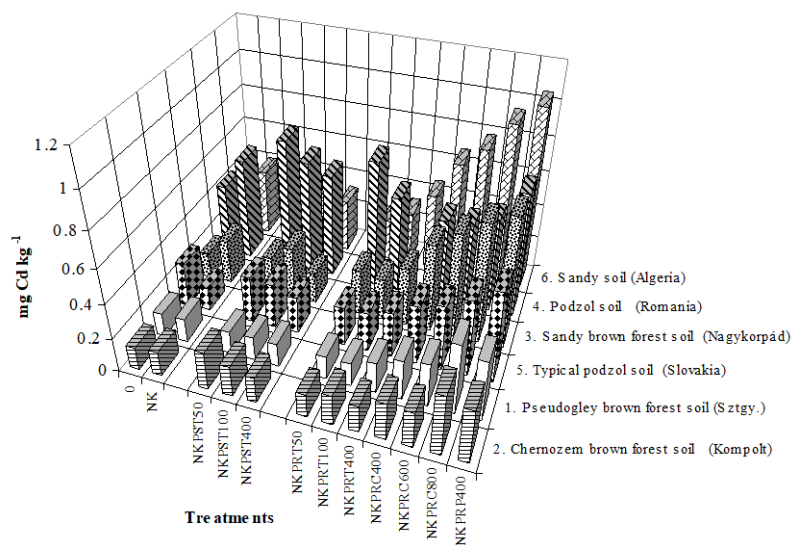


Figure 2: Cadmium concentration in spring barley by-products

Sr is chemically similiary to Ca, and is capable of substituing it partly in plants. The danger in plant uptake of Sr is purported by ⁹⁰Sr isotope (nuclear explosion). Spring barley grain Sr concentration was a magnitude lower than by-product Sr content (Fig.3.).

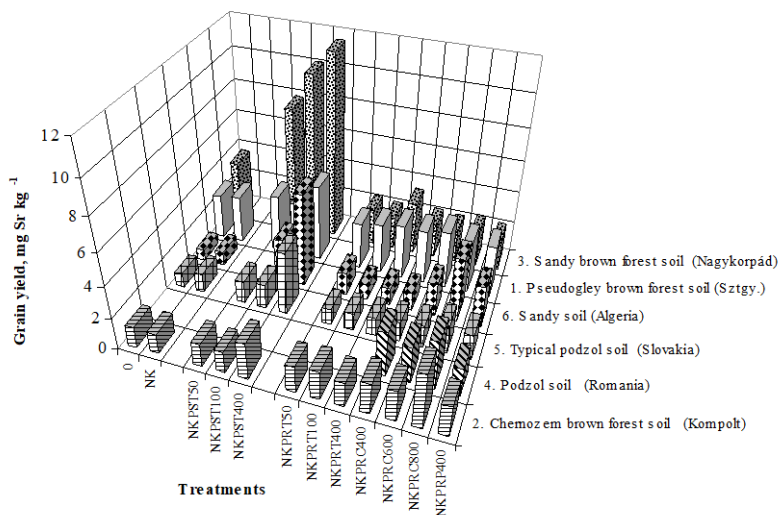


Figure 3: Spring barley grain Sr concentration

High Sr contamination in Kola superphosphate resulted in an increase of both grain and by-product Sr concentrations (Fig. 3). Among P treatments, highest barley Sr contents were obtained at the 400 mg P_2O_5 kg^{-1} superphosphate dose (grain: 2.3 to 11.5 mg kg^{-1} , by-product: 49 to 730 mg Sr kg^{-1}). Highest grain Sr content was detected in the superphosphate treatments in the extremely acid Nagykorpad soil (7.8 to 11.5 mg Sr kg^{-1}). Highest by-product Sr concentrations were obtained at the superphosphate treatments of the extremely acid soils (100 to 730 mg Sr kg^{-1}). All over highest plant Sr content were measured in the underdeveloped plants grown in the Rumanian soil. Independently from soil properties, by-product Sr contents were not increased at such a level, not even at the extremely high rock phosphate treatments.

The Mn concentration of the plants grown in pots is higher than other element concentrations. This is probably due to the character of the pot experiment itself. In the pot experiment soils are moist during plant development. Mn uptake from the soil is influenced mainly by pH and oxidation–reduction conditions, which depend on soil moisture conditions.

In Mn concentrations of the spring barley (by-products and grains) great differences were found among the six soils which could be related to the differences among the original pH and texture of the soils, and to the changes in soil pH caused by the different P forms and rates of P-fertilization treatments. Mn contents in the plants were smaller on the slightly and moderately acidic than on the strongly, and extremely strongly acidic soils and the P fertilization had slightly effect on the uptake (Fig. 4.).

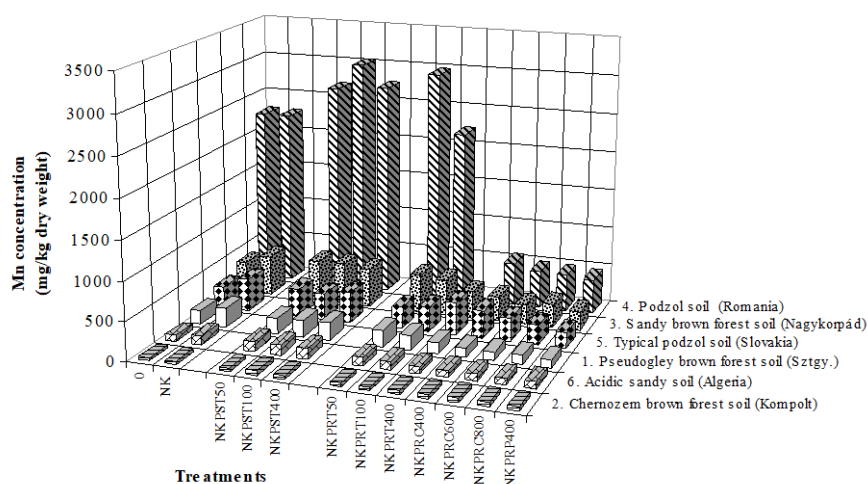


Figure 4: Mn concentration in by-products of spring barley

The Mn concentrations in the vegetative parts were about one order of magnitude greater than those in the grains (except the slightly acidic chernozem brown forest soil, Kompolt).

The yields of the experimental plants on the extremely strongly acidic soils were strongly depressed in the treatments of the lowest soil pH values (yield was very low or no grains developed). Mn concentrations in these plants were very high (On the most acidic Rumanian podzol soil there were above 2000 mg kg⁻¹ dry weight.). On the extremely strongly acidic soils at increasing rock phosphate application rates, the Mn content of the plants decreased, where the soil pH exceeded the original values measured in the control treatment, or for the extremely acidic podzol soil was above pH 4.

While the Mn- concentration of the vegetative parts was strongly dependent on soils' original pH (Fig. 4.), Mn concentrations in the grains were only slightly. In consequence, the Mn concentration ratios between the by-products and the grains were lower at the higher pH values.

Discussion and Conclusions

At increasing P application rates, the original pH of the soils decreased when superphosphate was applied but increased when the P was given in the form of rock phosphate.

Plant element uptake was determined by the soil properties of the six soils. Usually, element concentration was lower in the plants grown in slightly acidic soils, than in those grown in strongly or extremely acid soils. Plant element uptake was also affected by the amount of metals given with P-fertilizers (Cd, Sr), as well as by the changes in soil pH caused by the different P-fertilization treatments (Mn).

Cr and Mn content of underdeveloped plants grown in extremely acid soils was several times higher than of those in by-products of healthy plants. Mn concentrations in the vegetative parts were generally higher than those in the grains. While the Mn-content of the vegetative parts of spring barley was strongly dependent on soils' original pH, Mn concentrations in the grains were only slightly dependent. In consequence, the Mn concentration ratios between the by-products and the grains were higher at the lower pH values. Soil pH was found to be the soil factor greatly influencing the soil-plant transfer of Mn. Our data indicate that not only the soil-plant transfer of Mn, but also the distribution of Mn already taken up into the plant among the vegetative and reproductive parts is strongly affected by soil pH.

Spring barley grain and by-product Sr content ncreased significantly as an affect of superphosphate application.

The Cd and Cr content of the applicated rock phosphate was higher than the permitted Hungarian threshold level. However, none of these elements were detectable in spring barley grain yields, grown in our pot trials, not even at the extremely high rock phosphate treatments. Cr content of the by-products were also under the detectable limit, even in healthy plants grown in extremely acid soils. By-products Cd contents, however, were increased in some extend, depending on soil properties.

Acknowledgment

This study was conducted in the topic of the Hungarian National Research Fund (OTKA) under Grant No. T 038046.

References

- Gavi, F., Basta, N. T. & Raun, W. R., 1997. Wheat Grain Cd as Affected by Long-term Fertilization and Soil Acidity. *J. Environ. Qual.* 26. 265-271.
- Győri, Z., Goulding, K., Blake, L. & Prokicsh, J., 1994. Soil Analyses in the Rothamsted Park Grass Experiment. *Agrokémia és Talajtan* 43. 319-327.
- Van Kauwenbergh, S. J., 1997. Cadmium and Other Minor Elements in World Resources of Phosphate Rock. *Fertilizer Society* 1-40.
- Kponblekou, A. & Tabatabai, M., 1994. Metal Contents of Phosphate Rocks. *Commun Soil Sci Plant Anal.* 26. 2781-2882.
- McLaughlin, M.J., Tiller, K.G., Naidu, R. & Stevens, D. P., 1996. Review: The Behavior and Environmental Impact of Contaminants in Fertilizers. *Aust. J. Soil Res.* 34. 1-54.
- Mortvedt, J. J. & Beaton, J. D., Heavy Metal and Radionuclide Contaminants in Phosphate Fertilizers. In *Phosphorus in the global environment. Transfers, cycles and management.* Tiessen, H., Ed.; SCOPE. Wiley & Sons Ltd, 1995; 93-105.
- Mortvedt, J. J., 1996. Heavy Metal Contaminants in Inorganic and Organic Fertilizers. *Fert. Res.* 43. 55-61.
- Rothbaum, H. P., Goguel, R. L., Johnston, A. E. & Mattingly, G. E. .G. M., 1986. Cadmium Accumulation in Soil from Long-continued Applications of Superphosphate. *J. Soil Sci.* 37. 99-107.
- Sauerbeck, D., 1992. Conditions Controlling the Bioavailability of Trace Elements and Heavy Metals Derived from Phosphate Fertilizers in Soils. *Proc. IMPHOS. Conf. On Phosphorus, Life and Environment, Casablanca,* 419-448.
- Syers, J. K., Mackay, A. D., Brown, M. C. & Currie, L. D., 1986. Chemical and Physical Characteristics of Phosphate Rock Materials of Varying Reactivity. *J. Sci. Food Agric.* 37. 1057-1064.
- Syers, J. K. & Cisse L., 2000. Regional Differences in the Inputs of Cadmium to Soils. *Environmental Cadmium in the Food Chain: Sources, Pathways, and Risk*; Syers, J. K., Gochfeld. M., Eds.; Proceedings of the SCOPE Workshop Belgian Academy of Sciences, Brussels, Belgium, 54-59.

DISSOLVED ORGANIC CARBON (DOC) AND DISSOLVED ORGANIC NITROGEN (DON) CONTENT OF AN ARENOSOL AS AFFECTED BY LIMING IN POT EXPERIMENT

T. Filep¹, P. T. Nagy², I. Kincses² and A. B. Kovács²

¹Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Budapest, Hungary

²University of Debrecen, Department of Agricultural Chemistry, Debrecen, Hungary

Introduction

Dissolved organic matter (DOM) participates in numerous processes in soils, e. g. mineral weathering (Raulund-Rasmussen et al., 1998) and transport of nutrients and pollutants (Kalbitz et al., 1997; Qualls et al., 1991). Nevertheless, DOM can be regarded as an easily mineralisable nutrient source not only for plants, but also for microorganisms.

Physical, chemical and biological factors and/or the combination of this control the DOM content of soil (Kalbitz et al., 2000). Changes in soil pH by the use of liming materials result in physico-chemical changes and microbiological alteration in soils and these changes have an influence on DOM concentration. In addition to changes in DOM quantity, there may be an alteration in the composition of dissolved organic matter, e. g. the carbon and nitrogen content of that (dissolved organic carbon, DOC and dissolved organic nitrogen, DON) changes after liming.

Relations between DOC and liming have been investigated in several studies (Grieve, 1990; Andersson et al., 1994). It has been concluded that the DOC concentration increased with increasing lime doses. The reason for this is that the solubility of DOM increased with pH by increasing the negative charge of the molecule (Tombácz and Meleg, 1990). In addition – because of increased microbial activity – the DOC concentration increased (Kreutzer, 1995), because of increasing the organic matter degradation rate.

There have been a few studies on the effect of liming on DON content of soil. Kreutzer (1995) and Andersson et al. (1999, 2000) showed an increase in DON concentration as the amount of lime materials applied increased. It means that the DOC/DON ratio was unaffected by liming. In these experiments, either DON was roughly estimated from DOC concentration (Kreutzer, 1995) or changes of DOC and DON concentrations were investigated in experiment without plants (Andersson et al., 2000), therefore the present study examined DOC and DON dynamics in the plant-soil system.

The objectives were: (i) to investigate the lime effects on DOC, DON content and the ratio of DOC/DON in the soil.

Materials and Methods

Sites and Sampling

The soil used was a Luvic Arenosol (according to FAO classification) from Kisvárda. The samples were taken from the 0-20 cm layer, air-dried and passed through a 2-mm sieve.

Soil Characterisation and Analysis

Soil pH was measured in aqueous suspension following 24 h sedimentation at room temperature. CEC were determined, using non-buffered $\text{BaCl}_2\text{-MgCl}_2$ solution (Houba et al., 1989). Hydrolytic acidity (y_1) was determined by means of titration of 50 g soil extracted with Ca-acetate (pH 8.2). The total carbon and nitrogen content of the soil were analysed using an Elementar Vario EL CNS analyser based on the dry combustion method.

The selected properties of the soil were: pH (1:2.5 soil/ H_2O) 4.38; CEC (cmol+/kg) 2.67; y_1 12.6; C (g/kg) 3.65; N (g/kg) 0.47; C/N 7.8.

Pot Experiment

11 kg previously sieved (2 mm) soil was dispensed into each pot. The oat seeds (*Avena sativa* L.) were sown on 7th April 2000. Water content was set to 75% of the water capacity. Water loss via evapotranspiration was determined by weighing and was replaced with deionized water.

The experimental design was randomised complete block with 7 treatments and 9 replicates. The treatments applied are shown in Table 1. The liming materials have been mixed thoroughly with the soil. Lime doses were calculated from the hydrolytic acidity of the soil (Filep, 1999; Balogh, 1992). Treatments were performed with the same amount 90.9 mg/kg soil of N, P and K (introduced in a mixture of $\text{NH}_4\text{H}_2\text{PO}_4$, NH_4NO_3 and KCl).

Soil samples (3-3 replicates) were taken three times during the growing period, 6, 10 and 15 weeks after planting, respectively.

Table 1: Treatments

<i>Treatments</i>	<i>Lime doses (g kg)</i>	<i>Remarks</i>
Control	0	
C ₁	1	Calcite, a half lime dose calculated
C ₂	2	Calcite, lime dose calculated
C ₃	3	Calcite, 1.5 fold lime dose calculated
D ₁	0.92	Dolomite, a half lime dose calculated
D ₂	1.84	Dolomite, lime dose calculated
D ₃	2.76	Dolomite, 1.5 fold lime dose calculated

DOC and DON concentrations were measured in 0.01 M CaCl₂ extracts for 2 h with 1:10 soil:solution ratio (Jászberényi et al., 1994). DOC was estimated by spectrophotometry by calibrating the absorbance of the extracts at $\lambda = 254$ nm with soils of known DOC content (Moore, 1985). DON was determined by measuring the difference between total dissolved nitrogen and inorganic nitrogen ($\text{NO}_3^- + \text{NH}_4^+$) as described by Houba et al. (1994).

The statistical analysis was performed using SPSS 9.0 for Windows. Treatment effects were estimated by one-way ANOVA with Tukey's HSD range test at $p < 0.05$.

Results and Discussion

Effect of Liming on DOC, DON Concentration and DOC/DON Ratio

Dissolved organic carbon content of the soil increased significantly with increasing liming at all three samplings (Table 2).

The main external factors influencing DOM solubility are pH and ionic strength (Tipping and Woof, 1990). Increasing pH induced the application of lime materials, the net negative charge of the molecule increased, leading to a steric conformation change of that. At high pH, DOM molecules are in an expanded structure (Rice et al., 2000), because charges endeavour to situate themselves as far apart as possible. Owing to the expanded structure and the net negative charge, the molecule can be penetrated fully by water (Tombácz and Rice, 1999), therefore it become hydrophilic.

It also can be taken account that changes in pH involve the alteration of adsorption/desorption conditions of DOC. In most studies (Jardine et al., 1989; Gu et al., 1994) the increased pH

resulted in DOC desorption as a consequence of the decrease in positive charge of clay minerals and Al-, Fe-hydroxides.

Table 2: Effect of lime treatments on dissolved organic carbon (DOC) and nitrogen (DON) content of the soil

<i>Treatment</i> ¹	<i>1st Sampling</i>		<i>2nd Sampling</i>		<i>3rd Sampling</i>	
	DOC	DON	DOC	DON	DOC	DON
mg/kg						
Control	12.5 <i>a</i> ²	5.7 <i>a</i>	9.4 <i>a</i>	3.8 <i>a</i>	20.0 <i>a</i>	4.8 <i>a</i>
C ₁	34.9 <i>ab</i>	5.6 <i>a</i>	21.4 <i>ab</i>	3.6 <i>a</i>	28.5 <i>ab</i>	5.0 <i>a</i>
C ₂	56.9 <i>bc</i>	6.1 <i>a</i>	45.9 <i>cd</i>	4.3 <i>a</i>	50.9 <i>cd</i>	5.2 <i>a</i>
C ₃	70.0 <i>c</i>	7.4 <i>b</i>	58.5 <i>d</i>	4.4 <i>a</i>	62.0 <i>d</i>	5.7 <i>a</i>
D ₁	25.1 <i>ab</i>	5.4 <i>a</i>	21.1 <i>ab</i>	4.2 <i>a</i>	21.6 <i>ab</i>	3.7 <i>a</i>
D ₂	40.4 <i>abc</i>	5.9 <i>a</i>	36.4 <i>bc</i>	4.8 <i>a</i>	41.4 <i>bc</i>	5.1 <i>a</i>
D ₃	45.7 <i>abc</i>	5.4 <i>a</i>	54.5 <i>d</i>	5.6 <i>a</i>	54.7 <i>cd</i>	5.2 <i>a</i>

¹ for abbreviation of treatments see Table 1

² letters *a-d* denote significant difference at $p < 0.05$ within each column

In addition to these abiotic controls on DOC concentration, there has also been a biotic influence. The degradation rate of organic matter increased, as the microbial activity in the soil increased with increasing pH (Higashida and Takao, 1986), which results in low molecular weight, water-soluble materials.

The effect of pH on DOC concentration is shown in Figure 1. Because of the above-mentioned effects, the DOC concentration increased exponentially with increasing pH in the range investigated (pH 4-7).

In the case of DON a significant treatment effect occurred only at the first sampling, in the remainder of the growing period the increase in DON concentration was not confirmed statistically, while the DOC/DON ratio increased significantly with liming throughout the growing period (Table 3).

In literature there is some confusion, whether DON decay is faster than DOC? According to Qualls and Haines (1992) the DON degradation rate is not higher than that of DOC. In contrast to this, Scherrer et al. (1992) found that DON was more biodegradable than DOC. It seems to be the rate of the biodegradation processes differs in our study. Although the amount of

dissolved organic matter increased with pH, its N content decreased by degradation processes, which changed the C/N ratio in DOM.

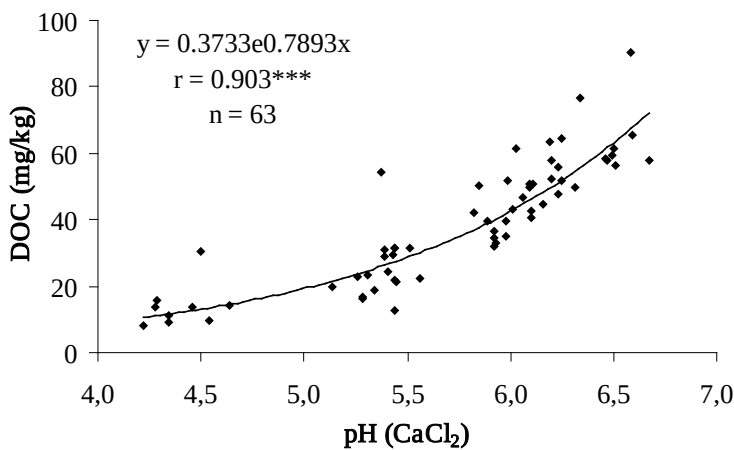


Figure 1: The effect of pH on DOC concentration in pot experiment

Table 3: Treatments effect on DOC/DON ratio in soil

<i>Treatment</i> ¹	<i>1st Sampling</i>	<i>2nd Sampling</i>	<i>3rd Sampling</i>
	DOC/DON	DOC/DON	DOC/DON
	mg/kg		
Control	2.2 <i>a</i> ²	2.8 <i>a</i>	4.3 <i>a</i>
C ₁	6.3 <i>ab</i>	6.0 <i>ab</i>	5.7 <i>ab</i>
C ₂	9.3 <i>b</i>	10.9 <i>b</i>	9.8 <i>c</i>
C ₃	9.5 <i>b</i>	13.9 <i>c</i>	10.9 <i>c</i>
D ₁	4.7 <i>ab</i>	5.2 <i>ab</i>	5.9 <i>ab</i>
D ₂	6.8 <i>ab</i>	7.6 <i>ab</i>	8.5 <i>bc</i>
D ₃	8.4 <i>b</i>	9.7 <i>b</i>	10.7 <i>c</i>

¹⁾for abbreviation of treatments see Table 1

²⁾ letters *a-c* denote significant difference at $p < 0.05$ within each column

In addition to above mention, there may be an other reason for an increase in the DOC/DON ratio. Liming increased the amount of nitrogen poor hydrophobic compounds more than the amount of nitrogen rich hydrophilic compounds (Andersson et al., 2000). As hydrophobic compounds have greater selectivity to soil than hydrophilic ones (Andersson et al., 1999), this has caused an increase in the DOC/DON ratio.

Acknowledgement

This work was funded by the Hungarian Research Fund (OTKA F 032328).

References

- Andersson, S., Nilsson, I. and Saetre, P. (2000) Leaching of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) in mor humus as affected by temperature and pH. *Soil Biol. Biochem.*, **32**, 1-10.
- Andersson, S., Nilsson, I. and Valeur, I. (1999) Influence of dolomitic lime on DOC and DON leaching in a forest soil. *Biogeochemistry*, **47**, 297-317.
- Andersson, S., Valeur, I. and Nilsson, I. (1994) Influence of lime on soil respiration, leaching of DOC, and C/S relationships in the mor humus of a haplic podsol. *Environ. Int.*, **20**, 81-88.
- Balogh, I. (1992) Improving Mg supply with chemical melioration (in Hung.). In: *The importance and source of magnesium*. (Eds. Fazekas, T., Selmeczi, B. and Stefanovits, P.). Akadémiai Kiadó. Budapest. 113-115.
- Filep, Gy. (1999) Soil amelioration (in Hung.). In: *Soil science*. (Eds. Stefanovits, P., Filep, Gy. and Fülek, Gy.). Mezőgazda Kiadó. Budapest. 347-362.
- Grieve, I.C. (1990) Seasonal hydrological, and management factors controlling dissolved organic carbon concentrations in the loch fleet catchments, Southwest Scotland. *Hydrol. Process.*, **4**, 231-239.
- Gu, B., Schmitt, J., Chen, Z., Liang, L. and McCarthy, J.F. (1994) Adsorption and desorption of natural organic matter on iron oxide: Mechanisms and models. *Environ. Sci. Technol.*, **28**, 38-46.
- Higashida, Sh. and Takao, K. (1986) Relations between soil microbial activity and soil properties in grassland. *Soil Sci. Plant Nutr.*, **32**, 587-597.
- Houba, V.J.G., Novozamsky, I. and Temminghoff, E. (1994) Soil and plant analysis. Part 5A. Soil analysis procedures extraction with 0.01 M CaCl₂. Wageningen Agricultural University. Wageningen. 12-22.
- Houba, V.J.G., van der Lee, J.J., Novozamsky, I. and Walinga, I. (1989) Soil and Plant Analysis, a series of syllabi. Part 5. Wageningen Agricultural University. Wageningen. 6/1-6/7.
- Jardine, P.M., Weber, N.L. and McCarthy, J.F. (1989) Mechanism of dissolved organic carbon adsorption on soil. *Soil Sci. Soc. Am. J.*, **53**, 1378-1385.
- Jászberényi, I., Loch, J. and Sarkadi, J. (1994) Experiences with 0.01 M CaCl₂ as an extraction reagent for use as a soil testing procedure in Hungary. *Comm. Soil Sci. Plant Anal.*, **25**, 1771-1777.
- Kalbitz, K., Popp, P., Geyer, W. and Hanschmann, G. (1997) β -HCH mobilization in polluted wetland soils as influenced by dissolved organic matter. *Sci. Total Environ.*, **204**, 37-48.
- Kalbitz, K., Solinger, S., Park, J.H., Mihalzik, B. and Matzner, E. (2000) Controls on the dynamics of dissolved organic matter in soils: a review. *Soil Sci.*, **165**, 277-304.
- Kreutzer, K. (1995) Effect of liming on soil processes. *Plant Soil*, **168-169**, 447-470.
- Moore, T.R. (1985) The spectrophotometric determination of dissolved organic carbon in peat waters. *Soil Sci. Soc. Am. J.*, **49**, 1590-1592.
- Qualls, R.G. and Haines, B.L. (1992) Biodegradability of dissolved organic matter in forest throughfall, soil solution and stream waters. *Soil Sci. Soc. Am. J.*, **56**, 578-586.
- Qualls, R.G., Haines, B.L. and Swank, W.T. (1991) Fluxes of dissolved organic nutrients and humic substances in deciduous forest. *Ecology*, **72**, 254-266.
- Raulund-Rasmussen, K., Borregaard, O.K., Hansen, H.C.B. and Olsson, M. (1998) Effect of natural soil solutes on weathering rates of soil minerals. *Eur. J. Soil Sci.*, **49**, 397-406.
- Rice, J.A., Guetloff, T.F. and Tombácz, E. (2000) Investigations of humic materials aggregation with scattering methods. In: *Humic substances. Versatile components of plants, soil and water*. (Eds. Ghabbour, E.A. and Davies, G.). The Royal Society of Chemistry. Cambridge. 135-141.
- Scherrer, H.W., Werner, W. and Rossbach, J. (1992) Effects of pretreatment of soil samples on N mineralization in incubation experiments. *Biol. Fertil. Soils*, **14**, 135-139.
- Tipping, E. and Woof, C. (1990) Humic substances in acid organic soils: Modeling their release to the soil solution in terms of humic charge. *J. Soil Sci.*, **41**, 573-586.
- Tombácz, E. and Meleg, E. (1990) A theoretical explanation of the aggregation of humic substances as a function of pH and electrolyte concentration. *Org. Geochem.*, **15**, 375-381.
- Tombácz, E. and Rice, J.A. (1999) Changes of colloidal state in aqueous systems of humic acids. In: *Understanding humic substances. Advanced methods, properties and applications*. (Eds. Ghabbour, E.A. and Davies, G.). The Royal Society of Chemistry. Cambridge. 69-78.

THE EFFECT OF MICROELEMENT LOADS ON THE NH_4NO_3 -EXTRACTABLE TRACE ELEMENTS CONTENT OF THE SOIL

T. Filep and I. Kádár

Research Institute for Soil Science and Agricultural Chemistry of Hungarian Academy of Sciences,
Budapest, Hungary

Introduction

As a result of man's activities, concentrated metal deposits that were confined to earthcrust and usually harmless to humans have been dispersed in the environment at a rate which has been greatly accelerated during the 20th century. Mobile trace elements in soils can adversely affect the quality of food and fodder plants, the growth of plants, the activity of soil microorganisms and the quality of the groundwater.

The objectives of this work was to study the NH_4NO_3 -extractable trace elements content of the soil.

Materials and Methods

The experiment was set up in 1991 at the Experimental Station of the Research Institute for Soil Science and Agricultural Chemistry in Nagyhorcsök on a calcareous chernozem soil formed on loess (Kádár et al., 2000). The ploughed layer of the site contained around 5 % CaCO_3 and 3 % humus, while the nutrient supplies were very good for Ca and Mn, good for Mg and Cu, moderate for N and K, and poor for P and Zn. The groundwater depth was 15 m and the water balance of the area was negative, tending to drought.

In order to judge the effect of microelement soil pollutants on soil fertility and maize development, the salts of 13 elements were applied at four levels each prior to sowing in spring 1991. The 52 treatments were set up in a split-plot design with two replications. The loads were 0, 90, 270 and 810 kg/ha for each element, applied in the form of AlCl_3 , NaAsO_2 , BaCl_2 , CdSO_4 , K_2CrO_4 , CuSO_4 , HgCl_2 , $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24}$, NiSO_4 , $\text{Pb}(\text{NO}_3)_2$, Na_2SeO_3 , SrSO_4 and ZnSO_4 . The extremely high rates served to model soil pollution levels.

The NH_4 -acetate + EDTA-extractable (Lakanen and Erviö, 1971) and NH_4NO_3 -extractable (Prüß et al., 1991; Prüß, 1992) element content was measured from the soil samples.

The NH_4NO_3 method contains the following procedure: Place 20 g air dry soil in a shaking bottle (100-150 ml), add 50 ml ammonium nitrate solution (1 mol/l) and shake for 2 hours at 20 revolutions per min. at room temperature. Then allow the solid particles to settle for 15 min.

Decant the supernatant solution and filter (0,45 µm). Dispose the first 5 ml of the filtrate. Collect the remaining solution in a 50 ml bottle.

Results and Discussion

The results for 13 elements were shown in Table 1. The Al, Pb and Zn concentrations using NH₄NO₃ solution were under the detection limit. On one hand, the soil investigated was neutral, moderately alkalic, which resulted in a low concentration limit in cationic microelement concentration. On the other hand, in contrast to Lakanen-Erviö solution the NH₄NO₃ solution is a non-buffered extractant, therefore its ability to remove elemets from alkalic soils much lower than that of Lakanen-Erviö solution.

In all elements, strong, linear correlation was found between the LE-soluble and ammonium-nitrate- soluble concentrations (Figure 1).

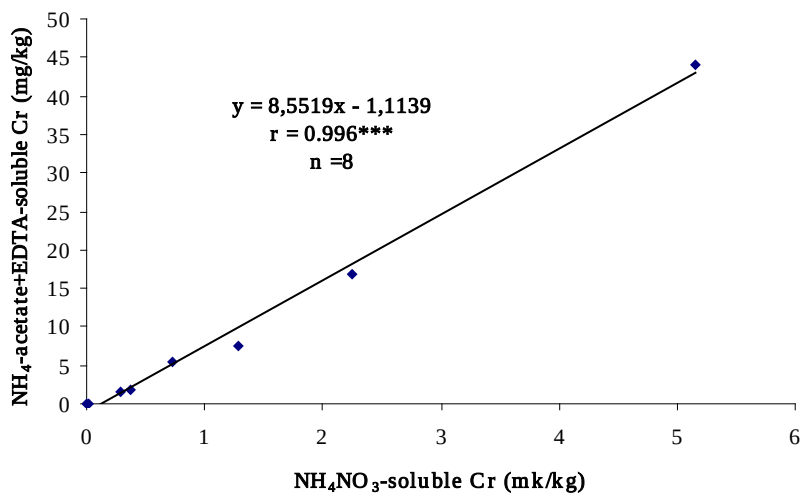


Figure 1: Relationship between 1 M NH₄NO₃- soluble and Lakanen-Erviö-soluble Cr concentrations

Table 1: The NH₄-acetate + EDTA and NH₄NO₃-extractable element content of the soil

Treatment/Element	Extractant	Load, kg/ha				Mean
		0/30	90	270	810	
<i>Al</i>	Lakenen-Erviö	67,0	73,0	86,5	90,0	79,3
	NH ₄ NO ₃	¹	-	0,47	-	0,47
As	Lakenen-Erviö	2,3	6,7	18,2	66,4	23,4
	NH ₄ NO ₃	0,15	0,23	0,80	4,39	1,39
Ba	Lakenen-Erviö	19,5	29,0	41,0	100,0	47,4
	NH ₄ NO ₃	13,8	22,1	34,3	94,5	41,2
Cd	Lakenen-Erviö	14,5	59,5	172,0	456,5	175,6
	NH ₄ NO ₃	0,15	0,80	3,10	13,85	4,48
Cr	Lakenen-Erviö	0,05	1,70	6,45	30,40	9,65
	NH ₄ NO ₃	0,01	0,33	1,00	3,70	1,26
Cu	Lakenen-Erviö	7	24	49	110	47,5
	NH ₄ NO ₃	0,14	0,27	0,48	1,06	0,49
Hg	Lakenen-Erviö	0,01	4,00	49,25	189,00	60,57
	NH ₄ NO ₃	0,04	0,19	0,89	4,09	1,30
Mo	Lakenen-Erviö	1,0	21,0	26,5	104,0	38,1
	NH ₄ NO ₃	0,4	7,3	11,2	27,8	11,7
Ni	Lakenen-Erviö	2,8	14,5	40,5	73,5	32,8
	NH ₄ NO ₃	0,01	0,11	0,33	0,72	0,29
Pb	Lakenen-Erviö	5,2	29,3	56,0	158,0	62,1
	NH ₄ NO ₃	-	-	-	-	-
Se	Lakenen-Erviö	1,1	7,4	22,5	122,5	38,4
	NH ₄ NO ₃	0,28	2,17	6,17	46,55	13,79
Sr	Lakenen-Erviö	31	49	67	147	73
	NH ₄ NO ₃	5,7	10,8	22,5	55,2	23,5
Zn	Lakenen-Erviö	2,0	13,5	54,5	153,0	55,7
	NH ₄ NO ₃	-	-	0,08	0,36	0,22

¹ concentrations under the detection limit

References

- Kádár I., Radics L. és Bana K.-né (2000) Mikroelem-terhelés hatása a kukoricaállományra karbonátos csernozjom talajon. *Agrokémiai és Talajtan*, **49**, 181-204.
- Lakanen, E. and Erviö, R. (1971) A comparison of eight extractants for the determination of plant available micronutrients in soils. *Acta Agr. Fenn.*, **123**, 223-232.
- Prüß A., Turian G. and Schweikle V. (1991) Ableitung kritischer Gehalte an NH_4NO_3 -extrahierbaren ökotoxikologisch relevanten Spurenelementen in Böden SW-Deutschlands, *Mitt. Dtsch. Bodenkdl. Ges.*, 66/1: 385-388, Oldenburg.
- Prüß A. (1992) Vorsorgewerte und Prüfwerte für mobile und mobilisierbare, potentiell ökotoxische Spurenelemente in Böden, Verlag Ulrich E. Grauer, ISBN 3-9803063-4-8: 145 S.; Wendlingen, Stuttgart.

THE IMPACT OF NUTRIENT SUPPLY ON THE YIELD OF MAIZE HYBRIDS

P. Jakab

University of Debrecen, Centre of Agricultural Sciences, Department of Crop Production and Applied Ecology, Hungary

Introduction

Nutrient supply is one of the most important agrotechnical elements of maize production. Numerous researchers have been involved in determining the optimum NPK fertilizer doses for the different maize hybrids.

Considering the aspects of efficiency and environment protection, maize needs only N_{60-120} , $P_2O_5_{45-90}$, K_2O_{53-106} kg ha⁻¹ active agent. With larger N doses than N_{60-120} kg ha⁻¹ the quantity of NO_3-N reaches 150-200 mg kg⁻¹ in the 100-120 cm soil profile which can result in marked environment pollution (Sárvári, 1995).

In the N_0 treatment, the yield decreased gradually and the cumulated yield difference was 74,0 t ha⁻¹ as compared to the basis treatment (N_{80}). In the average of 1970-1991, the grain yield of maize (t ha⁻¹) was the following as per N-treatments: N_0 : 3.56, N_{80} : 6.93, N_{160} : 8.12 and N_{240} : 8.00. In the N_{160} treatment the yield surpassed that of N_{240} treatment after the 13th year of the trial, and the cumulated extra yield was 26.3 t ha⁻¹ in comparison with the basis treatment. In wet years, the grain yield of maize was higher depending on the N-treatment by 1.13-2.28 t ha⁻¹ than in the dry years (Berzsenyi 1993).

Dobos-Nagy (1998) examined the effect of year and fertilisation on the dry matter production of the maize hybrid Volga SC on a 5-year series of data in four replications, including two favourable and three unfavourable years, without fertilisation and with a fertiliser treatment involving 120 kg ha⁻¹ N+ 90 kg ha⁻¹ P_2O_5 + 106 kg ha⁻¹ K_2O .

In the unfertilised treatment there was a significant difference in the dry matter content of the maximum vegetative mass in the years examined. In the fertilised treatment higher values were recorded each year than in the control plots, the fertiliser effect being 17-19 % in 1991, 1993 and 1994 and 22-28 % in 1992 and 1995.

Nagy (1995) determined the profitable fertilizer rate in production practice, based on the experimental data, the fertilizer active agent quantities belonging to 10 kg grain yield were fixed, these values can be converted to different economic circumstances, as well. The fertilizer rate belonging to 10 kg marginal efficiency in the non-irrigated treatment, during four years, was 111 kg ha⁻¹ N (its extreme values 89-125 kg). In the irrigated treatment, on average a rate

of 158 kg ha⁻¹ N met the condition of 10 kg marginal efficiency, which varied between 147 kg and 170 kg. It was stated, that based on the experimental data - on similar production site - without irrigation a rate of 90-120 kg ha⁻¹ N and in irrigated production a rate of 150-170 kg ha⁻¹ N may be a normal dose.

Pepó (2001) found that crop rotation strongly modified the optimum N doses (+PK) of maize. The optimum N doses were N₁₁₃+PK in triculture, N₁₄₇+PK in biculture and N₁₈₇+PK in monoculture. The efficiency of fertilization was modified by crop rotation and the water supply of the crop year. The yield surpluses resulting from fertilization were 1378 kg ha⁻¹ in triculture (peas-winter wheat-maize), 2477 kg ha⁻¹ in biculture (winter wheat-maize) and 2325 kg ha⁻¹ in monoculture. There were hybrid-specific differences between the maize genotypes in optimum N doses (+PK) in the long-term experiments (in triculture N-opt+PK 60-180 kg ha⁻¹, in biculture N-opt+PK 120-180 kg ha⁻¹, in monoculture N-opt+PK 120-240 kg ha⁻¹ depending on genotypes). In practice, the best hybrids are those that can produce high yields with the application of moderate (low) N doses (+PK).

Methods

In my research, I measured the effect of NPK fertilization on the yield of maize hybrids in 1999-2001 years.

The experiment was set up in the demonstration garden of the Department of Crop Production and Applied Ecology Centre of Agricultural Sciences the University in Debrecen. The soil of the experiment is leached chernozem soil. Humus accumulation and easy tillage are typical for this soil. In the topsoil leaching is typical, lime can not be found there. The amount of carbonates is increasing gradually downwards, and forms a precipitate in the form of colloid or microcrystal in one layer. The soil was susceptible to cracking in dry periods originating from lime deficiency. The nutrient supply of the soil is satisfactory, its nutrient dynamism is good. Humus is 50 to 70 cm thick in horizon "A". Organic matter content is 2.57 %. Soil characteristics are shown in table 1.

Table 1: Main properties of the experimental field

pH (H ₂ O)	CaCO ₃	P ₂ O ₅ (mg kg ⁻¹)	K ₂ O (mg kg ⁻¹)	Humus (%)	Soil plasticity value (K _A)
7.0	In traces	100	165	2.57	45

1999 was a favourable year for maize. The amount of rainfall in the growing period exceeded the average 35.1 mm. In 2000 and 2001, the amount of precipitation in the vegetation period of corn was lower than the average of 30 by 64.4 and 23.9 mm, respectively. The average temperature showed a positive deviation compared to the average of several years. Our small-plot experiment in randomised blocks in three replications was set up in Debrecen in 1999-2001 on leached chernozem soil. Five fertilization steps were applied in I-III replication besides the control (non fertilized) where the smallest rate was 40 kg N; 25 kg P₂O₅; 30 kg K₂O of active ingredients per hectare. The largest rate was five times higher than the smallest one: 200 kg N; 125 kg P₂O₅; 150 kg K₂O, which is equal to 475 kg mixed active ingredients. Half of the nitrogen was applied in the autumn while the other half was applied in the spring, the total amount of phosphorus and potassium was applied in the autumn. The results were calculated with variation analysis.

Results

In 1999 Colomba SC (12.57 t ha⁻¹) and Filia SC (12.17 t ha⁻¹) reached the highest yields from the ten examined hybrids in the average of the fertilizer treatments (*Figure 1*). Only Colomba SC, Filia SC, and Mv TC 514 could obtain a six-tonne yield per hectare without any fertilizers (*Figure 2*). These hybrids had the best ability to absorb and utilize nutrients. This characteristic of the hybrids can be connected with the larger absorption capacity of root hairs and their higher nitrate reductase enzyme capacity.

In 2000, the yield of hybrids ranged between 8.12-11.28 t ha⁻¹ in the average of the fertilizer treatments (*Figure 3*). By assessing the hybrids, we can conclude, that Filia SC reached the highest yield with 13.03 t/ha. On the other hand, the smallest yield was achieved by Dekalb 366 SC which was, 9.63 t ha⁻¹. Without any fertilizers, the yield of the examined hybrids ranged between 3.44-5.2 t ha⁻¹. Filia SC, Mv TC 514 and Colomba SC had the best ability to absorb and utilize nutrients. They produced a yield of 4.88-5.2 t ha⁻¹ without any fertilizers (*Figure 4*).

In 2001, the production of the examined hybrids ranged between 9.15-11.55 t ha⁻¹ in the average of the fertilizer treatments (*Figure 5*). Without any fertilizers, yields ranged between 4.22-6.2 t ha⁻¹ (*Figure 6*). Filia SC, Mv TC 514, and Colomba SC produced the highest control yields (5.65-6.2 t ha⁻¹). The maximum yield was obtained by Colomba SC, Filia SC, and DK 471 SC : 12.91-13.23 t ha⁻¹.

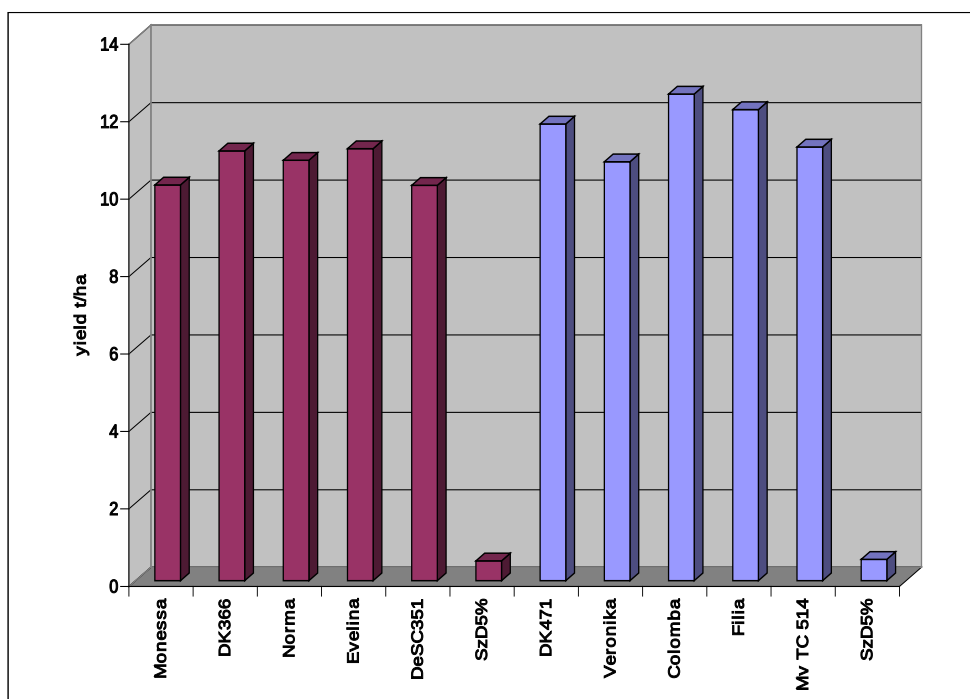


Figure 1: The yield of maize hybrids in the average of the fertilizer treatments, in 1999

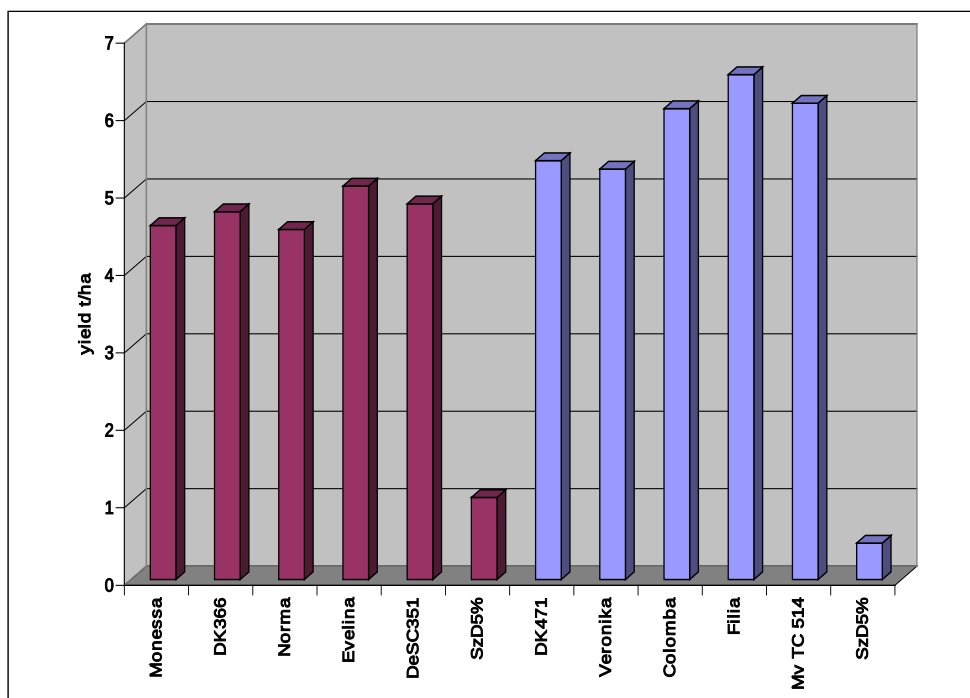


Figure 2: The natural nutrient exploration and utilisation capacity of maize hybrids in 1999

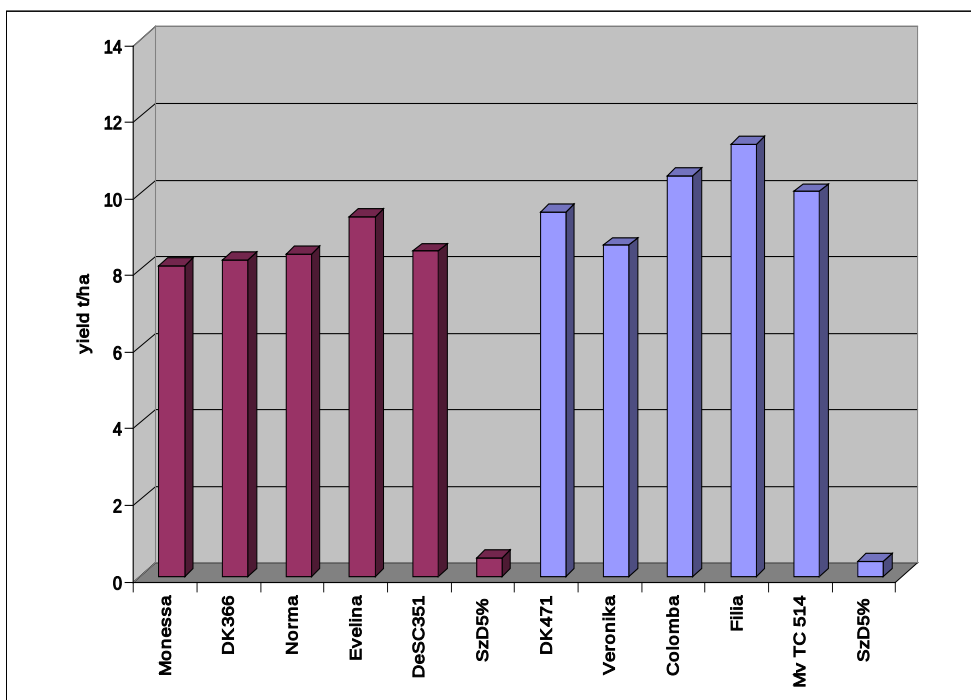


Figure 3: The yield of maize hybrids in the average of the fertilizer treatments, in 2000

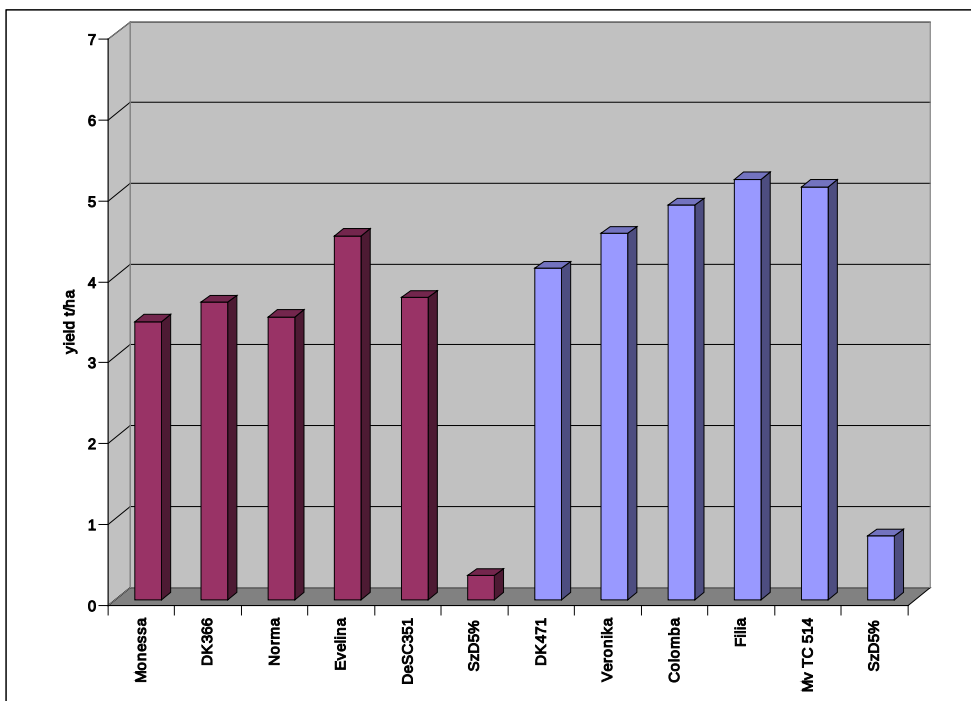


Figure 4: The natural nutrient exploration and utilisation capacity of maize hybrids in 2000

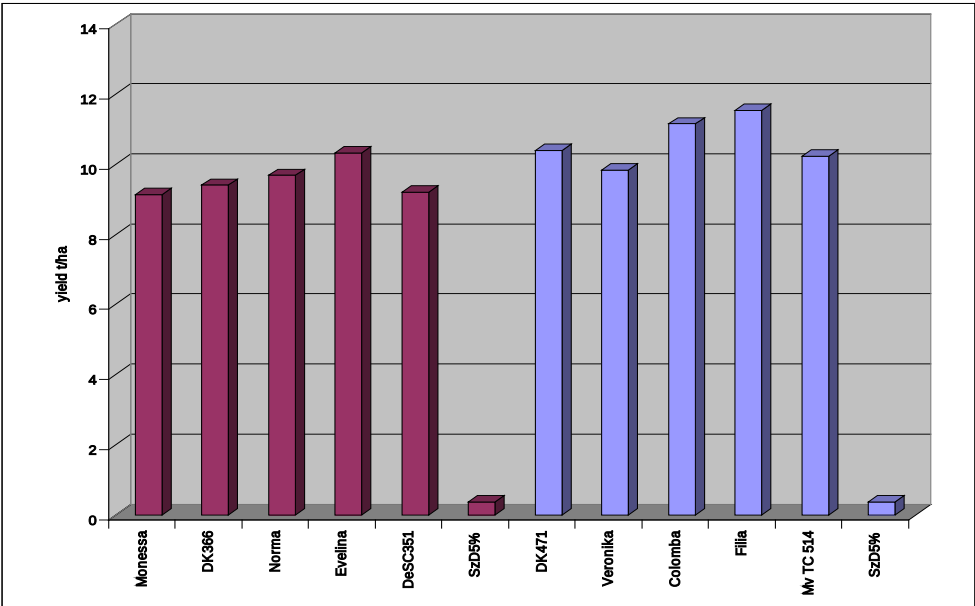


Figure 5: The yield of maize hybrids in the average of the fertilizer treatments, in 2001

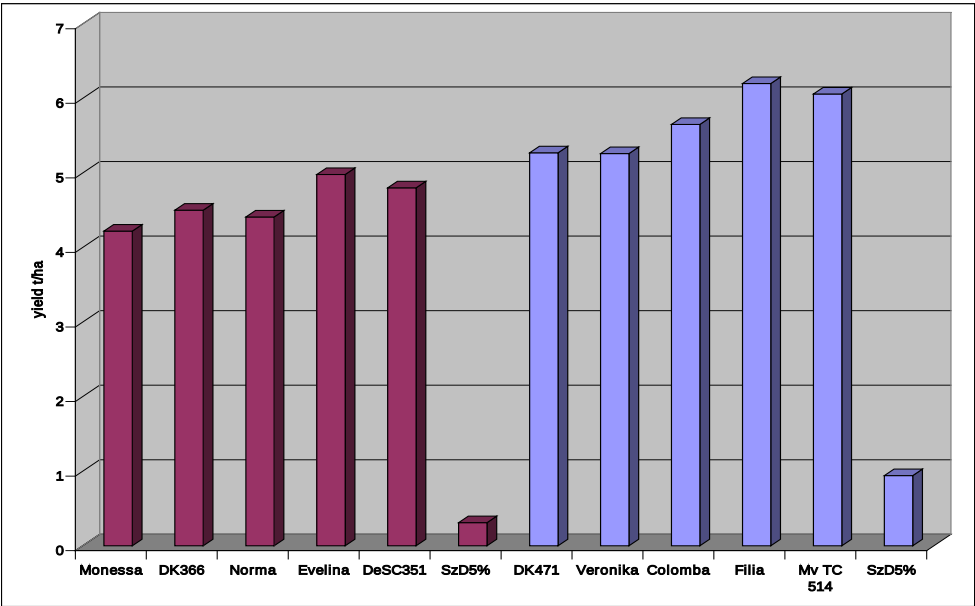


Figure 6 The natural nutrient exploration and utilisation capacity of maize hybrids in 2001

Conclusions

The year effect determines also the efficiency of NPK fertilisation to a great extent besides having impact on the yield of hybrids. In the three examination years, economical and reliable yield increase was achieved by $N_{40-120}+PK$ kg ha⁻¹ active nutrient dose depending on the hybrid and the year.

In all years, the hybrids Filia SC, Mv TC 514 and Colomba SC had the best natural nutrient exploration and utilisation capacity. These hybrids can be grown effectively at a low input level.

In corn production, increasingly newer hybrids are available which possess extremely high yield potential; however, weather extremities and drought years are more frequent due to global warming. Therefore, we need to endeavour to better utilise the positive interactions among ecological, biological and agrotechnical factors. One of these important factors is the use of hybrids with good adaptation qualities, the other is the application of hybrid-specific technique.

References

- Berzsenyi Z. 1993.: Effect of N-fertilization and year on the grain-yield and N-fertilizer-reaction in maize hybrids (Zea-Mays L.) in long-term trial in 1970-1991. *Növénytermelés*. Tom. 42. No. 1. 49-62.p.
- Dobos A.-Nagy J.1998.: Effect of year and fertilisation on the dry matter production of maize (Zea mays L.). *Növénytermelés*. Tom 47. No.5. 513-524.p.
- Nagy J. 1995.: Evaluation of fertilization effect on the yield of maize (Zea mays L) in different years. *Növénytermelés*. Tom. 44. No. 5-6. 493-506.p.
- Pepó P. 2001.: Role of genotype and crop rotation in the nutrient supply of maize on chernozem soil. *Növénytermelés*. Tom. 50. No. 2-3. 189-202.p.
- Sárvári M. 1995.: The productivity and fertilizer reaction of maize hybrids on meadow soil. *Növénytermelés*. Tom. 44. No.2. 179-191.p.

KINETICS OF ELEMENTAL SULFUR OXIDATION UNDER FIELD CONDITIONS

K. Cyna and W. Grzebisz

Department of Agricultural Chemistry, the Agricultural University of Poznań, 71F Wojska Polskiego street, 60-625 Poznań, Poland

Abstract

Field experiments were carried out to investigate the effect of elemental sulfur fertilization on yield of spring barley. One factorial experiment was established, with three S treatments (25, 50, 100 kg/ha) plus control, i.e. object without S applied. Yields of barley grain increased significantly due to S⁰ application but higher yields and higher yields increase were found in 2000, not in 2002. In the first year 30 mg/kg of soil S-SO₄ was enough to reach yield at the level of 5,3 t/ha. In the second year much lower final effect was attributed to 54 mg/kg of soil S-SO₄. It was also found that in the first year the yield prognosis at the stage of EC 37 was more significant than in the second year.

Introduction

Sulfur is considered to be an essential element for all living organisms. Plants take up this element from the soil in the form of SO₄⁻². In soils a dominant form of sulfur is an organic compound (95 % of total sulfur). Only a few percent of sulfur in the arable layer are sulfates, which are easily available for plants (Eriksen et. al. 1998).

In West European countries, in late 1970s and in Central Europe 20 years later a systematic decrease in sulfur dioxide emission occurred. In Poland, recently, an average sulfur emissions have been slightly over 20 kg S/ha/year showing high diversity in individual regions of the country (Polish Statistical Yearbook, 2002). As a result, the sound, efficient technology of sulfur fertilization became one of the most important agricultural problems to be solved. Sulfur fertilizers may be applied in different chemical forms at different stages of plant growth. However, following the rule *it is easier to prevent than to cure* the key point of S fertilizers application always is that it should always be applied before sowing.

The important source of S for plants is soil organic matter, but amounts of sulfate changed over the growing season depending on conditions for its organic S compounds mineralization. These include total humus content, temperature, humidity, acidity, and microbiological activity of soil (Eriksen et al., 1998). The same range of environmental conditions is decisive for elemental S oxidation (Germida and Janzen 1993).

In literature dealing with sulfur fertilization, there is little data presenting the fertilizer value of elemental sulfur. Therefore the main objective of the study was to assess spring barley response to rates of S applied as S⁰.

Materials and Methods

Field studies were conducted in 2001 and 2002 growing seasons. In one factorial experiment spring barley was a test crop. Sulfur as an elemental S was applied in pre-sowing at rates of 0; 25; 50 and 100 kg S/ha. The experiment was established on soil of the texture of loamy sand, of neutral pH, high phosphorus fertility and moderate potassium availability (determined by Egner-Riehm method). The initial concentration of sulfate sulfur in the 0 – 30 cm was variable in both years (Table 1).

Sulfate sulfur (S-SO₄) was determined in 8 stages of spring barley growth: EC-25; EC-31; EC-37; EC-49; EC-65; EC-75; EC-85; EC-91. Soil samples from the layer of 0 – 30 cm were analysed for monocalcium phosphate-extractable S-SO₄ and determined by turbidimetric method. Yields of grain and S-SO₄ content were statistically analysed using analysis of variance and linear regression.

Table 1: Agrochemical soil characteristics

Year	pH	Available nutrients, mg/100 g soil			
		P ₂ O ₅	K ₂ O	Mg	S-SO ₄
2001	7,1	33,3	14,9	6,4	0,2
2002	6,7	27,4	37,4	9,7	0,8

Results and discussion

Table 2: Grain yield of spring barley, t/ha

Rate of elemental sulfur kg/ha	Years	
	2001	2002
Control (without S)	4,14	2,86
25 S	5,18	3,23
50 S	5,19	3,64
100 S	5,33	3,62
LSD _{0,05}	0,70	0,35

The harvested grain yield of spring barley was highly influenced by the weather in both growing seasons. In 2001 yields ranged from 4,14 to 5,43 t/ha and in the 2002 from 2,86 to 3,64

t/ha (Table 2). The effect of sulfur was significant, but only in comparison to the control plots. In 2002 applied sulfur increased yield of grain in the range of 25%-28%. In the second year of the study it ranged from 13% to 27%.

In both years plots the highest concentration of S-SO₄ on the control was very close amounting, on average, to 27 mg/kg soil. However, an analysis of the soil S-SO₄ dynamics showed quite different patterns of elemental sulfur oxidization (Fig. 1). In 2001 the seasonal S-SO₄ distribution was best described by the quadratic equation. The concentration of sulfate sulfur was increasing up to the 95th day of spring barley vegetation, i.e. up to the stage of milk ripening. Then it dropped significantly. In 2002 distribution of S-SO₄ was best described by the linear regression with the highest content at maturity.

Sulfur added to the soil in the form of S⁰ also showed different patterns of oxidation as determined by means of the net S-SO₄ content (Fig. 2). In both years the effect of S rates was very similar. Irrespective of the stage of spring barley growth the S-SO₄ content followed applied S rates. The highest differences between S treatments were found in the period between flowering and milk ripening. In the early stages of barley growth content of S-SO₄ systematically increased up to about 30 mg/kg soil. The specific effect in this year became more visible at later stages of barley growth. In 2001 high decrease, even drop, of sulfate sulfur content was observed from the stage of flowering. In two of three S treatments content of S-SO₄ decreased below its content in the control plots, i.e. indicated the phenomenon of *priming effect*. This effect may be only explained by high temporary S needs of fast growing plants. Therefore in these years the cubic function described best the seasonal distribution of net sulfate sulfur (Fig. 2a). Quite opposite S-SO₄ patterns were found in the second year of study. In the period between EC 65 and EC 75 extremely high increase of sulfate content occurred (Fig. 2b). The same effect, but to a much lesser extent was observed a year before. In the first year, in the period of grain filling, the final soil S-SO₄ content stabilized at the level of about 5 mg/kg soil, but in the second year at 30 mg/kg soil. The obtained results are in agreement with the investigations carried out by **Eriksen et al., (2001)**. The authors suggest that the availability of soil or root S during grain filling is important for adequate S supply to the developing grains, as the distribution of S to the ears considerably exceeds the amount exported from the leaves.

In order to explain the yielding effect of S-SO₄ availability in any given growing season the regression analyses of its soil content versus yields of grain were conducted (Fig.3). The analyses performed at EC 37 showed significant effect in two years. Much more significant effect was found in 2001. It was stated that about 30 mg S-SO₄/kg soil allowed to achieve the

highest yield of grain, statistically amounted to 5,25 t/ha grain. In 2002 these numbers were, respectively, 54 and 3,6. These two pairs of data suggest much higher effect of S-SO₄ content on grain yield in the first than in the second year of study. The same analyses were repeated at EC 65. A significant relationship between soil S-SO₄ content and grain yield, as presented by the equation, was found only in 2002:

$$y = -0,0005x^2 - 0,052x + 2,2028 \quad \text{for } R^2 = 0,66 \quad n = 7$$

As was calculated by means of the equation presented in Fig. 2b the same content of 54 mg/kg of S-SO₄ was predicative for the final yield of grain. Therefore, the weather course over the growing season seems to be the most important factor: influencing the rate of elemental sulfur oxidation and its effect on grain yield. The obtained results and this general conclusion corroborate the results of other authors, stressing the predominant effect of moisture on kinetics of S⁰ oxidation (Watkinson and Lee, 1994).

Conclusion

1. Fertilizer value of elemental sulfur is determined by environmental conditions, mostly the weather course in the growing season.
2. Spring barley fertilized with elemental sulfur at the rate of 25 kg S/ha can increase significantly its grain yield.
3. The concentration of sulfate sulfur (S-SO₄) in soil at the phase of the appearance of the flag leaf (EC 37) can be used as successful estimator of grain yield of spring barley.

References

- Eriksen J., Murphy M.D., Schnug E. (1998): The soil sulfur cycle. In: Sulfur in Agroecosystems (ed.) Schnug, Kluwer Academic Publishers, Dordrecht –Boston-London, 39-73.
- Eriksen J., Nielsen M., Mortensen J.V., Schjorring J.K. (2001): Redistribution of sulfur during generative growth of barley plants with different sulfur and nitrogen status. *Plant and Soil* 230(2): 239-246.
- Germida J.J., Janzen H.H. (1993): Factors affecting the oxidation of elemental sulfur in soils. *Fert. Res.* 35: 101-114.
- Polish Statistical Yearbook, 2002.
- Watkinson J.H., Lee A. (1994): Kinetics of field oxidation of elemental sulfur in New Zealand pastoral soils and the effects of soil temperature and moisture. *Fert. Res.* 37: 59-68.

STORAGE PROTEINS A TOOL TO DETERMINE GRAIN CROP AND POTATO QUALITY

J. Bradová and S. Sýkorová

Research Institute of Crop Production, Drnovská 507, 161 06 Praha 6-Ruzyně, Czech Republic
E-mail: bradova@vurv.cz

Abstract

The methods which can characterize cultivar identity, purity and trueness are very important for the quality of agricultural products and foods. The composition of storage proteins of cereal grain (prolamins, glutelins) and potato tuber proteins is conditioned and fixed genetically by specific loci and this way the genotyp can be characterized. The gel electrophoresis of the mentioned proteins (SGE, PAGE, SDS-PAGE) is very suitable method for this purpose. Catalogues of protein genetic markers (gliadins, HMW-glutenins, hordeins and barley esterases) of Czech registered varieties and the catalogue of 60 registered potato varieties were constructed.

Keywords: wheat, barley, potatoes, varieties, gliadins, HMW-glutenins, hordeins, tuber proteins, electrophoresis, genotype characterization

Introduction

In all important cultivated agricultural crops variety (cultivar) is one of the carriers of qualitative characteristics, from the aspect of both the nutritional and the technological and sanitary quality. Therefore all methods allowing to describe the identity, source, purity and trueness of variety are highly important for the quality of agricultural products and foods. Most important plant species involve a high number of (frequently closely related) varieties. Their distinction and identification are of great economic importance, particularly in crops grown on large areas. Morphological traits are commonly used for distinction of varieties but it requires great experience in many commercially important crops (grain crops, sugar beet, corn, potatoes, forage crops, legumes) – most morphological traits are controlled by several genes and their expressions largely depend on external conditions (year, locality, nutrition, etc.). This is the reason why additional methods of variety identification were sought, e.g. use of different protein systems behaving as genetic markers that allow to describe a genotype on the basis of genetically defined polymorphism of particular protein components, practically independent of external factors. Genetic mechanisms of origination of such polymorphism are gene mutations, especially duplications of protein genes and uneven crossing-over of these genes. Naturally, the most reliable information on identity is provided by DNA or RNA analyses. The use of proteins as primary products of genes is a purposeful compromise between direct (and rather costly) study of genes and easily available methods when protein genetic markers are used.

Protein polymorphism

Proteins are primary gene products, characterized by lower phenotype epigenetic variability and higher heritability. Evolutionarily younger proteins are suitable for genotype identification such as storage proteins of seeds and some enzymes that are specific to lower taxa than the species – i.e. variety and genotype. Protein polymorphism is a precondition of using proteins as genetic markers, that means they are represented by different variants specific to a given genotype and are independent of external factors due to high heritability. They are a unique product of relevant genetic systems expressing genotype specificity as a result of the linkage of protein and other genes conditioning overall phenotype.

A gene or a closely related group of genes localized on a chromosome is designated as locus. In accordance with international conventions the locus name usually indicates protein, enzyme or trait controlled by this gene, or genome and sometimes chromosome number (e.g. Gli 1A, Glu 1A, Hor 1, Est 1, AcPh 1, etc.). The expression of a gene is a trait – allele specific to a given genotype. Some loci are inherited jointly in groups of closely linked genes, and their expressions are groups of alleles – allelic blocks. The external phenotypic expression of allele of a given locus is a specific protein component or group of components. Hence it is evident that the higher the number of alleles at a given locus (high degree of polymorphism), the more suitable the locus for a detailed distinction of genotype. From this aspect it is possible to use e.g. storage proteins of grain crops (mainly prolamines and glutelins), called gliadins and glutenins in wheat, and in barley prolamine fraction called hordeins.

Osborne's method based on different solubility of particular fractions is the oldest, still in use, technique of kernel protein cleavage in grain crops. Water-soluble fraction is called albumins, globulins are soluble in salt solutions, prolamines in diluted alcohols, glutelins in diluted solutions of acids or bases. From the functional aspect proteins are classified into enzymatic ones (albumins and some glutelins) that participate in metabolic processes and storage ones (prolamines and glutelins) that are an energy and constitution pool for the germinating grain.

The fraction of prolamines – called gliadins in wheat and hordeins in barley, and the fraction of glutelins – called glutenins in wheat, are characterized by highest polymorphism. Some enzyme systems that belong to fractions of albumins and globulins also display some polymorphism and can be used for genotype identification in many crops (e.g. high number of alleles of barley esterases).

Tuber proteins of potatoes are also characterized by a high degree of polymorphism and contain a high number of components independent of external factors, so they can be used for variety

identification. From the functional aspect they are mostly albumins and globulins with enzymatic activity (Sýkorová, 1999).

Methods of protein polymorphism study

Electrophoresis of proteins or enzymes is an elementary method that can be used for the study of protein and enzyme polymorphism. It is based on the movement of electrically charged particles (specifically protein molecules) in a direct-current electric field. A compound mixture is decomposed into particular protein components (according to the size, shape and electric charge of the molecule). Each component is expressed as an individual band in electrophoregram. Electrophoretic techniques have been improved over the years, from carrier-free or paper electrophoresis through electrophoresis on various gel carriers to contemporary high-performance capillary electrophoresis that is the most perfect technique for the time being. Electrophoresis in gel carriers, e.g. in starch or polyacrylamide gel, is currently used in biochemical laboratories. Sodium dodecylsulfate (SDS) electrophoresis is a specific technique when the components are decomposed solely according to molecular weight, which is used for its determination.

The result of electrophoresis is an electrophoretic spectrum of proteins – a system of all bands of protein components stained on a carrier (gel). The spectrum of an unknown sample is compared with so called standard variety of a given crop, and either we can read the alleles of studied loci – so called electrophoretic allelic pattern can be made (genetic interpretation) or we can determine similarity of spectra by measuring the position of particular bands of the standard and the sample (biochemical interpretation). The results of electrophoresis can be processed by software specific programs, libraries of spectra can be created and unknown samples can be identified from them.

Our laboratory employs starch gel electrophoresis of storage proteins of wheat and barley kernels – gliadins and hordeins, polyacrylamide gel electrophoresis of proteins and enzymes (in barley and potatoes) and SDS – polyacrylamide gel electrophoresis of wheat glutenins and barley hordeins. Biochemical-genetic interpretation of spectra is always used in grains, and biochemical interpretation in potato proteins.

Genetic structure of grain crop varieties

In the seventies and eighties electrophoresis of storage proteins of wheat and barley kernels was studied in great detail by a team of Academician Sozinov in former All-Union Institute of

Genetics at Odessa, who described a large number of allelic blocks of gliadins at 7 loci of wheat on 6 chromosomes and 5 loci of barley on one chromosome.

In our laboratory where electrophoretic techniques of protein cleavage have been used by Ing. Šašek from the early seventies, this technique has been developed and applied to collections of domestic and world wheat and barley varieties. The study of a definite number of particular kernels of a given variety indicates that from the aspect of genetic structure a morphologically homogeneous variety can be characterized by one genotype (protein line) or it can be composed of several genotypes (related proteins lines). It is a result of the combination of alleles at examined loci. Based on these studies catalogues of protein genetic markers have been updated every year where it is possible to find a description of each variety, its genetic structure (line composition) and whether it contains markers of important traits and characteristics (Bradová et al. 1998, Šašek et al. 2000). In wheat these are catalogues of gliadin and glutenin markers of varieties. Unfortunately, polymorphism of hordein components in barley is not high enough to clearly distinguish all varieties, therefore another enzyme marker is used – polymorphic enzyme system of esterases. (Table I shows examples from current catalogues of protein genetic markers of wheat and barley).

Markering of traits and characteristics

Proteins can be used not only for genotype identification but also for markering of traits and characteristics on the basis of gene linkage when the allele of one locus can serve as a signal allele for a certain trait in the linkage. Examples in wheat are markering of stem rust resistance, technological quality of flour or freezing tolerance through some alleles of gliadins and glutenins. Some enzyme systems are also linked with genes of e.g. resistance to viroses. The presence of linked trait can be assumed on the basis of expression of a markering allele. Coefficients of correlation between the presence of markers and actual expression of linked trait are usually quite high.

So called score markering values are used to determine the effect of particular markers; these values are determined by comparison of a higher number of sib lines and the scores indicate the “strength of the effect” of particular alleles on the expression of markering trait. For instance if gliadin marker of low technological quality and glutenin marker of high technological quality are present, the value of the latter decreases due to the effect of gliadin marker. These studies were carried out within our research project that terminated in 2000, when it was necessary to

describe individual sib lines by help of markers and simultaneously to determine the actual expression of marked traits.

Selection of suitable parental combinations and construction of genotypes with required characteristics – detection of the homo- and heterozygous state of protein genes

Protein genes are characterized by codominant inheritance, in the case of enzymes hybrid proteins are sometimes produced; it enables to distinguish homozygotes and heterozygotes in protein genes in early hybrid generations (in F₂, or F₃ and F₄) and to select these homozygous individuals for further breeding. A model study was carried out on several hybrid combinations. A statistically significant positive correlation was found between the average sedimentation value of combined genotypes with positive or negative transgression and the predictive marking score value of gliadin and glutenin markers of baking quality, which confirmed the conclusions of e.g. Bingham (1983) about the usefulness of electrophoresis of gliadins and subunits of HMW glutenins as a selection criterion for the creation of wheat varieties with higher baking quality (Šašek et al., 1989).

Checks of variety composition stability

Repeated checks of the genetic structure of some multiline barley varieties by hordein electrophoresis indicated that the representation of lines in the variety changed throughout several years, which documents interventions in genetic structure as well as a change in the variety structure in the course of time (Bradová et al. 2001).

Catalogue of electrophoretic spectra of tuber proteins of registered potato varieties

Many literary sources have reported that variety identification in potatoes by electrophoresis of tuber proteins or enzymes is quite reliable because electrophoretic spectra of these proteins are highly variety specific and genetically conditioned, independent of external conditions and not changing in dormant tubers after several-month cold storage (Sýkorová, 1999). Some studies were conducted in our laboratory when we tried to make catalogues of varieties registered in the CR (ca. 60 varieties) using polyacrylamide or starch gel electrophoresis of tuber proteins. When the similarity of electrophoretic spectra of tuber proteins was compared by help of identity indexes, it was evident that the varieties could be distinguished easily.

Reference Laboratory of Protein Electrophoresis

Reference Laboratory of Protein Electrophoresis, established by the Ministry of Agriculture of CR, has existed in RICP since 1988; research knowledge is applied to practical identification, characterization and checks of variety trueness. Every year thousands of analyses of single kernels of grain crops and potato tubers are carried out, reports containing their results are submitted to the Ministry of Agriculture and workshops are organized to inform the professional community.

Checks of variety declaration

In Reference Laboratory checks of (wheat and barley) grain samples are carried out every year that come from harvest monitoring, supplies to Agricultural Supplying and Purchasing Companies, to mills when sometimes high-quality food varieties are confounded with lower-quality varieties or varieties unsuitable for the baking industry – which will decrease the quality of end products. About 20% of checked samples are found not to comply with variety declaration.

In recent years checks of variety declaration (and quality checks in imported products) have been carried out in commercial samples of potatoes in cooperation with the Czech Agricultural and Food Inspection. In ware potatoes the supplier has to indicate variety declaration on packed potatoes (pursuant to Act No. 110/97 on Foods and Tobacco Products). Admixtures amounting to 2% only are permitted. In 2000 in potatoes 93 samples of potato tubers (by 15 tubers on average) were checked; out of them 65 samples, i.e. ca. 70%, complied with variety declaration or requirements for homogeneity and 28 samples, i.e. ca. 30%, did not satisfy these requirements. In 2001 ninety-one samples of domestic late potatoes and 91 samples of imported early potatoes were checked; 15% of late samples and 38.5% of early samples of potatoes did not comply with Act No. 110/97. In 2002 even 140 samples of domestic late and 112 samples of mainly imported early potatoes were checked; 14% of late samples and 29% of early samples did not comply.

Reference

- Bingham,J.: trends in wheat breeding Australian Plant Breeding Conference. Adelaide, 1983, s. 1-18.
- Bradová,J.,Sýkorová,S.,Šásek,A.: Hordeinový a esterázový polymorfismus odrůd ječmene registrovaných v roce 1997 v ČR (Hordein and esterase polymorphism of barley varieties registered in the Czech republic in 1997). Czech J.Genet.Plant Breed.,34,1998:131-138
- Bradová,J., Sykorová,S., Šásek,A., Černý,J.: Identification of common barley varieties by parallel electrophoresis of hordeins and esterases. Rostl.Výroba, 47, 2001(4):167-173.

- Sýkorová,S.: Identifikace odrůd brambor (*Solanum tuberosum* L.) pomocí elektroforézy proteinů a enzymů (Identification of potato varieties using electrophoresis of proteins and enzymes). Rostl.Výr., 45,1999(4):193-196
- Šašek,A., Černý,J., Sýkorová,S., Bradová, J.:Inovované katalogy bílkovinných genetických markerů pšenice seté a ječmene (The innovated catalogues of protein markers of wheat and barley varieties). ÚZPI Praha 2000 (51 s.)
- Šašek,A., Černý,J., Sýkorová,S., Kubánek,J.: Construction of Wheat Genotypes with Higher Baking Quality by Electrophoresis of Gliadins and HMW Subunits of Glutenins. Sci.Agric.Bohemoslov., 21,1989, č.3,s.171-175.

Acknowledgements

This project is supported by the Ministry of Agriculture of Czech Republic (QF3050/2003)

Table 1: Examples from catalogues of protein genetic markers of wheat and barley varieties

a) Gliadin and glutenin genetic markers of selected winter wheat varieties registered in the CR

Variety	Gliadin markers								Glutenin markers			
	Gld line	GLD allelic blocks on chromosomes							Glu line	HMW-GLU allelic blocks on chrom.		
		1-1A	2-1A	1B	1D	6A	6B	6D		1A	1B	1D
Example of gliadin and glutenin homogeneous variety (1 line)												
Alana	A	3	0	4	9	2	2	9	a	0	7+8	2+12
Example of gliadin heterogeneous (2 lines) a glutenin homogeneous (1 line) variety												
Brea	A	2	0	1	1	1	1	1	a	0	7+9	5+10
	B	2	0	4	1	1	1	1				
Example of gliadin heterogeneous (3 lines) a glutenin homogeneous (1 line) variety												
Windsor	A	2	0	4	1	3	12	5	a	0	6+8	2+12
	B	2	0	3	1	3	12	5				
	C	9	0	4	1	3	12	5				
Example of gliadin heterogeneous (2 lines) a glutenin homogeneous (1 line) variety												
Asta	A	4	0	4	9	2	16	19	a	0	7+9	5+10
									b	0	6+8	5+10
Example of gliadin heterogeneous (2 lines) and glutenin heterogeneous (2 lines) variety												
Sofia	A	3	2	3	1	1	1	6	a	0	6+8	5+10
	B	3	2	3	1	1	1	4	b	1	7+9	5+10

b) Hordein and esterase genetic markers of selected spring barley varieties registered in the CR

Variety	Hordein markers				Esterase markers				
	rd line	HRD allelic blocks			st. line	Alleles of esterase loci			
						st-1	st-2	st-4	st-5
Example of hordein and esterase homogeneous variety (1 line)									
Malvaz			7		a	a	r	u	i
Example of hordein heterogeneous (2 lines) and esterase homogeneous (1 line) variety									
Kompakt			9		a	r	r	u	i
Example of hordein homogeneous (1 line) and esterase heterogeneous (3 lines) variety									
Profit			5		a	a	r	u	i
					b	r	r	u	i
					c	a	r	t	i
Example of hordein heterogeneous (2 lines) and esterase heterogeneous (2 lines) variety									
Primus			5		a	a	r	u	I
			5		b	a	r	u	i

EFFECT OF NUTRIENT SUPPLY ON THE ARSENIC AND MERCURY TURNOVER IN TRITICALE

B. Lásztity and P. Csathó

Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences,
Budapest, Hungary, Email: csatho@rissac.hu

Abstract

The biological effects of plant nutrition on the arsenic and mercury concentration and accumulation dynamics in the triticale species KT 77 during the vegetation period were studied in a Hungarian field experiment carried out on calcareous sandy soil at different N, P and K fertilisation levels. Various P and K supply levels were achieved by means of build-up mineral fertilisation. Samples were generally taken from 4 m row length every ten days in the phenophases of tillering, shooting, heading, flowering, milky ripeness and full ripeness. After hydrochloric acid hydrolysis the concentrations were determined using an ICP instrument.

The results can be summarised as follows:

The concentration dynamics showed a decreasing tendency almost throughout the vegetation period. Maximum concentrations were measured in the phase of tillering.

The concentrations of As and Hg were higher in the grain at full maturity.

NPK fertilisation only resulted in a significant increase in As and decrease in Hg concentrations during vegetative growth.

Arsenic uptake continued till full ripeness without element loss. Mercury uptake continued till the flowering phase, then element loss was recorded till maturity.

Because of the wide straw/grain ratio, the As and Hg uptake of the straw at harvest was larger than the grain As and Hg uptake.

Compared to the control, accumulation increased significantly in the fertilised treatments.

Introduction, literary review

It is a well-known fact that the elements occurring in plants do not all bear the same importance; some are essential, others only have a stimulating effect, while some, among them the heavy metals, have a toxic effect, especially at higher concentrations (Allaway 1995, Csathó 1994, Marschner 1995, Pethő 1993, Pais 1991, Szabó et al. 1994). Mineral elements participate in the biological cycles and are important components in the food chain (Kádár 1995), so their investigation is justified to clarify the role they play.

Triticale is a stable hybrid produced by human manipulation from a cross between wheat and rye. It was first produced by botanists, but later drew the attention of breeders (Tarkowski 1972). The first hybrids in the world were produced at the end of the nineteenth century, while the first hybrid in Hungary was developed in 1950 by Á. Kiss and G. Rédei (Szabó 1992). In Hungary the crop is economically grown on sandy soils.

The arsenic and mercury turnover in triticale was investigated as a function of the vegetation period and the nutrient supply on a relatively unpolluted area where anthropogenic effects were manifested to a lesser extent due to the distance from any industry, main roads or communal activities (Kádár and Koncz 1993, Mészáros et al. 1993).

Materials and Methods

The element turnover in triticale was examined in samples taken during the major developmental stages (on Mar. 31, Apr. 21, 30, May 11, 21, Jun. 1, 10, 22, Jul. 17) in a field experiment set up on sandy soil. The samples consisted of the aboveground parts of 4-metre rows. After hydrolysis with hydrochloric acid the tested elements were analysed using an ICP instrument in the Hajdú-Bihar County Laboratory of the Plant Protection and Agricultural Chemistry Centre of the Ministry of Agriculture. The soil of the experimental area contained 1.2 % humus, 1–3 % CaCO₃, 15 % fine fraction (<0.02 mm), 36 mg/kg AL-soluble K₂O, 78 mg/kg AL-soluble P₂O₅ and 0.11 % total N. Build-up rates of P and K were applied in the experiment, while the N rate was uniform (Table 1). With the help of the PK build-up rates, various nutrient supply levels were created.

Results and Conclusions

Dry matter accumulation

By tracing changes in the accumulation of plant dry matter during the vegetation period, it is possible to study the soil-plant relationship and interactions between plant nutrition and yield. The biomass production is influenced partly by genetic coding and partly by external ecological factors, especially the nutrient supplies (Fischer 1973, Graham et al. 1983, Kiss 1968).

Table 1: Effect of fertilisation on the dry matter accumulation (t/ha) of triticale cultivar KT-76 during the vegetation period (Calcareous soil, Órbottyán, 1981)

Phenophase	Treatments								LSD _{5%} Mean	%
	O	N	P ₁ K ₁	NP ₁	NK ₁	NP ₁ K ₁	NP ₂ K ₂			
Tillering 1	0.38	0.49	0.34	0.54	0.46	0.59	0.53	0.09	0.47	7
Tillering 2	0.68	0.99	0.70	1.17	0.94	1.19	1.26	0.21	0.99	15
Shooting 1	1.12	1.65	1.23	2.00	1.74	2.75	1.97	0.41	1.78	27
Shooting 2	1.50	1.93	1.37	2.45	1.97	2.59	2.37	0.38	2.03	30
Heading 1	2.26	2.92	2.09	3.13	3.00	3.96	3.68	0.66	3.01	45
Heading 2	2.92	4.03	2.72	4.78	4.38	5.07	5.34	0.85	4.18	62
Flowering 1	2.96	4.85	2.77	5.81	4.52	6.32	6.92	1.39	4.88	73
Flowering 2	3.61	5.90	3.07	6.93	5.47	7.16	6.96	1.35	5.59	83
Milky ripeness	4.08	6.61	3.72	6.67	6.44	6.99	8.08	1.60	6.08	91
Grain	1.40	2.66	1.60	3.24	2.92	3.06	3.80	1.09	2.67	40
Straw	2.30	3.91	2.71	4.81	4.44	4.74	5.70	1.01	4.03	60
Total	3.70	6.57	4.31	8.05	7.36	7.80	9.50	2.37	6.70	100

The dry matter accumulation of triticale in the whole of the aboveground parts continued, with various degrees of intensity, right up to full maturity, when averaged over all the treatments, with the exception of the control. In all the treatments the most intensive accumulation took place between shooting and heading, as in other winter cereal species, indicating the presence of genetic determination. During this 20-day period the plant produced almost a third of the total dry matter. An analysis of the effect of mineral fertilisation indicated that there was significantly higher accumulation than in the control at all sampling dates in the NP and NPK treatments and at most sampling dates in the N and NK combinations. At harvest the grain to straw+chaff ratio was 1:1.5, with slight deviations in various treatments in favour of either the grain or the vegetative organs. Treatments including nitrogen led to significant grain and dry matter surpluses.

Arsenic (As)

Arsenic is not essential for plants and is generally considered to be a toxic element. Toxic effects are very rarely recorded, however, even on sandy soils, primarily due to the antagonistic interaction with phosphorus. The total quantity of arsenic in soils ranges from 2 to 20 mg/kg (Kloke 1980). Measurements in Hungary have shown values of 2 mg/kg for the total arsenic content and 0.1 mg/kg for the available content on both loam and sandy soils (Kádár 1991, 1995).

In the aboveground organs the arsenic concentration during the vegetation period has a value in the µg/kg range. The maximum value was recorded in the tillering stage, after which it Table 2.

Effect of mineral fertilisation on the arsenic turnover during the vegetation period in the triticale cultivar KT-77 (Órbottyán, 1981)

Phenophase	Treatments							LSD _{5%}	Mean	%
	O	N	P ₁ K ₁	NP ₁	NK ₁	NP ₁ K ₁	NP ₂ K ₂			
As concentration, µg/kg										
Tillering 1	85	106	83	104	101	101	99	26	97	100
Shooting 1	29	33	23	26	24	25	25	6	26	27
Heading 1	22	30	16	28	21	15	16	4	21	22
Heading 2	18	13	14	17	23	21	15	5	17	18
Flowering 1	19	17	21	18	13	14	16	4	17	18
Flowering 2	21	20	19	18	22	13	17	5	18	19
Milky ripeness	19	13	16	17	13	8	8	7	13	13
Grain	37	40	34	33	28	35	27	8	34	30
Straw	32	28	29	34	29	32	35	3	32	33
As uptake, mg/ha										
Tillering 1	58	104	58	122	95	121	124	23	97	44
Shooting 1	32	63	28	64	49	69	59	10	52	24
Heading 1	50	88	33	87	63	59	59	13	63	29
Heading 2	52	63	38	81	101	107	80	19	75	35
Flowering 1	56	82	58	104	59	88	111	21	80	37
Flowering 2	76	118	58	125	120	93	118	26	101	47
Milky ripeness	78	86	59	113	84	56	65	29	77	36
Grain	52	106	54	107	82	107	103	27	87	40
Straw	74	109	79	163	129	152	199	18	129	60
Total	126	215	133	270	211	259	302	34	216	100

gradually declined, reaching its lowest value in the milky ripe stage. After this stage the concentration increased again until full maturity, in both the grain and the straw, having much the same concentration in both organs. Mineral fertilisation had practically no influence on the arsenic concentration.

The accumulation of arsenic per hectare can be measured in milligrammes. The quantity increased parallel to dry matter formation, reaching a maximum at full maturity. The total quantity accumulated was distributed in the grain and straw+chaff with a ratio of 40:60. Mineral fertilisation led to a significant rise in the arsenic accumulation compared with the control, with the exception of the PK treatment.

Mercury (Hg)

Mercury, which is known to be a highly toxic element, only occurs in plants in extremely small quantities and no cases of poisoning are generally recorded. The mercury content in Hungarian soils, measured using various extractants, ranges from 0.14 to 0.4 mg/kg

Table 3: Effect of mineral fertilisation on the mercury (Hg) turnover during the vegetation period in the triticale cultivar KT-77 (Örbottyán, 1981)

Phenophase	Treatments							LSD _{5%}	Mean	%
	O	N	P ₁ K ₁	NP ₁	NK ₁	NP ₁ K ₁	NP ₂ K ₂			
Hg concentration, µg/kg										
Tillering 1	24	30	24	30	30	29	29	7	28	100
Shooting 1	18	18	19	19	8	8	8	9	14	50
Shooting 2	8	12	10	11	10	10	10	2	10	36
Heading 1	10	11	9	10	9	9	9	1	10	36
Heading 2	8	8	8	10	8	8	8	1	8	29
Flowering 1	8	8	8	10	6	9	8	1	8	29
Flowering 2	10	10	8	7	8	8	8	1	8	29
Milky ripeness	5	4	6	6	6	6	7	2	5	18
Grain	3	3	3	3	3	3	3	NS	3	11
Straw	1	1	1	1	1	1	1	NS	1	4
Hg uptake, mg/ha										
Tillering	16	29	17	35	28	34	38	6.4	28	60
Shooting 1	20	30	23	38	14	22	16	9.0	23	50
Shooting 2	12	23	14	27	20	26	24	4.0	21	46
Heading 1	23	32	19	31	27	36	32	4.4	29	63
Heading 2	23	32	22	48	35	41	43	5.6	35	76
Flowering 1	24	39	22	58	27	57	55	5.5	40	87
Flowering 2	36	59	25	48	44	57	56	8.0	46	100
Milky ripeness	20	26	22	40	39	42	56	10.7	35	76
Grain	4	8	5	10	9	9	11	1.3	8	/66/
Straw	2	4	3	5	4	5	6	0.6	4	/34/
Total	6	12	8	15	13	14	17	4.2	12	26

(Fekete 1989), with values of 0.1 mg/kg on areas with background pollution (Kádár 1995). No mercury could be detected in the mineral fertilisers applied in the treatments.

Mercury is only found in extremely low concentrations in the aboveground parts of triticale. During the vegetation period it averaged 28 µg/kg at tillering and 5 µg/kg at milky ripeness. The contents in the grain and straw were even lower, being only slightly above the detection limit. The effect of mineral fertilisation was not consistent, but in general the concentration exhibited a reduction, which was significant at flowering, for example, in the NP, NK and NPK treatments.

Accumulation increased from tillering to the end of flowering, though the maximum value still only had a magnitude of mg/ha. In later stages of the vegetation period there was a substantial drop, the lowest values being recorded at full maturity. At harvest the total quantity of Hg absorbed was stored in the grain and straw yield at a ratio of 2:1. A significant increase in uptake was observed in the mineral fertiliser treatments compared with the untreated control, with the exception of the PK treatment.

Under the given natural and environmental conditions, and considering the genetic characteristics of the triticale plant, the following major conclusions can be drawn on the turnover of these toxic elements:

- The nutrient supplies have a decisive effect on the dry matter production and consequently on the accumulation of As and Hg.
- In certain cases, mineral fertilisation had an influence on changes in the concentrations during the vegetation period, but this effect was not consistent.
- For both elements there was an increase in the concentration in the end-products following translocation. A larger proportion was accumulated in the straw in the case of As, and in the grain in the case of Hg.
- The Hg and As concentrations recorded in the experiment did not reach the limit values permitted in Hungary, so at present there is no danger of them entering the food chain.

References

- Allaway B.J. (Ed.): Heavy metals in soils. 2nd edition. Wiley. New York. 1995.
- Csathó P.: A környezet nehézfém szennyezettsége és az agrártermelés. MTA TAKI. Budapest. 1994
- Fekete A.: Hazai talajok nem esszenciális (toxikus) mikroelem tartalma. Agrokémia és Talajtan. 38. 174-176. 1989.
- Fischer, R.A.: Agronomy and physiology of triticale. In: Triticale. Proc. of Intern. Symp. El Batan. Mexico. 201-209. 1973.
- Kádár I.: A talajok és növények nehézfém tartalmának vizsgálata. KTM - MTA. TAKI. kiadványa, Budapest. 1991.
- Kádár I.: A talaj - növény - állat - ember tápláléklánc szennyeződése kémiai elemekkel Magyarországon. Környezet- és Természetvédelmi Kutatások. KTM - MTA TAKI. Budapest. 1995.
- Kádár I. – Koncz J.: Effect of traffic and urban-industrial load on soil. Acta Agron.Hung. 42. 155-161. 1993.
- Kiss, Á.: Triticale – a homok új gabonája. Mezőgazdasági Kiadó, Budapest. 1968.
- Kloke, A.: Orientierungsdaten für tolerierbare Gesamtgehalte einiger Elemente in Kulturböden. Mitt.VDLUFA. H.1. 9-11. 1980.
- Marscher, H.: Mineral Nutrition of Higher Plants. Academic Press. London.1995.
- Mészáros E. – Molnár Á. – Horváth Zs.: A mikroelemek légköri ülepedése Magyarországon. Agrokémia és Talajtan. 42. 229-242. 1993.
- Pais I. Criteria of essentiality, beneficiality and toxicity. What is too little and too much? In: Cycling of Nutritive Elements in Geo- and Biosphere 59-77. Proc. IGBP., Budapest. 1991.
- Pethő M.: Mezőgazdasági növények élettana. Akadémiai Kiadó, Budapest. 1993.
- Szabó S.A. – Régiuszné Mócsényi Á. – Győri D.: Mikroelemek a mezőgazdaságban. Toxikus mikroelemek. Akadémiai Kiadó, Budapest. 1994.
- Tarkowski, Cz.: Hodowla Triticale. Bul. Inst. Aklim. Rosl. 5-6. 71-74. 1972.

CHANGE OF SOME PROPERTIES AND NUTRIENT CONTENT OF SOILS AS AFFECTED BY FERTILISATION

É. Lehoczky*, K. Debreczeni and Z. Tóth

University of Veszprém Georgikon Faculty of Agriculture, P.O. Box 71, H-8361 Keszthely, Hungary
E-mail: lehoczky@georgikon.hu

Introduction

The National Fertilisation Long-term Trials were set up more than 30 years ago and in that time soil and water protection and environmental relations of fertilisation had not been the direct aim of research.

Since then more and more demand have arisen from environmental point to get knowledge of macro, micro and toxic element content of soils. The acidification of soils increases the solubility of metal elements, which through unwanted concentration levels may result toxicity.

The agricultural load has the widest extent and affects the whole biosphere. Fertilisation changes the nutrient status, pH, etc. of soils. Some heavy metals may accumulate in the soil or the solubility change.

The aim of our research was to study the influence of long-term, intensive fertilisation on the available microelement content and accumulation in different soils.

Samples were collected from 8 experimental sites with equal treatments from the depth of 0-20 cm. The so-called available, 0,1M KCl + 0,05M EDTA extractable element content was determined. In the paper the results of Cu, Zn are discussed in details.

The Zn content of soils varies between 0,001-0,03%. According to rock analysis the Zn content of acid rocks (granite) is low, around 60 mg kg⁻¹, basic rocks, e.g. basalt contains on average 130 mg kg⁻¹ Zn, while in sediments approximately 80 mg kg⁻¹ Zn can be found (Stefanovits, 1992).

The total Zn content of soils in Hungary varies in wide interval. In sandy soils the lowest amount (30 mg kg⁻¹), in forest soils 70-115 and in chernozems 120-150 mg kg⁻¹ Zn can be found (Győri, 1984). The available form is relatively low compared to the total Zn content. In acid soils the water soluble and exchangeable forms are significantly higher than in neutral or basic soils.

The total Zn content in the plough layer is between 90-450 kg ha⁻¹. The available forms, in average, are only 1% of total. P- Zn antagonism is well known, this case Zn fertilisers, e.g. ZnSO₄ may help in plant Zn uptake (Kádár and Shalaby 1984; Debreczeni 1984).

The total Cu content of soils is determined by the parent material (rock). In case of Cu the similar phenomenon can be observed as in case of Mn and Zn, so the highest Cu content can be registered in basic rocks (140 mg/kg), while the acid rocks contains the lowest Cu content (30 mg/kg). The sedimentary rocks occupy an intermediate position with their 57 mg/kg Cu content. The average Cu content of soils is 20 mg/kg (Győri, 1987).

The total Cu content of soils alike other plant nutrients can be considered as the potential reserve, so this total amount is not available for the plants completely. Only a certain part of this total amount exist in easily soluble mobile form in the soil, which is uptakeable by the plants.

Materials and Methods

The National Fertilization Long-term Trial Network was set up in 1967, in eight different agro-ecological regions (Debreczeni and Debreczeniné, 1994). NPK fertilizer levels are as follows: N= 0 – 50 – 100 – 150 – 200 – 250 kg N ha⁻¹ year⁻¹, P (P₂O₅) = 0 – 50 – 100 – 150 kg ha⁻¹ year⁻¹ and K (K₂O) = 0 – 100 – 200 kg ha⁻¹ year⁻¹. These treatments cannot be found in all combinations.

Cropping pattern is a winter wheat-maize-maize-pea cropping system in a four-year rotation. There has been 4-8-12-16-20-24-28-32 year with eight rotation cycles. Total application of fertilisers after 32 years: 1600-3200-4800-6400-8000 kg N ha⁻¹, 1600-3200-4800kg P₂O₅ ha⁻¹, 3200-6400 kg K₂O ha⁻¹.

For the study treatments as follows have been selected:

Fertilization (NPK) treatments

1/ unfertilised control	(coded: 000)
2/ 50 kg N ha-1, 50 kg P2O5 ha-1, 100 kg K2O ha-1 (coded: 111)	
3/ 100 kg N ha-1, 50 kg P2O5 ha-1, 100 kg K2O ha-1	(coded: 211)
4/ 100 kg N ha-1, 100 kg P2O5 ha-1, 100 kg K2O ha-1	(coded: 221)
5/ 150 kg N ha-1, 100 kg P2O5 ha-1, 100 kg K2O ha-1	(coded: 321)
6/ 200 kg N ha-1, 150 kg P2O5 ha-1, 200 kg K2O ha-1	(coded: 432)

Samples were collected from 8 experimental sites with equal treatments at the end of the rotations, after the winter wheat harvest from 0-20 cm depth. The so-called available, 0,1M KCl + 0,05M EDTA extractable Zn and Cu content was determined (Baranyai et al., 1987). These elements have been determined from soil samples collected in the 32th year of the long-term trial. Mathematical statistical analysis of the experimental data was done by ANOVA using of SPSS for windows statistical program.

Results and Discussion

In the soils of the experimental sites the KCl+EDTA soluble Cu content ranged between 1,57-7,24 mg/kg (Table 2).

Table 2: The Cu concentration (mg/kg soil) in experimental soils

NPK treatments	Experimental Sites							
	NH ^a	IR	KE	HB	BI	PU	KA	KO
	calcarious		acidic			strongly acidic		
000	1,59	1,89	3,25	7,24	4,88	2,79	4,76	3,84
111	2,20	2,16	3,54	5,98	4,63	2,72	4,59	3,72
211	1,90	2,35	2,41	7,24	4,62	2,77	4,43	3,96
221	2,34	2,15	2,74	5,13	4,52	2,67	4,45	3,79
321	1,71	2,41	3,04	6,16	4,50	2,85	4,41	3,75
432	1,57	2,20	2,75	5,39	4,49	3,16	4,38	3,83
Mean	1,89	2,19	2,96	6,07	4,60	2,83	4,50	3,82
LSD _{5%}	0,69	0,41	1,00	1,74	0,24	0,41	0,36	0,55

^aExperimental sites: NH: Nagyhőrcsök; IR: Iregszemcse; BI: Bicsérd; KO: Kompolt; KA: Karcag; PU: Putnok; KE: Keszthely; HB: Hajdúböszörmény;

This shows that the different between the soluble Cu content of soil can be as big as 4,5 fold. Compared to the soluble Zn content of soil it can be concluded that the differences in the soluble Cu content were much bigger. The average soluble Cu content of soils is several times bigger than the soluble Zn content.

The smallest KCl+EDTA soluble Cu content was measured in the calcaric NH, IR soils (both are Calcaric Phaeozem) and in the KE Ramann-type brown forest soil (Eutric Cambisol).

The pH of soil dominantly influences the solubility of metallic elements, but the reason for the differences between the soluble Cu contents is not always only the pH. In this regard the soil

type and the parent material has great importance. In the strongly acidic PU Ochric Luvisol soil the soluble Cu content was much more smaller than in the slightly acidic heavy meadow HB soil (Luvic Phaeosem) and in the BI acidic chernozem brown forest soil (Luvic Phaeosem). In these soils (BI and HB) as an effect of higher fertiliser rates (321, 432) the soluble Cu content was smaller, in spite of the fact that with the rise in fertiliser rates the pH of the BI soil decreased.

Table 3: Zn concentration (mg/kg soil) in experimental soils

NPK treatments	Experimental Sites							
	NH ^a	IR	KE	HB	BI	PU	KA	KO
	calcarious			acidic			strongly acidic	
000	0,86	0,65	1,12	1,33	1,01	1,03	1,69	1,22
111	0,85	0,67	1,46	0,92	0,83	1,01	1,83	1,21
211	0,77	0,73	1,01	0,94	0,67	1,09	1,80	1,18
221	0,91	1,03	1,18	0,78	0,71	1,07	1,74	1,17
321	0,72	0,74	1,16	0,80	0,74	1,14	2,05	1,22
432	0,73	1,01	1,24	1,08	0,74	1,79	2,65	1,20
Mean	0,81	0,81	1,19	0,94	0,78	1,19	1,96	1,20
<i>LSD</i> _{5%}	0,19	0,81	0,57	0,37	0,24	0,35	0,87	0,45

^aExperimental sites: NH: Nagyhörcsök; IR: Iregszemcse; BI: Bicsérd; KO: Kompolt; KA: Karcag; PU: Putnok; KE: Keszthely; HB: Hajdúböszörmény;

Regarding the Zn content there are great differences between the soils. The easily soluble, so called „available” Zn content altered between the end values of 0,65-2,65 mg/kg soil (Table 3). The Karcag (KA) meadow chernozem soil (Luvic Phaeosem) contained a higher amount of an average value of 1,96 mg/kg Zn. As an effect of high rates of fertilisers (321, 432) the soluble Zn content increased. In the strongly acidic Putnok (PU) Ochric Luvisol as an effect of high rates of fertilisers (432) the Zn content of soil increased as well compared to the control plots from the value of 1,03 mg/kg to 1,79 mg/kg.

The increase in the Zn content of soil can also be registered as an effect of fertiliser application in the IR (Iregszemcse) Calcaric Phaeozem too. On the unfertilised control plots this soil type had the smallest Zn content: 0,65 mg/kg. The available Zn content of soil in the NH Calcaric Phaeozem as well as in the IR Calcaric Phaeozem soil was relatively low, which can be

explained by the pH of this soils (Table 4). As an effect of fertiliser application the pH of the BI (Luvic Phaeosem) soil decreased.

Table 4: The pH of experimental soils

NPK treatments	Experimental Sites							
	NH ^a	IR	KE	HB	BI	PU	KA	KO
	calcareous		acidic			strongly acidic		
000	7,42	7,40	6,90	5,78	5,55	4,41	4,76	4,23
111	7,42	7,42	7,13	5,76	5,19	4,28	4,59	4,12
211	7,42	7,41	7,35	5,91	4,84	4,21	4,43	3,98
221	7,37	7,39	7,20	6,37	4,89	4,31	4,45	4,01
321	7,39	7,37	7,25	6,35	4,82	3,99	4,41	3,99
432	7,41	7,39	7,30	6,37	4,80	4,18	4,38	3,81
Mean	7,40	7,39	7,19	5,93	5,01	4,23	4,50	4,02

^aExperimental sites: NH: Nagyhörcsök; IR: Iregszemcse; BI: Bicsérd; KO: Kompolt; KA: Karcag; PU: Putnok; KE: Keszthely; HB: Hajdúböszörmény;

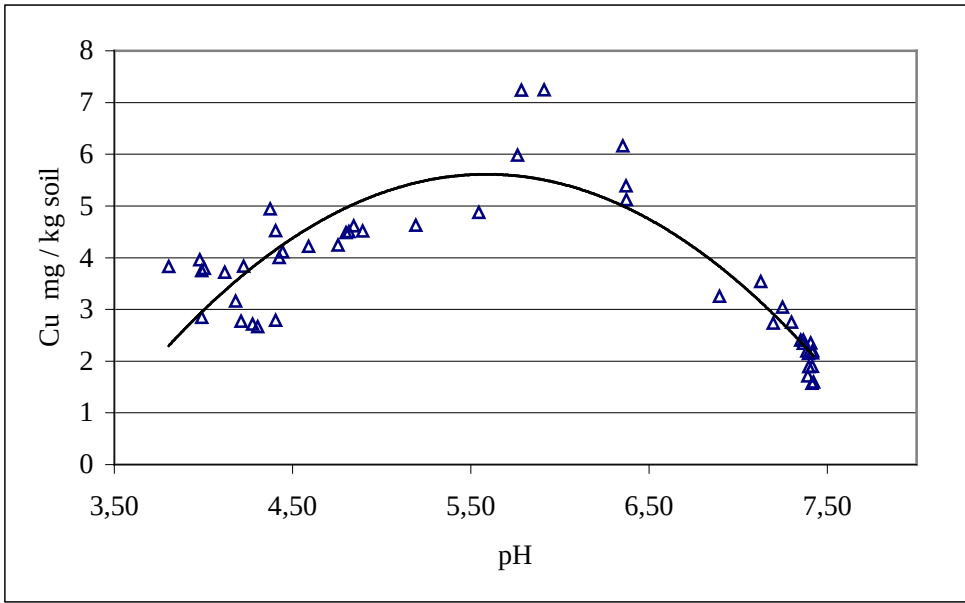


Figure 1: Correlation between the pH and the KCl+EDTA soluble Cu content of soils

$$y = -1,0438x^2 + 11,664x - 26,973 \quad r^2 = 0,7471 \quad n=48 \quad P<0.01$$

The correlation between the soluble Cu content and the soil pH can be described by polynomial function. In the extremely acidic (pH 3,5-5,0) soils the KCl+EDTA soluble copper content increases as a function of increasing pH and it reach its maximum between the pH values of 5-6,5, then it decreases between the pH values of 6,5-7,5 (Figure 1).

Between the soluble Zn content and the pH of the soil statistically significant and professionally interpretable correlation can not be proved.

Conclusions

The differences between the soluble Cu content of the soil within different conditions were several times bigger than in case of Zn. The pH of soil influences the solubility of Cu, but the reason for the differences between the soluble Cu contents of soils is not always only the pH. The soil type and the parent material also has great importance in this regard.

Concerning the Zn content there are great differences between the soils. The soluble Zn content of soils varied between 0,65-2,65 mg kg soil⁻¹, but fertilisation had no significant effect on this property.

Acknowledgments

Authors wish to express their sincere thanks for the financial support by the Hungarian National Research Fund (OTKA) T037925 and staff at the OMTK experimental sites for their cooperation and help.

References

- Debreczeni, B. 1984. A talajtermékenység fokozása c. tudományos ülészak főbb megállapításai, ill. ajánlásai. *Agrokémia és Talajtan*, 33(1-2): 340-343.
- Debreczeni, B. – Debreczeni, K.(1994): *Trágyázási Kutatások 1960-1990*. Akadémiai Kiadó Budapest
- Győri, D. 1984. A talajok termékenysége. *Mezőgazdasági Kiadó*, Budapest, Hungary.
- Győri, D. 1987. Mikroelemek a mezőgazdaságban. *Esszenciális mikroelemek*. *Mezőgazdasági Kiadó*, Budapest, Hungary.
- Kádár, I. – Shalaby, M.H. 1984. A nitrogén- és réztrágyázás közötti kölcsönhatások vizsgálata meszes homoktalajon. *Agrokémia és Talajtan*, 33(1-2): 268-274.
- Stefanovits, P. 1992. *Talajtan*. *Mezőgazda Kiadó*, Budapest, Hungary.

Table 1: Soil Properties of the Eighth Sites of the Long-Term Field Experiment Network „OMTK” 1967. (Debreczeni and Debreczeniné, 1994)

Experimental								
Sites								
Properties	NH ^a	IR	BI	KO	KA	PU	KE	HB
Soil type (FAO)	Calcaric	Calcaric	Luvic	Haplic	Luvic	Ochric	Eutric	Luvic
	Phaeosem	Phaeosem	Phaeosem	Phaeosem	Phaeosem	Luvisol	Cambisol	Phaeosem
Soil type (USDA)	Mollisol	Mollisol	Mollisol	Mollisol	Mollisol	Alfisol	Alfisol	Vertisol
Soil texture	Loam	Loam	Loam	Clay loam	Clay loam	Clay loam	Sandy loam	Clay
Soil OM, %	2.7	2.4	1.9	2.6	2.7	2.0	1.7	3.5
Soil pH _{KCl}	7.2	7.4	5.6	3.9	4.7	3.9	5.9	6.1
CaCO ₃ , %	5.0	8.0	-	-	-	-	0.1	Traces
Clay % (<0.002 mm)	23	22	33	41	37	28	24	35

^aExperimental sites: NH: Nagyhöröcsök; IR: Iregszemcse; BI: Bicsérd; KO: Kompolt; KA: Karcag; PU: Putnok; KE: Keszthely; HB: Hajdúböszörmény

SUSTAINABILITY OF CROPPING SYSTEMS IN A LONG-TERM NUTRIENT SUPPLY EXPERIMENT

T. Szalai¹, É. Lehoczy², F. H. Nyárai¹, S. Holló³

¹Szent István University, Gödöllő, H-2103 Gödöllő, Páter K. u. 1., Hungary

²Georgikon Faculty of Agricultural Sciences, Veszprém University
H-8360 Keszthely, Deák F. u. 16. , Hungary

³Fleischmann Rudolf Agricultural Research Institute, H-3356 Kompolt, Hungary

Introduction

Cropping patterns and nutrient supply are important elements of sustainable crop production (Györfy, 1975). The site-specific information on the relation of yield and nutrient supply may significantly contribute to the realisation of economic and ecological sustainability (Ángyán-Menyhért, 1997). The base of our study was the long-term crop rotation and nutrient supply experiment, which was set up at Kompolt, Hungary in 1961.

Cropping systems that are widely used in practice (crop rotation, winter wheat-maize double cropping and maize monoculture) has been analysed under different levels and forms of nutrients. Problems with extreme doses of N fertilisers or manure are well known in intensive agriculture. Improper use of fertilisers on arable land has the risk of contaminating the environment. To understand the role of fertilization in this harmful process and to study the fate of nitrogen in the soil - plant - environment system, long-term field experiments are one of the best tools (Németh, 1994). In semi-arid regions where the water balance is negative only over-fertilization, or some leguminous plants may cause nitrate leaching (Campbell et al 1994). Experimental results and opinion about legumes assume positive environmental effects, but there is evidence of increased soil N levels as well (Braulsema and Christie, 1987, Russelle and Hargrove, 1989). The aim of our study was to obtain additional information on nitrate behaviour from a double-cropping system (winter wheat-maize), characteristic in Hungarian crop production. Beside this the long-term crop rotation experiment gives patterns for sustainable cropping systems as well (Holló, 1993, Szalai, 1999).

From the agricultural sources of microelement pollution the soil fertilizers are the most important ones to study. Soils have been given special emphasis in heavy metal uptake and transport in science as well as in the society. The development of analytical methods (AAS, ICP) ensures the monitoring of the environment (Adriano, 1986, Alloway, 1995). Györi (1984) has dealt in detail the microelement content of Hungarian soils.

Fertilizers influence the nutrient balance of soils and pH status. The availability of microelements may change and plant uptake can be modified. Literature shows that extreme differences exist between the microelement content of soils due to human activities. From the nutrients phosphate-base fertilizers can be an important source of contamination (Kádár, 1995). Sharpley and Menzel (1987) reported about the side effects of P fertilizers. Cadmium in the soils originated from P fertilizers was $2\text{--}13\text{ g}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ in the USA, $1,6\text{--}9,4\text{ g}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ in Western Europe. In Hungary, with the very low ($1\text{ mg}\cdot\text{Cd/kg P fertilizer}$) it did not exceed $0,3\text{--}0,5\text{ g}\cdot\text{ha}^{-1}$ during the intensive agricultural period of the 80's (Csathó, 1994).

The importance of long-term trials has increased. Under the real field conditions these experiments can provide data from the past and present for the future. Nutrient supply long-term trials ensure the base to analyse the soil-plant-environment system on consequent standard bases. The objective of this study was to obtain information as to how the nutrient supply can influence the soluble (AAAc+EDTA) essential (Fe, Mn, Cu, Zn) and toxic (Cd, Pb, Sr) element content of the experimental soil. Authors also wanted to determine differences in the content of these elements with fertilized treatments or cropping patterns.

Materials and Methods

The long-term crop rotation and fertilization experiment in which the measurements were taken is a split-split-plot randomised design with 4 replication, had been set up in 1961 at. Kompolt. The soil type is chernozem brown forest soil with clay content of 46 %. The pH is very low ($\text{pH}_{\text{KCl}} = 4.0\text{--}4.7$). Hydrophysical properties are unfavourable. Mean (90 years) precipitation is 549 mm.

There are three cropping patterns on the main plots:

A – maize monoculture

B – maize-wheat double cropping (maize-maize-winter wheat-winter wheat)

C – four-phase rotation (maize-spring barley-pea-winter wheat)

On the subplots A3-B3-C3 the same crop sequence was used, but for four-year periods lucerne was grown, while on A2-B2-C2 the cropping pattern described above was repeated. Thus, besides the widely practiced sequences the post effect of lucerne could be studied as well.

From the 12 nutrient supply treatments five were selected:

- Control (1)
- FYM + M2 (2)
- Crop Residues + M2 (3)
- M3 (4)
- M4 (5)

In each fourth year 34.5 t ha⁻¹ manure (FYM) was applied. The NPK content was equal with M1 fertilizer dose (44-22-52 kg ha⁻¹ N, P₂O₅, K₂O, respectively).

M2: doubled M1 dose

M3: tripled M1 dose

M4: fourfold M1 dose

Crop residues: maize stover and wheat straw was ploughed in after chopping.

Deep drilling was carried out in late August 1996 in 20 cm depth intervals at 0-300 cm in three replications. Nitrate-N content (ppm values) was transformed to kg ha⁻¹ level using bulk density data between 1.36-1.64 kg dm⁻³ according to depth. Soil nitrate-N was determined after 1% KCl extraction with steam-distillation (14) in three replications.

The available form of microelements was determined using AAAC+EDTA extraction as described by Lakanen and Erviö 1971. The microelement contents were determined with an ICP-AES. Experimental data was subjected to the analysis of variance.

Results and Discussion

Winter wheat and maize are traditionally the two main crops in Hungary occupying almost half of the arable land. The long-term effect of different nutrient supply on the yield of winter wheat can be seen in Table 1.

Table 1: The effect of different nutrient supply and the post-effect of lucerne on the yield of winter wheat (t/ha) at Kompolt, 1996

	Treatment				
Rotation	control	FYM+M2	CR+M2	M3	M4
B2	1.59	4.64	4.65	4.74	4.87
B3	3.33	4.63	4.23	5.03	4.76

LSD_{5%} = 0.642

There is significant difference between control plots: yield was double in B3 rotation compared to that of B2. This advantage was due to lucerne grown in B3 plots. This tendency could be

followed in earlier years also with maize within this cycle. Since there are no significant differences between the different nutrient supplies except the control, we assume that in the M3 and M4 level of NPK supply (132 and 176 kg N ha⁻¹) the additional nitrogen source (lucerne) could not be utilised because of other limiting factors.

The yield of maize is characterised by the mean of ten years, where rotation and nutrient supply can be followed in Figure 1.

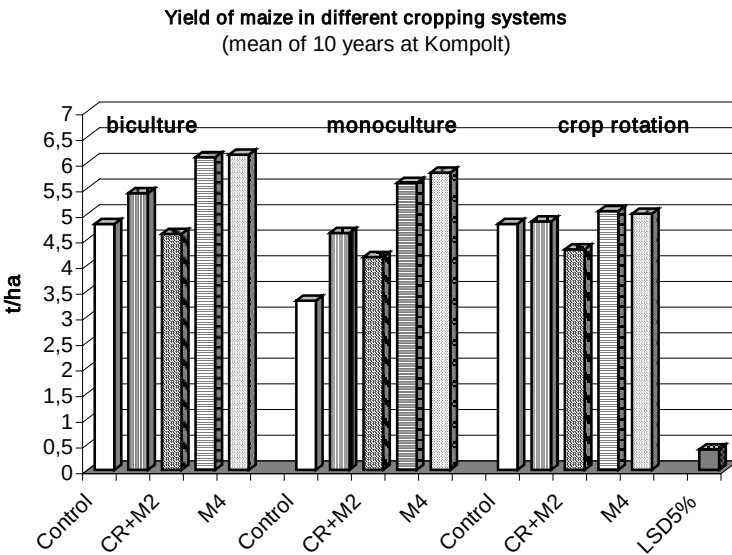


Figure 1

With the presentation of yield data we would just like to emphasise that sound agricultural practice may include different approaches in nutrient supply as well. Lucerne has been a classical crop that provides nitrogen into a cropping system; however there have often been different opinions about its post-effect (15-18).

Figure 2 shows data of nitrat-N (kg/ha) in different depths.

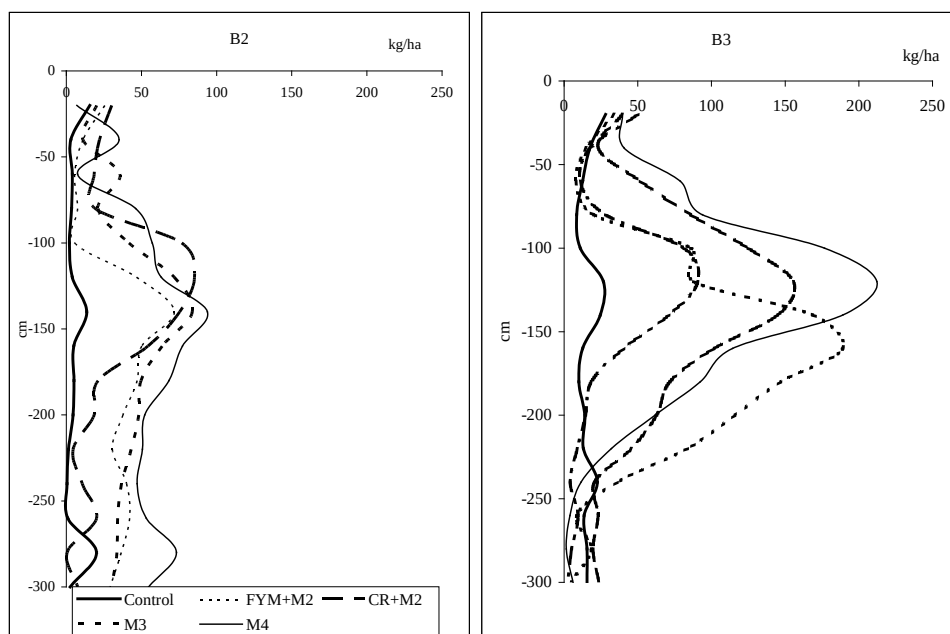


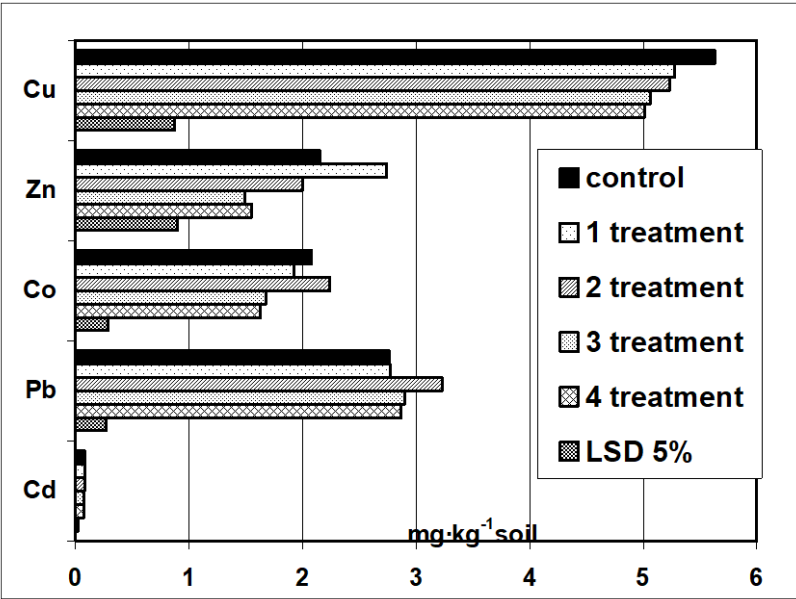
Figure 2: The effect of different nutrient supply and post-effect of lucerne on the nitrat-N content (kg/ha) of the soil profile in B2-B3 rotation at Kompolt

Data of the control plots show significant differences between B2 and B3 rotations. Lucerne that has changed the double cropping 4-year system in each fourth year for four years (B3) has had outstanding impact on soil nitrate-N in all depths. The soil of the "undisturbed" rotation (B2) contained only 85.86 kg nitrate-N ha⁻¹ in 0-300 cm while, the B3 rotation it was almost three-fold. Although actual yield did not show significant differences (Table 1), nitrate-N content of the soil profile did. Based on replacement methodology, Braulsema and Christie (1987), Fox and Piekielek (1988) credit the lucerne crop with a nitrogen contribution of 100-125 kg N ha⁻¹, however, the actual contribution measured with ¹⁵N method was only 24 kg N/ha (18). All nutrient levels correlated with higher amounts of nitrate-N in B3 rotation within 0-300 cm, except treatment No. 2.

On B2 plots (no lucerne) some nitrate accumulation occurs between 100-150 cm depth at all nutrient levels, except the control. The peak in the highest NPK dose (M4) did not exceed 100 kg N ha⁻¹ in the given layer. The differences between the curves of B2 and B3 rotations are remarkable. The 0 control represents, probably the best the long-term post-effect of lucerne. Additional nutrient (N) supplies resulted in higher nitrate-N accumulation. The peaks can be found around 150 cm depth. The highest N dose (M4) caused extreme nitrate-N accumulation, exceeding 200 kg N ha⁻¹. Treatment No. 5 (M4) did not increase yield compared to lower

nutrient levels (M3), thus crops could not utilise this surplus nitrogen. Different forms of nutrient supply show higher variation, since the theoretically similar NPK levels (treatment No. 2-3-4) resulted in peaks of 90-160-190 kg N ha⁻¹, respectively. Nowadays, in many countries of the world efforts have been done to turn agriculture more sustainable. Sustainability consists of several parts. In crop production nutrient supply and rotation effects are important tools in meeting actual economic demand. We think that results from this long-term experiment may give some background to establish environmentally sound crop production.

Figure 3: Shows the AAAC+EDTA extractable microelement content of soil from rotation “C”



The cropping patterns influenced the Fe and Zn content of soil. The “B” rotation showed significant increase in Fe content in each fertilization treatment. In the case of “C” rotation only treatment 2 (crop residues incorporated) resulted in significant increase of soil Fe content. The pure fertilizer treatments resulted lower Zn content in the soil than the treatment with FYM application. Results from treatments with FYM and crop residues suggest that from these sources important amount of Zn may get into soil. From the toxic elements the Pb and Cd contents of soil was relatively low and there were no important changes due to fertilization. Crop rotations had no significant influence on the Sr content of soil, however the higher amounts of fertilizer treatments showed the highest Sr content as well.

Conclusions

The long-term effect of fertilization and cropping patterns on the yield, nitrate-N accumulation and microelement content of soil were studied.

Lucerne caused significant differences in nitrate-N content of different soil layers in a maize-wheat double-cropping system. The peak of nitrate-N accumulation occurred in 150 cm depth. The maximum amount of nitrate-N originated from the highest (176 kg N ha^{-1}) treatment level without lucerne in the rotation and has not reached 100 kg N ha^{-1} , while it reached more than 200 kg N ha^{-1} with lucerne. The advantage of lucerne resulted in double yield in the control but no significant difference was observed at other nutrient levels.

Long-term post-effect of lucerne may increase nitrate-N leaching at elevated (M3-M4) level of nutrient supply.

We have found different effects, depending on elements. In some cases the effect of fertilization could be observed but with some other elements no significant difference occurred in the AAAC+EDTA extractable microelement content of soil. Soil samples were from two different rotations having the same nutrient supply, thus the effect of nutrient supply could also be compared by rotation. The cropping patterns influenced the Fe and Zn content of soil. The “B” rotation showed significant increase in Fe content in each fertilization treatment. In the case of “C” rotation only treatment 2 (crop residues incorporated) resulted in significant increase of soil Fe content. The pure fertilizer treatments resulted lower Zn content in the soil than the treatment with FYM application. Results from treatments with FYM and crop residues suggest that from these sources important amount of Zn may get into soil. From the toxic elements the Pb and Cd contents of soil was relatively low and there were no important changes due to fertilization. Crop rotations had no significant influence on the Sr content of soil, however the higher amounts of fertilizer treatments showed the highest Sr content as well.

Nowadays, in many countries of the world efforts have been done to turn agriculture more sustainable. Sustainability consists of several parts. In crop production nutrient supply and rotation effects are important tools in meeting actual economic demand. We think that results from this long-term experiment may contribute to establish environmentally sound crop production.

References

Adriano, D.C. 1986. Trace elements in the terrestrial environment. Springer Verlag, New York.

- Alloway, B.J. 1995. Heavy Metals in Soils. Second Edition. Blackie Academic & Professional, London, England. 368.pp.
- Ángyán, J.; Menyhért, Z. (Ed.) Alkalmazkodó növénytermesztés, ésszerű környezetgazdálkodás, Budapest, 1997; 414 pp.
- Braulsema, T. W. - Christie, R. B. Nitrogen contribution to succeeding corn from alfalfa and red clover. *Agron. J.* 1987, 79, 96-100.
- Campbell, C. A.- Lafond, G. P.- Zentner, R.P.- Jame, Y.W. Nitrate leaching in a Udic Haploborol as influenced by fertilization and legumes. *J. Environ. Qual.* 1994, 23,195-201.
- Csathó, P. 1994. A környezet nehézfém szennyezettsége és az agrártermelés. Magyar Tudományos Akadémia Talajtani és Agrokémiai Kutató Intézete, Budapest, Hungary. 176.pp.
- Fox, R. H. - Piekielek, W. P. Fertilizer N equivalence of alfalfa, birdsfoot trefoil, and red clover for succeeding corn crops. *J. Prod. Agric.* 1988, 1, 313-317.
- Győri, D. 1984. A talajok termékenysége. Mezőgazdasági Kiadó, Budapest, Hungary. 251.pp.
- Győrffy, B. Vetésforgó - monokultúra – vetésváltás. *Agrártudományi Közlemények*, Akadémiai Kiadó, Budapest, 1975, 34, 1-2, 61-81
- Holló, S. A szerves- és műtrágyázás hatásának összehasonlítása vetésforgó trágyázási kísérletekben. Kandidátusi értekezés, Kompolt. 1993; pp. 142.
- Kádár, I. 1995. A talaj – növény – állat - ember tápláléklánc szennyeződése kémiai elemekkel Magyarországon. Környezetvédelmi és Területfejlesztési Minisztérium MTA Talajtani és Agrokémiai Kutató Intézete, Budapest, Hungary. 388.pp.
- Lakanen, E. and R. Erviö. 1971. A comparison of eight extractants for the determination of plant available micronutrients in soils. *Acta Agr. Fenn.* 123:223-232.
- Németh, T. Nitrate-N accumulation in the soil profiles of long-term fertilizer experiments. *Agrokémia és Talajtan*, 1994, 43., 231-238.
- Russelle, M. P. - Hargrove, W. L. Cropping systems. In: Nitrogen Management and Ground Water Protection. New York, Elsevier, Ch. 10, 1989; 277-317. p.
- Szalai, T. A talajművelési és növénytermesztési rendszerek néhány agronómiai összefüggése a fenntartható földhasználat kialakításához. Kandidátusi Disszertáció. Gödöllő, Hungary, 1999; 122 pp.
- Sharpley, A. N. and R. G. Menzel. 1987. The impact of soil and fertilizer phosphorus on the environment. *Adv. Agron.* 41:297-324.

UTILIZATION FORMS OF AVAILABLE PHOSPHORUS FOR DETERMINATION STABILITY OF SOIL FERTILITY

V. Macháček

Research Institute of Crop Production, Division of Plant Nutrition, Drnovská-Rd 507, 161 06 Praha 6,
Czech Republic, e-mail: machacek@vurv.cz

Abstract

The basic arable soils of Czech Republic are divided into four groups, each of those having specified the category of reserve available phosphorus for method Mehlich 3. Equations for calculation of P-fertiliser rates are determined.

Keywords: Available phosphorus, phosphorus fertilisation, soil fertility

Introduction

Economic pressures at present and also in future prospects, at least up to the year 2005, lead to a disproportionate decrease of phosphorus fertilisers. The decreased consumption of these fertilisers are not only our problem; it is an all-European trend. Unlike the Czech Republic where it is exclusively an economic pressure, people in some countries come to this conclusion after the discovery of phosphorus regime in productive soils.

At the Research Institute of Plant Production, Prague - Ruzyně work is done on the solution of the project "Stabilisation of soil fertility from the point of view of the nutrition of plants by phosphorus and potassium". Its partial purpose is on the basis of research of a phosphorus regime in the basic agricultural productive soils of the Czech Republic to learn about the release of phosphorus from difficult-to-release bonds with the help of supplementary methods for the purpose of the division of soils according to the categorisation of the supply of soils by phosphorus.

Material and Methods

For the project, results were used from a long-term, polyfactorial trial from nine stations of the Research Institute of Plant Production which included the main productive soil types and productive areas in the Czech Republic. The trials were increasingly fertilised by phosphorus dosage of 20 kg P ha⁻¹ up to dosages of 80 kg P ha⁻¹ at constant dosages of nitrogen, potassium, magnesium, manure and liming.

With the help of the cation exchanger method, it is possible to state an important index which show the relative amount of phosphorus which, after the release of water soluble (partially also

labile fixed) phosphorus (P_w), is still able to release from the soil complex after complex adsorption actions and is still accessible to plants. This index is called “mobile phosphorus” (P_{mob}), it also can be called “old soil strength” and its sum with P_w creates so-called “overall-available phosphorus” ($P_{mob} + P_w$). In the majority of cases, $P_{mob} + P_w$ have a clear relationship between various methods for the determination of accessible phosphorus and the values of P_w and P_{mob} together with the indexes of adsorption (Bache, Williams, 1971). Available P was determined by method Mehlich 3 (1984).

Results and Discussion

According to the relative values of these indexes, especially $P_{mob} + P_w$ and P_{mob} , the monitored soils from various productive areas were divided in four groups and for each group three graded categories of phosphorus supply in the soils were determined (table 1). It follows from this table that in all groups it is approximately the same content level of P_w at various content levels of overall accessible phosphorus ($P_{mob} + P_w$) and mainly P_{mob} .

The groups in which soils were included according to P_{mob} values are possible to characterise like this:

1. The most fertile lowland soils - predominantly climatic area very warm, warm 1 and 2; pH does not fall below 6.5; soil type is mostly medium heavy to heavy; the productive area is the corn belt and sugar beet growing region.
2. Fertile lowland soils - predominantly climatic area warm 3, mildly warm 1 and 2; pH is mostly 5.5 - 6.5; soil type is mostly medium heavy and occasionally also light and heavy; the productive area is predominantly the sugar beet growing region.
3. Lower hills on the edge of fertile soils - climatic area is mildly warm 1 up to 3; pH is mostly 5.5 - 6.5; soil type is light to medium heavy and occasionally also heavy; the productive area is typically the potato-growing region.
4. Soils of upper hills and highlands - climatic region is mildly warm 3 - 4 and mildly cold; pH is lower than 6.0; soil type is predominantly light and medium heavy; productive area is the potato-growing region and the mountainous country.

Table 1: Groups of forms soil phosphorus depending on the location.

Group of soils	Content of P	Pmob	Pw	SI
1.	High	>190	>30	2.08-2.58
	Middle	142-189	20-29	
	Low	<141	<19	
2.	High	>87	>35	0.73-1.40
	Middle	43-86	23-34	
	Low	42	22	
3.	High	72	32	0.95-2.80
	Middle	43-71	22-31	
	Low	43	21	
4.	High	70	30	3.10-5.90
	Middle	31-69	15-29	
	Low	30	15	

Pmob, Pw – mg P kg⁻¹, SI (sorption index) – non-dimensional

Table 2: Categories of the soil phosphorus supply for Mehlich's method 3.

Group of soils	Yield	pH soils	Content of P		
			Texture		
			Light	Middle	Heavy
1.	>5.0	>6.5	61 - 86	44 – 61	31 – 47
2.	4.0 – 5.0	>6.0	68 - 96	48 – 66	34 – 51
		5.6 – 6.5	75 - 106	54 – 73	36 – 54
3.	3.5 – 4.5	5.6 – 6.5	105 - 145	74 – 97	56 – 77
		<5.5	129 - 176	91 – 120	68 – 94
4.	<3.5	5.6 – 6.5	92 - 127	64 – 85	45 – 65
		<5.5	109 - 151	78 – 105	56 – 73

Yield – t ha⁻¹ (cereal units), Mehlich 3 – mg P kg⁻¹.

Because it is not useful to spread the supplementary cation exchanger method and from the practical point of view, it is necessary to build on the Mehlich method 3 which was established for the control of soil fertility with the help of an agrochemical examination of the agricultural soil. The categories of soil supply for the Pmob index were calculated with the help of regression equations to the Mehlich method 3 in such a way that it achieved the range of the content of accessible phosphorus at which it is still possible to calculate for the plant's nutrition with mobilised phosphorus from the soil supply (table 2).

The soils were divided at first according to soil type, then according to pH and then an appropriate category was stated. Table 2 also contains stated average values EVH (ecologically-productive level) which are minimally received at the given range of phosphorus content at fertilisation by other fertilisers.

From the primary point of view of the plants nutrition by phosphorus, priority is placed on the determination of the dosage of phosphorus fertiliser from the category of soil phosphorus supply. In our case it is the determination of such a dosage of phosphorus fertiliser in the use of soil phosphorus supply (Pmob), which for a certain period of time can still be used by plants without an abrupt decrease of accessible phosphorus. According to table 2, it is possible for the dosage of phosphorus fertiliser to be determined by three means:

1. If the phosphorus content is in the range stated in the table than the dosage in kg of $P_2O_5 \cdot ha^{-1}$ is calculated according to regression equations of a polynomial of the first grade stated in table 3.
2. If the phosphorus content is higher than the stated range, then the dosage of phosphorus fertiliser is determined according to the average intake of phosphorus in a crop rotation.
3. In case the phosphorus content is lower than the stated range, it is impossible to count on the use of the soil phosphorus supply and the dosage of phosphorus fertiliser should be determined according to classical methodical of plant nutrition.

May be that vivid description will best clarify the determination of phosphorus fertilisation in the use of soil phosphorus supply with the help of a field which could be included in the 1st group of soils: the content of accessible phosphorus is $57 \text{ mg} \cdot \text{kg}^{-1}$, soil type - medium heavy, pH 6.8, EVH does not drop below 5.0. Fertilisation will be then accomplished by a dosage of P_2O_5 calculated according to the equation: $P_2O_5 \text{ kg} \cdot ha^{-1} = 112 - 0.769 \cdot x = 112 - 0.769 \cdot 57 = 68 \text{ kg } P_2O_5 \cdot ha^{-1}$.

Table 3: Regression equations for calculating of doses. ($\text{kg } P_2O_5 \text{ ha}^{-1}$)

Group of soil	pH	Texture		
		Light	Middle	Heavy
1.	>6.5	$110 - 0.526 x$	$112 - 0.769 x$	$104 - 0.833 x$
2.	>6.0	$104 - 0.476 x$	$105 - 0.714 x$	$97 - 0.769 x$
	5.6 – 6.5	$103 - 0.417 x$	$106 - 0.667 x$	$98 - 0.714 x$
3.	5.6 – 6.5	$101 - 0.333 x$	$107 - 0.556 x$	$100 - 0.625 x$
	<5.5	$102 - 0.286 x$	$108 - 0.454 x$	$98 - 0.501 x$
4.	5.6 – 6.5	$86 - 0.370 x$	$92 - 0.625 x$	$82 - 0.666 x$
	<5.5	$86 - 0.313 x$	$89 - 0.476 x$	$95 - 0.769 x$

x – content of available phosphorus (Mehlich 3) $\text{mg P} \cdot \text{kg}^{-1}$.

Conclusion

Recommended levels of phosphorus fertilisation are based on the principles which were set up in the period of time of the intensification of plant production. At the present time, there are three variants of phosphorus fertilisation (average in kg of $P_2O_5 \cdot ha^{-1}$): intensive (45 - 50), thrifty (32 - 35) and minimal (15 - 18). As it was stated, because of economical reasons production minimal phosphorus fertilisation or does not fertilise by phosphorus at all even without the knowledge of a lower limit of dosages. The plants' nutrition is provided by old soil strength. For the present it is not known when this chaotic way of fertilisation will show up in the total devastation of soil, how long it would take to return to its original state and how much it would cost.

In the article, the data for phosphorus fertilisation is stated. In this case determined dosages during seven-years' crop rotation did not have a substantially negative influence upon the devastating decrease of soil phosphorus. From the time point of view of the use of this type of fertilisation I assume that without a higher risk it is possible to use it for a period of four years.

Reference

- Bache, B.W., Williams, E.G. 1971. A phosphate sorption index for soil. *J. Soil Sci.*, 22(3): 289-301.
Macháček, V. 1986. The determination of release resource phosphorus from soil. Patent AO 247986.
Mehlich, A. 1984. Mehlich No. 3 soil test extractant: A modification of Mehlich No. 2. *Common. Soil Sci. Plant Anal.*, 15: 477-492.

Acknowledgements

This research is funded under Ministry of Agriculture - National agency for agriculture research as grant QD 1326.

EFFECT OF SULPHUR FERTILIZATION ON THE DINAMICS OF SULPHUR CONTENT OF THE WINTER WHEAT IN THE VEGETATION PERIOD

É. Mars*, Z. Györi, K. Puy and P. Sipos

University fo Debrecen, Centre for Agricultural Science, Faculty of Agronomy, Department of Food Science and Quality Assurance, 138. Böszörményi Str., 4032 Debrecen, Hungary
Tel/fax: +36-52-417-572

Summary

The number of experiments dealing with the function of S in the plant cultivation has increased worldwide in the last years. In many countries the use of superphosphate as P-containing fertiliser decreased, and in accordance with the demanding air-protection orders, the S-deposition proportion from the atmosphere to the soil also decreased. The result is that many places have to calculate with negative S-balances and increasing S-deficiency in the future.

In a large scale sulphur fertilization experiment on brown forest soil we examined the effect of treatments on the sulphur-, nitrogen content and the N/S ratio of winter wheat in the whole upperground plant and in the grain and straw at harvest.

Samples were taken from spring to harvesting, at the critical phenophases. In this study we discuss only the values from the stooling and stalking and the results of analysis of grain and straw at harvest. We made the following conclusions based on our examinations:

- the concentration of sulphur in the whole upperground parts of winter wheat showed increase to the end of vegetation independently of fertilization;
- the N/S ratio was from 8% to 12% in the growth period while the ratio in the grain was 13-14%;
- we got the highest sulphur content in the leaf when we examined the whole upperground plant, stalk and leaf at stalking;
- the middle level sulphur fertilization dose (4 l/ha) increased mostly the sulphur accumulation in the green plant;
- the greatest part of accumulated sulphur is in the grain at total maturing, but then the effect of fertilization is less glaring.

Introduction

The sulphur become one of the most important performance-restrict element of our plant production in the last years while we managed to pass many nutrient unnecessary to the agroecosystem nowadays. The problems of sulphur supply of the cultivated plants were not in the focus of the researches until the beginning of the eighties, the atmospherical S-deposition and the S-mass from the mineralization of the organic matter of soils were able to cover the needs of our cultivated plants (DÄMMGEN, ET AL. 1998; ERIKSEN ET AL., 1998.). With the initiation of the air-protection orders these sulphur sources were continously loosed their importance and nowadays they are not able to cover the needs of the plants without fertilization.

We must calculate with negativ sulphur balance and increasing sulphur deficit at many cropping sites.

The number of examinations about the role of sulphur in the plant production has increased worldwide. In many countries the use of superphosphate as P-containing fertiliser decreased too (GYÖRI, 1998), the superphosphate was substituted by triple superphosphate and the automatical sulphur fertilization vanished. The superphosphate extractioned by H_2SO_4 contains 50 mol% sulphate (BOHN ET AL, 1985).

We need adequate sulphur supply to manage covering the required yield and quality. The sulphur deficit result in less yield, decreasing the baking quality and causes reduced degree nitrogen efficiency (SCHNUG AND HANEKLAUS, 1994; HANEKLAUS AND SCHNUG, 1992;. SCHNUG ET AL., 1993; HANEKLAUS ET AL., 1992; SCHNUG, 1993). The baking quality of winter wheat in mainly influenced by the gluten content of flour which shows strong connection to the whole nitrogen content of the grain (BELITZ AND GROSCH, 1985). The not suitable sulphur supply make the noodles sticky and it decreases the baking quality of wheat (BYERS, M.-BOLTON, J. 1979; HANEKLAUS, S.- SCHNUG, E. 1992). The sulphur deficit has a delaying effect on the growth of plants (RATNER, 1963; BÚZÁS, 1983; FÜLEKY, 1999; SOLTÍ, 2000).

The adequate sulphur supply can be insured when the plants are able to take up the ground water rich in sulphate close to surface and the groundwater raised by capillary (BLOEM, 1998).

Materials and Methods

Large scale sulphur fertilization experiment on brown forest soil was started in the autumn of 2001 at the Agricultural Cooperative of Felsőzsolca. We fertilized with sulphur with the beginning of the vegetation period in spring, at the end of the stooling with Fitohorm 32S leaf fertilizer (Table 1.) In autumn there was only a nitrogen fertilization in one step with the ploughing. The examined variety was the GK Élet.

The samples are from spring to harvesting, from the critical phenophases (stooling, stalking, heading, flowering, maturing). After suitable preparation and digestion by nitric acid/hydrogen-peroxide solution we measured the nitrogen and sulphur content with ICP-OES at the DE-ATC Central Laboratory. The results were analysed by base statistical methods (means, standard deviations, variance).

Results and Discussion

Table 1. shows the means for the measured sulphur concentrations in the different phenophases. We experienced the significant effect of fertilization on the sulphur content at stalking the whole surface upper parts ($LSD_{5\%}=363,1$) and leaves ($LSD_{5\%}=496,3$). We have no experienced significant connection between the sulphur content and the sulphur fertilization at stooling and harvesting.

In the whole surface upper part of the winter wheat the sulphur concentration decreased in the whole vegetation period independently of the fertilization. Considering 100% the stooling concentration at the maturing the sulphur concentration decreased to about 45-47% caused by dilution.

Table 1: The effect of fertilization on the sulphur content of winter wheat (%)

(Felsőzsolca, 2001-2002. GK-Élet)

Treatments	Stooling	Stalking			Maturing
		Whole surface upper parts	Leaves	Stalk	Grain
1. Ø	0,39	0,26	0,41	0,17	0,20
2. 2 l/ha S	0,43	0,27	0,41	0,20	0,20
3. 4 l/ha S	0,40	0,33	0,53	0,20	0,19
4. 6 l/ha S	0,42	0,29	0,44	0,19	0,19

Comparing the results of the whole green plant, leaves and stalk, the highest sulphur content was found in the leaves after the spring loaf fertilization (stalking) (Figure 1.). Examining the effect of treatments we found the highest sulphur content in the case of the middle (4l/ha S) fertilizer dose in the green plant.

The greatest part of sulphur in the grain at maturing. The effect of fertilization does not show realizable differences.

The physiological importance of sulphur, the protein synthesys require the harmonical plant supply so the references give great importance of the adequate N/S ratio provided (KANWAR ÉS MUDAHAR, 1986; SAALBACH, 1982; RASMUSSEN ET AL., 1975; STEWARD ÉS PORTER, 1969).

LÁSZTITY (1991) was examined the effect of NPK fertilization on the changings of N/S ratio of winter wheat on calcareous chernozem soil in the whole vegetation period. He experienced N/S ratio was between 10,8 and 17,3, the greatest N/S ratio was found at the maturing of winter wheat and the lowest at heading.

GYÖRI (1998) called attention to the fact that there is a strong connection between the nitrogen and sulphur content. He reported for the winter wheat about 15 as N/S ratio in average years while the ratio becomes about between 16 and 17,5 in drought weather years especially in years with dry May.

We found different results as it was reported in the references. We measured N/S ratio between 7,65 and 11,10 in the green plant at the beginning of vegetation and about 14 in the grain at maturing (Table 2.)

Figure 1: Effect of sulphur fertilization on the sulphur content of winter wheat in the individual plant parts at stalling (Felsőzsolca, 2001/2002.)

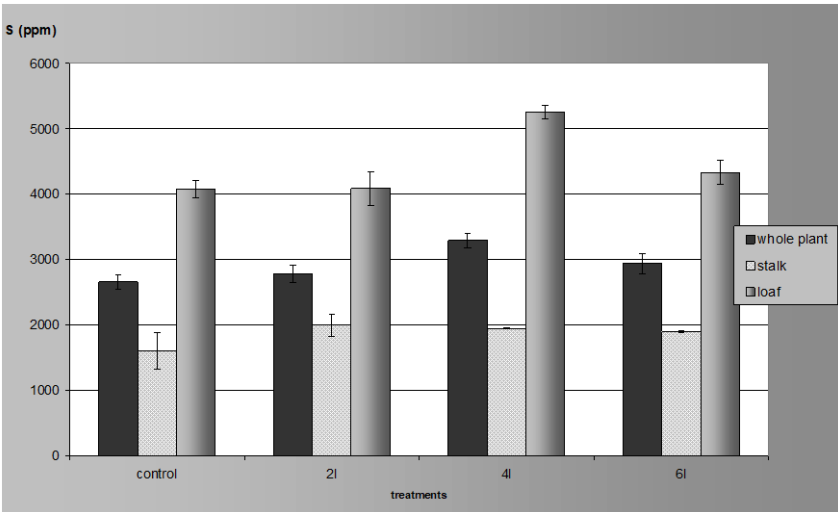


Table 2: Effect of sulphur fertilization on the changing of N/S ratio of winter wheat in the vegetation period (%) (Felsőzsolca, 2001-2002. GK-Élet)

Treatments	Stooling	Stalking			Maturing
		Whole green plant	Loaf	Stalk	Grain
1. Ø	11,10	9,10	9,35	9,69	13,39
2. 2 l/ha S	10,64	9,00	9,54	8,01	13,39
3. 4 l/ha S	10,50	7,65	7,38	8,32	13,62
4. 6 l/ha S	10,50	9,56	9,39	9,45	14,03

Analyzing the effect of sulphur fertilization in our experiment we kept the formation of quantity of yield in view too. We found higher yield in the case of the second treatment based to the

control but more increasing sulphur loaf fertilizer doses at the spring has not resulted more increasing in yield (Table 3.).

We are planning to analyze the periods of heading and flowering and to explore the exact dynamic of sulphur accumulation in the future.

Table 3: Effect of sulphur fertilization on the yield of winter wheat (t/ha)

(Felsőzsolca, 2002. GK-Élet)

Treatments	1 st plot	2 nd
1. Ø	2,4	2,6
2. 2 l/ha S	2,6	2,8
3. 4 l/ha S	2,4	2,9
4. 6 l/ha S	2,7	2,5

References

- BELITZ, H.-D. AND GROSCH, W. 1985: Lehrbuch der Lebensmittelchemie. 2. Auflage Springer Verlag, Berlin und Heidelberg. 514-558.p.
- BLOEM, E. 1998: Bedeutung hydrologischer und physikalischer Bodeneigenschaften für die Schwefelversorgung von Kulturpflanzen. Diss. TU-Braunschweig.
- BOHN, H. L.- MCNEAL, B. L.- O'CONNOR, G. A., 1985: Talajkémia. Mezőgazdasági Kiadó- Gondolat Kiadó, Budapest.
- BÚZÁS I., 1983: Növénytáplálás zsebkönyve. Mezőgazdasági Kiadó, Budapest.
- BYERS, M.- BOLTON, J. 1979: Effects of nitrogen and sulphur fertilizers on the yield, N and S content, and amino acid composition of the grain of spring wheat. Journal of the Science of Food and Agriculture 30. 251-263.p.
- DÄMMGEN, U.- WALKER, K.- GRÜNHAGE, L.- JÄGER, H.-J. 1998: The atmospheric sulphur cycle. In: Sulphur in Agroecosystems (ed. E. Schnug), Kluwer Academic Publ.. Dordrecht. Boston. London. 75-114.p.
- ERIKSEN, J.- MURPHY, M. D.- SCHNUG, E. 1998: The soil sulphur cycle. In: Sulphur in Agroecosystems (ed. E. Schnug), Kluwer Academic Publ.. Dordrecht. Boston. London. 39-74.p.
- FÜLEKY GY., 1999: Tápanyaggazdálkodás. Mezőgazda Kiadó, Budapest.
- GYÖRI Z., 1998: A termesztési tényezők hatása egyes gabonafélék és maghüvelyesek minőségére. Akadémiai doktori értekezés. Agrártudományi Egyetem. Debrecen. 198pp.
- HANEKLAUS, S.- EVANS, E.- SCHNUG, E. 1992: Baking quality and sulphur content of wheat. I. Influence of grain sulphur protein concentration on loaf volume. Sulphur in Agriculture. 16. 31-35.p.
- HANEKLAUS, S.- SCHNUG, E. 1992: Baking quality and sulphur content of wheat II: Evolution of the relative importance of genetics and environment including sulphur fertilization. Sulphur in Agriculture. 16. 35-38.p.
- KANWAR, J. S. - MUDAHAR, M. S., 1986: Fertilizer sulfur and food production Martinus Nijhoff. Dr. W. Junk Publishers. Dordrecht.
- LÁSZTITY B., 1991: Az NPK-tápanyagellátás hatása az őszi búza kéntartalmának és felhalmozásának dinamikájára. Agrokémia és Talajtan. 40 (1-2) 131-139.p.
- RASMUSSEN, P. E. ET AL., 1975: Nitrogen sulfur relations in soft white winter wheat II. Initial and residual effect of sulfur application on nutrient concentration, uptake and N/S ratio. Agron. J. 67 224-228.p.
- RATNER, E. I., 1963: A növények táplálkozása és a trágyázás. Mezőgazdasági Kiadó, Budapest.
- SALLBACH, E., 1972: Über den Schwefelbedarf landwirtschaftlicher Nutzpflanzen. Landw. Forsch. 27/1 Sonderh. 224-228.p.
- SCHNUG, E. 1993: Ökosystemare Auswirkungen des Einsatzes von Nährstoffen in der Landwirtschaft. In: Schriftenreihe des Bundesministers für Ernährung, Landwirtschaft und Forsten, Reihe A: Angewandte Wissenschaft. 426. Nährstoffe und Pflanzenschutzmittel in Agrarökosystemen. 25-47.p.
- SCHNUG, E.- HANEKLAUS, S. 1994a: Sulphur deficiency in Brassica napus –Biochemistry- Symptomatology- Morphogenesis-. Landbauforschung Völkrode, Sonderheft 144.
- SCHNUG, E.- HANEKLAUS, S. 1994b: The ecological importance of sulphur. Norwegian Journal of Agricultural Sciences. Suppl. No.15. 149-156.p.

- SCHNUG, E.- HANEKLAUS, S.- MURPHY, D.1993: Impact of sulphur fertilization on fertilizer nitrogen efficiency. Sulphur in Agriculture. 16. 31-34.p. The Sulphur Institute. Washington DC.)
- SOLTI G., 2000: Talajjavítás és tápanyag-utánpótlás az ökológiai gazdálkodásban. Biogazda kiskönyvtár. Mezőgazda Kiadó, Budapest.
- STEWART, B. A. - PORTER, L. K., 1969: Nitrogen- sulfur relationship in wheat corn and beans. Agron. J. 61 267-271.p.

NITROGEN X DESFERAL FERTILIZATION EFFECTS ON MICRO AND TRACE ELEMENT UPTAKE OF *CROTALARIA JUNCEA* L.

L. Márton* and P. Csathó

Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences
1022 Budapest, Herman O.u.15., Hungary

Summary

Soil fertility and plant production are the two most important parts of the agricultural activity on all over the world. Soils, their fertility have almost always dictated the spread of agricultural farmlands, including the plant production-, grain harvest levels possible. The success of agriculturists in the 20th and 21th century, particularly in the Europe has relied on improved soil fertility managements and appropriate crop production. We can improve the situation by using different plant species (*Crotalaria juncea* L.) x macro nutrients (nitrogen) x chelating agents (Desferal as deferoxamine-mesilate: $C_{25}H_{48}N_6O_8-CH_4O_3S$) method. *Crotalaria* has a very potential and important role in soil fertility as a green manure crop in the design of plant rotation to field plant production, in the animal foraging as a fodder-crop with a high protein content (30%) and in the pyto remediation possibilities. Field experiment was carried out on a calcareous chernozem meadow soil (Kunság-region of Hungary, Kunmadaras) in partly of *crotalaria* experiment series (5 years) in 2001. The agrochemical parameters of the ploughed layer of the region soils were as follows: humus 2.5-3.0%, pH (H₂O) 7.7, pH (KCl) 7.0, LE (Lakanen & Erviö 1971)-P₂O₅ 1830-2180 mg kg⁻¹, LE-K₂O 820-1150 mg kg⁻¹, LE-Ca 1.3%, LE-Mg 560-605 mg kg⁻¹, LE-Mn 450-465 mg kg⁻¹ according to soil analysis. Nitrogen (N) x Desferal ("D"-Novartis Pharma AG Basie, Switzerland, Suiza 500 mg) x Genotype ("G"-India-University of Agricultural Sciences, Bangalore) x Time (T) experiment involved 4Nx2DxGx3T=24 treatments in 3 replications giving a total of 72 plots. The N levels were 0, 100, 200 and 300 kg ha⁻¹ year⁻¹, and Desferal 0 and 20 kg ha⁻¹ year⁻¹. The plot size had an area of 4x2=8 m². Experimental datas were estimated by MANOVA of SPSS. The main results can be summarised as follows: a., At harvest, total air dry phytomass (straw+leaf) yield ranged between 8.7-16.5 t ha⁻¹, depending on the N-treatment applied. By N+Desferal combinations the air dry straw+leaf mass achieved 19.3 t ha⁻¹, changed between 14.2-19.3 t ha⁻¹ depending on the treatment rates. b., On this humus-rich calcareous chernozem soil the micro and trace element translocation from soil (actual translocation index "ATI") to plants can be characterized by x_1 nutrient concentration of plant divided by x_1 nutrient concentration of soil⁻¹ by N treatment average effects of Al: 1.55, B: 16.90, Ba: 0.58, Cd: 1.08, Co: 0.02, Cr: 1.88, Cu: 0.76, Fe: 0.87, Hg: 2.02, Mg: 11.17, Mn: 0.17, Mo: 24.14, Na: 2.52, Ni: 0.05, Pb: 0.09, S: 122.31, Se: 0.36, Sr:

3.85 and Zn: 1.77. The “ATT” values by N+D treatment average effects were in case of the Al: 1.48, B: 13.30, Ba: 0.98, Cd: 1.17, Co: 0.02, Cr: 1.53, Cu: 0.71, Fe: 0.81, Hg: 0.59, Mg: 9.49, Mn: 0.14, Mo: 30.15, Na: 0.81, Ni: 0.02, Pb: 0.09, S: 104.63, Se: 0.80, Sr: 3.06 and Zn: 2.71. c., Depending on the N and N+D treatments, 80.0-89.5 kg Mg, 42.1-50.5 kg S, 2.5-3.1 kg Fe, 1.9-2.3 kg Al, 0.8-2.1 kg Na, 1.3-1.4 kg Sr, 1.0 kg Mn, 650-666 g B, 345-686 g Zn, 242-523 g Ba, 193-231 g Cu, 31-42 g Mo, 14-17 g Pb, 3-6 g Ni, 4-5 g Cr, 2 g Cd, 0.5-2.0 g Se, 1 g Co and 0.2-0.6 g Hg accumulated in the 12.6 t ha⁻¹ (average of N treatments) and 16.1 t ha⁻¹ (average of N+Desferal treatments) phytomass (straw+leaf) air-dry aboveground yield by *Crotalaria micro* and trace element uptake. d., On the given soil the highest quantity of 300 kg ha⁻¹ year⁻¹ N+20 kg ha⁻¹ year⁻¹ D chelating agent seemed to give already over fertilization negativ effects on all experimental results. Thus, the maintenance and improvement of the fertility of our soils has never been more important than it is today.

Introduction

These days sustainable agricultural production has become the major issue following global and climat change in all the world over. It is well known that it has a well established on soils. The functioning and their ability to supply nutrients, store water, release gases, modify pollutants, decrease physical degradation and produce crops is profoundly influenced by their fertiliy. During the last fifty years phenomenal progress has been made in several areas of ecology of different trace elements in soils. Today, concerns regarding heavy metals contamination in the environment affecting all ecosystem componets, including “soil-plant-animal-human” chain, have been identified with increasing efforts on limiting their bioavailability. Many sites have been identified as hasardous waste sites because of the presence of elevated concentrations of these elements (Kádár 1992). They will remain a threat to the environment until they are removed or immobilized. We can improve these situation by using different plant species (Purseglove 1974)-(*Crotalaria juncea* L.) x macro nutrients (nitrogen) x chelating agents (Shenker et al. 1996)-(Desferal as deferoxamine-mesilate: C₂₅H₄₈N₆O₈-CH₄O₃S) method. *Crotalaria* has a very potential and important role in soil fertility as a green manure crop (Márton & Jose 2001), in the design of plant rotation to field plant production (Márton & Pekli 2003), in the animal foraging as a fodder-crop with a high protein content (30%) and in the pyto remediation possibilities. Nitrogen can be of considerable importance for cation-anion balance in plants. The content of this element required for optimal growth varies between 2 and 5% of the plant dry weight (Horst 1986). When the supply is suboptimal growth is retarded, nitrogen is mobilized in mature leaves and retranslocated to areas of new growth. An increase in

the supply delays senescence and stimulates growth (Werner 1992). Chelating agents as the Desferal has a very important deal of ion exchanges in soils. It is regulate anion and cation concentrations in rooth zone (Shenker et al. 1996).

Materials and Methods

Field experiment was carried out on a calcareous chernozem meadow soil (Kunság-region of Hungary, Kunmadaras) in partly of crotalaria experiment series (5 years) in 2001. The agrochemical parameters of the ploughed layer of the region soils were as follows: humus 2.5-3.0%, pH (H₂O) 7.7, pH (KCl) 7.0, LE (Lakanen & Erviö 1971)-P₂O₅ 1830-2180 mg kg⁻¹, LE-K₂O 820-1150 mg kg⁻¹, LE-Ca 1.3%, LE-Mg 560-605 mg kg⁻¹, LE-Mn 450-465 mg kg⁻¹ according to soil analysis. Nitrogen (N) x Desferal (“D”-Novartis Pharma AG Basie (2001), Switzerland, Suiza 500 mg) x Genotype (“G”-India-University of Agricultural Sciences, Bangalore) x Time (T) experiment involved 4N x 2D x G x 3T = 24 treatments in 3 replications giving a total of 72 plots. The N levels were 0, 100, 200 and 300 kg ha⁻¹ year⁻¹, and Desferal 0 and 20 kg ha⁻¹ year⁻¹. The plot size had an area of 4x2=8 m². Composite soil samples consisting of 15 subsamples were collected at harvest time (20.10.2001) from the ploughed layer (0-40 cm) of each plot. Plant samples were taken using 15 plants (leaf+straw) plot⁻¹ randomly at the beginning of flowering (23.08.2001). In the soil samples the so-called “mobile” fraction extracted with ammonium-acetate+EDTA (AAc+EDTA, Lakanen & Erviö 1971) was determined by inductively coupled plasma atomic emission spectrometry (ICP-AES) detecting 23 elements at Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences (RISSAC-HAS). The total amount of the elements in homogenized plant samples were measured after microwave digestion using cc. HNO₃+H₂O₂. The composition of prepared samples was analysed by ICP-AES technics detecting 23 elements at RISSAC-HAS. Experimental datas were estimated by MANOVA of SPSS.

Results and Discussion

At harvest, total air dry phytomass (straw+leaf) yield ranged between 8.7-16.5 t ha⁻¹, depending on the N-treatment applied. By N+Desferal combinations the air dry straw+leaf mass achieved 19.3 t ha⁻¹, changed between 14.2-19.3 t ha⁻¹ depending on the treatment rates. It was increased on average with an 28 % compared to mean of N doses effect. The mobile, i.e. available fraction in soil-extracted with the mixture of AAc+EDTA-varied widely for the different examined treatments. Micro-, and trace nutrients rates (%) by N and N+Desferal treatments (x₁

element concentration at the N-150 kg ha⁻¹ year⁻¹ multiplied by 100 and divided by x₁ element concentration at the N-150+Desferal-10 kg ha⁻¹ year⁻¹) were 77% in case of the Se, 91: S, 94: Fe, 97: Mg, 99: in case of the Sr, Ba, Cr and Zn, 100: in case of the Co, Ni Mn and Cu, 101: Cd, 102: Al, 103: B, 105: Pb, 115: Hg and 118 % Mo. Element concentrations of plants were also influenced greatly by treatments applied. Rates of elements (%) by N and N+Desferal treatments (x₁ element concentration at the N-150 kg ha⁻¹ year⁻¹ multiplied by 100 and divided by x₁ element concentration at the N-150+Desferal-10 kg ha⁻¹ year⁻¹) were 34% in case of the Se, 59: Ba, 64: Zn, 94: Mo and Cd, 101: Co and Fe, 106: S, 107: Cu, Al and Pb, 114: Mg, 118: Mn, 121: Cr, 124: Sr, 131: B, 220: Ni, 353: Na and 396% Hg. On this humus-rich calcareous chernozem soil the element translocation from soil (actual translocation index "ATI" by Márton 2001) to plants can be characterized by x₁ nutrient concentration of plant divided by x₁ nutrient concentration of soil⁻¹ by N treatment average effects of Al: 1.55, B: 16.90, Ba: 0.58, Cd: 1.08, Co: 0.02, Cr: 1.88, Cu: 0.76, Fe: 0.87, Hg: 2.02, Mg: 11.17, Mn: 0.17, Mo: 24.14, Na: 2.52, Ni: 0.05, Pb: 0.09, S: 122.31, Se: 0.36, Sr: 3.85 and Zn: 1.77. And, the "ATI" values by N+Desferal treatment average effects were in case of the Al: 1.48, B: 13.30, Ba: 0.98, Cd: 1.17, Co: 0.02, Cr: 1.53, Cu: 0.71, Fe: 0.81, Hg: 0.59, Mg: 9.49, Mn: 0.14, Mo: 30.15, Na: 0.81, Ni: 0.02, Pb: 0.09, S: 104.63, Se: 0.80, Sr: 3.06 and Zn: 2.71. Depending on the N and N+Desferal treatments, 80.0-89.5 kg Mg, 42.1-50.5 kg S, 2.5-3.1 kg Fe, 1.9-2.3 kg Al, 0.8-2.1 kg Na, 1.3-1.4 kg Sr, 1.0 kg Mn, 650-666 g B, 345-686 g Zn, 242-523 g Ba, 193-231 g Cu, 31-42 g Mo, 14-17 g Pb, 3-6 g Ni, 4-5 g Cr, 2 g Cd, 0.5-2.0 g Se, 1 g Co and 0.2-0.6 g Hg accumulated in the 12.6 t ha⁻¹ (average of N treatments) and 16.1 t ha⁻¹ (average of N+Desferal treatments) phytomass (straw+leaf) air-dry aboveground yield by crotalaria micro-, and trace element uptake. On the given soil the highest quantity of 300 kg ha⁻¹ year⁻¹ N+20 kg ha⁻¹ year⁻¹ Desferal chelating agent seemed to give already over fertilization negativ effects on all experimental results.

Acknowledgement

This study was supported by Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences H-Budapest, The Hebrew University of Jerusalem Faculty of Agricultural, Food and Environmental Quality Sciences, Department of Soil and Water Sciences I-Rehovot and Department of Soil Science and Agricultural Chemistry of the University of Agricultural Sciences, I-Bangalore

References

- Horst M. 1986. Mineral nutrition of higher plants. Academic Press, London Orlando San Diego New York Austin Boston Sydney Tokyo Toronto
- Kádár I. 1992. Principles and methods in plant nutrition. RISSAC-HAS, Budapest, 398p.
- Lakanen E. & Erviö R. 1971. A comparison of eight extractants for the determination of plant available micronutrients in soils. Acta Agr. Fenn, 123:223-232.
- Márton L. 2001. Scientific report. RISSAC-HAS, Budapest
- Márton L. & Jose E.M. 2001. Effects of *Crotalaria juncea* L. and *Crotalaria spectabilis* ROTH on soil fertility and soil conservation in Hungary. Acta Agronomica Óváriensis, 43:1-8.
- Márton L. & Pekli J. 2003. *Crotalaria (Crotalaria juncea* L.) production. SZIE, Gödöllő
- NPAG. 2001. Databank, Basie
- Purseglove J.W. 1974. Tropical crops. I-II. Longman Group Limited, London
- Shenker M., Hadar Y. & Chen Y. 1996. Stability constants of the fungal siderophore rhizoferrin with various microelements and calcium. Soil Sci. Soc. Am. J., 60:1140-1144.
- Werner B. 1992. Nutritional disorders of plants development, visual and analytical diagnosis. Gustav Fischer Verlag Jena, Stuttgart, New York. 741p.

ENVIRONMENTAL FRIENDLY SIDE-PRODUCT (BIOFERT) APPLICATION IN SUNFLOWER FERTILIZATION SYSTEM

P. Pepó, L. Zsombik and A. Szabó

University of Debrecen, Faculty of Agronomy
Hungary

Abstract

In synthetic fermentation of lysine (amino-acid) a side-product (Biofert) originates which can be characterized by 6 % N-content and other ingredients (vitamins, enzymes, microelements etc). In large plot experiments Biofert was studied in different agroecological (cropyear, soil), biological (genotypes) and agrotechnical (no fungicide and fungicide treatments) conditions to get information about agronomic efficiency and environmental effects of its application in sunflower fertilization system.

In our research project we studied the effects of Biofert on the phenological, agronomical parameters, the infections of sunflower on different subtypes of meadow soils in 2001-2002 cropyears.

Our scientific results proved that the appropriate application of Biofert could increase the yield of sunflower. The yield surpluses were 200-400 kg ha^{-1} in 2001 (control 2500-2600 kg ha^{-1}) and 400-600 kg ha^{-1} in 2002 (control 2300-2400 kg ha^{-1}), respectively. According to our results both the autumn and spring application (before planting) were effective in sunflower production. The optimum N-dose was 45 kg ha^{-1} using in autumn and in spring too. The application of fungicide did not result yield-surpluses in 2001 and 2002 cropyears because low infection of fungi (mainly *Diaporthe helianthi* and others) on the stem and head of sunflower.

Our results proved that the side-product (Biofert) had the same agronomic efficiency comparing with the traditional N-fertilizers, but Biofert had advantages from economic (cheaper) and environmental (less N-leaching in soils) aspects in sunflower production.

Introduction

In the past time the sunflower production could be characterized by extensive agrotechnical management system but nowadays the technological input level increased up to the medium one. The reason of the increasment is the changes of biological background, the new portfolio of sunflower production.

The sunflower production has very important role in Hungarian arable crop production. Sunflower is the third important crop in Hungary, the average planting area is 350-450 thousand ha-s. Because of economic-financing problems the average yields dropped in Hungary in the last decade (in 1980's were 1,8-2,0 t ha^{-1} , in 1990's were 1,2-1,6 t ha^{-1}).

It is well-known that sunflower has a very good natural nutrient utilization ability so it has moderate fertilizer demand and response. This situation slightly changed because of the new genotypes. In the new crop management of sunflower the fertilization has bigger and more

decisive role than it was before. Especially the N-supply and N-fertilization has a very important role in sunflower production because it has determinative effect on the yield, oil content and infection of leaf-, stem- and head-diseases. Usually the traditional nitrogen mineral fertilizers are used in sunflower production but it is possible to use the other environmental friendly N-forms (like Biofert).

The fertilization has two main aims in the sunflower productions: firstly to increase the yield and oil content, secondly to maintain soil fertility (Kádár, 1999). According to the experiments of Harmati (1992) the fertilization has the decisive role on such soil types which could be characterized by bad nutrient husbandry.

The international and Hungarian literature state that the low and high fertilizer doses comparing to the optimum doses (mainly nitrogen) decrease both yield quantity and quality (Harmati 1993, Simkins-Overdahl 1982, Csizmazia-Horváth 1997). The infection of *Diaporthe helianthi* depended on genotype, but the infection of *Sclerotinia sclerotiorum* was influence by plant density and N-fertilizer doses (Németh *et al.*, 1998). Angelova (2001) proved that the optimum N-doses varied between 60-120 kg ha⁻¹. The optimum N-fertilizer doses varied between 30-90 kg ha⁻¹ on chernozem soil (Pepó *et al.*, 2002). The optimum N-doses in sunflower production was modified by genotypes, so it is very important to use hybrid-specific N-fertilization in the case of new genotypes (Pepó-Zsombik, 2003). Antal (1994) stated that the optimum N-fertilizer doses are 50-60 kg ha⁻¹ on chernozem soil and these doses could increase by 50-60 % on poor soil types.

Material and Methods

The large-pot experiments were carried out on alluvial loamy soil in eastern part of Hungary (Kisújszállás) in 2001 and 2002 years. The forecrops were silage maize.

In our experiments we used Biofert as a nitrogen fertilizer. Biofert is a side-product of the synthetic lysine production. Biofert has 6 % nitrogen and other microelements. In the field experiments the treatments were the followings:

Table 1: Treatments of field experiment (Kisújszállás, 2001)

Treatments	N-form	No fungicide			Fungicide		
		N-dose (kg ha^{-1})			N-dose (kg ha^{-1})		
		autumn	spring	total	autumn	spring	total
1	Control	0	0	0	0	0	0
2	Biofert	45	0	45	45	0	45
3	Biofert	45	45	90	45	45	90
4	Biofert	45	90	135	45	90	135
5	Biofert	90	0	90	90	0	90
6	Biofert	90	45	135	90	45	135
7	Biofert	0	45	45	0	45	45
8	Biofert	0	90	90	0	90	90
9	Biofert	0	135	135	0	135	135

Table : Treatments of field experiment (Kisújszállás, 2002)

Treatments	N-form	No fungicide			Fungicide		
		N-dose (kg ha^{-1})			N-dose (kg ha^{-1})		
		autumn	spring	total	autumn	spring	total
1	Kontroll	0	0	0	0	0	0
2	Biofert	0	45	45	0	45	45
3	Biofert	0	90	90	0	90	90
4	Biofert	0	135	135	0	135	135
5	Biofert	45	0	45	45	0	45
6	Biofert	45	45	90	45	45	90
7	Biofert	45	90	135	45	90	135
8	Biofert	90	0	90	90	0	90
9	Biofert	90	45	135	90	45	135

Results and Discussion

Our experimental results proved that sunflower could effectively utilize the natural nutrient content of soil. In alluvial loamy soil we obtained 2500 kg ha^{-1} in 2001 year, 2300 kg ha^{-1} in 2002 year in control treatment (without fertilization), respectively.

The yields varied between 1533-2975 kg ha^{-1} in 2001 year. This cropyear could be characterized by rainy June and July. Because of soil- and fungicide-stresses we obtained less yield in

fungicide-treatments (by 100-800 kg ha^{-1} yield decrease). In 2001 cropyear the maximum yield was 2975 kg ha^{-1} and the optimum N-dose was 45 kg ha^{-1} applied in spring (figure 1.).

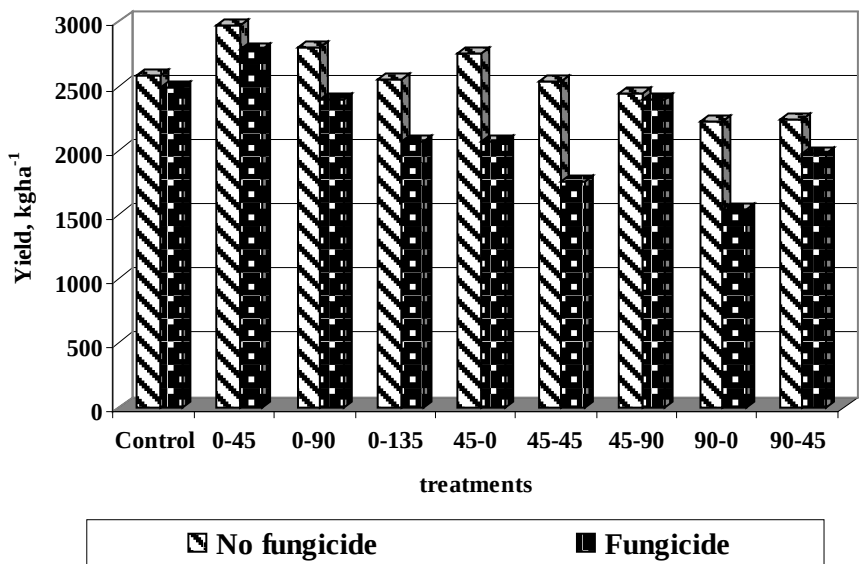


Figure 1: Effect of Biofert on the yield of sunflower (Kisújszállás, 2001)

In 2002 year we obtained higher yields in average because of favourable climatic conditions. The yields varied between 2202-2971 kg ha^{-1} depending on the treatments. In 2002 cropyear we obtained the maximum yield in N = 45 kg ha^{-1} treatment which was applied in autumn. In 2002 there were no differences between the fungicide and no fungicide treatment because the low levels of the infection of the most important leaf-, stem- and head-diseases.

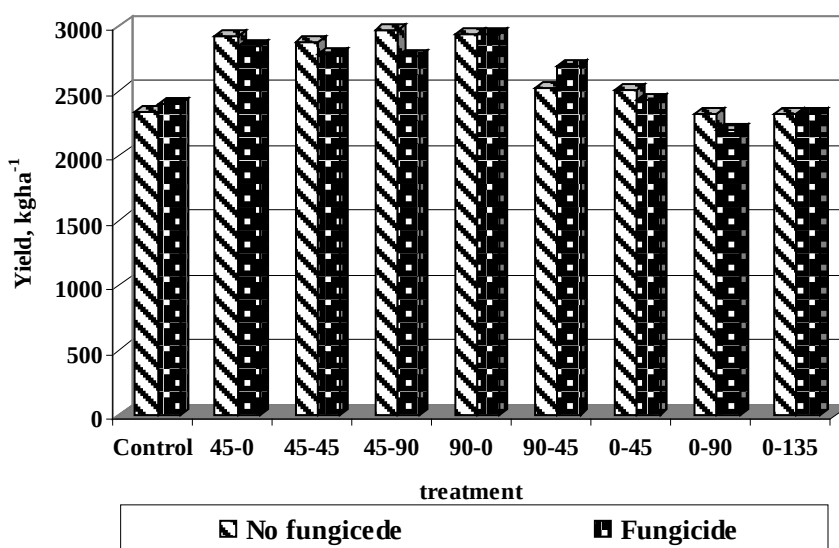


Figure .: Effect of Biofert on the yield of sunflower (Kisújszállás, 2002)

The increasing doses of nitrogen enlarged the infection of *Diaporthe helianthi*. We obtained the maximum infection value of *Diaporthe* in the treatment of N = 135 kg ha⁻¹ (49,5 %). The minimum infection was in the control treatment in 2001 year (26,2 % with fungicide using, 20,2 % without fungicide). The infection of *Diaporthe* occurred fairly late and the dynamics of infection was slowly in 2001 cropyear.

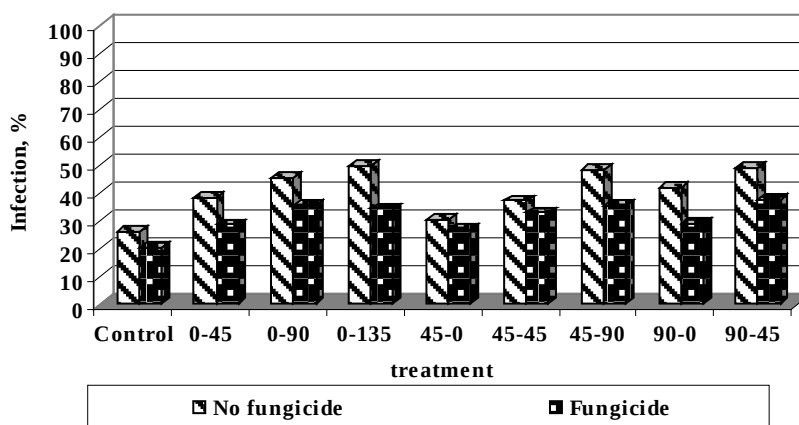


Figure 3: Effect of Biofert on the infection of *Diaporthe helianthi* (Kisújszállás, 2002)

We obtained lower infection level of *Diaporthe* in 2002 cropyear because of dry and hot weather condition in spring and summer. The dynamics of *Diaporthe* infection was moderated in 2002. The infection of *Diaporthe* varied between 9,5 and 28,0 %, respectively. We found minimum infection in control treatment (9,5 % with fungicide using, 12,5 % without fungicide). In 2002 cropyear the N-doses moderately increased the infection of *Diaporthe*. The maximum infection rate was in N = 135 kg ha⁻¹ Biofert treatment.

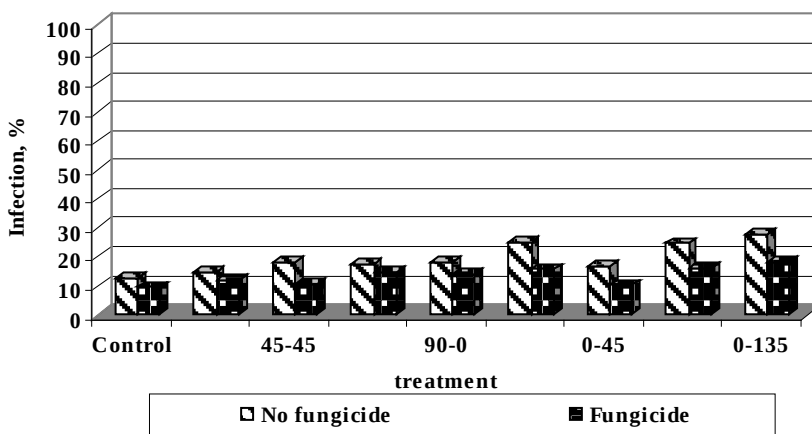


Figure 4: Effect of Biofert on the infection of *Diaporthe helianthi* (Kisújszállás, 2002)

References

- Angelova, M. (2001): The impact of nitrogen fertilization on the yield of sunflower when grown on calcareous black soil in North-West Bulgaria. *Rastenievodni Nauki*. 38. 1. 14-21.
- Antal, J. (1994): Szempontok a napraforgó termesztéséhez. *Agrofórum* 5. 4. Különszám 2-3.
- Csizmazia, J.-né-Horváth, Z. (1997): Még egyszer a napraforgó hiánytüneteiről. *Agrofórum*. 8. 8. 46.
- Harmati, I. (1992): A napraforgó műtrágyázása *Agrofórum* 3. 1. 18-22
- Harmati, I. (1993): Műtrágyázás hatása a napraforgó termésére. *Agrokémia és Talajtan* 42. 3-4. 289-292.
- Hocking, P.J.-Steer, B. T. (1989): Effect of seed size Cotyledon removal and nitrogen stress on growth and on yield components of oilseed sunflower. *Field Crop Research* 22. 1. 59-75.
- Kádár, I. (1999): A napraforgó trágyázásáról. *Agrofórum* 10. 12. 57-60.
- Németh, R.-Vágvölgyi, S.-Sziklai, Z. (1998): A napraforgó hibridek állományosűrűségéről és tápanyagellátottságáról. *Agrofórum* 9. 4. 13-17.
- Pépó, P.-Zsombik, L.-Borbélyné, H.É. (2002): A napraforgó-termesztés agrotechnikai fejlesztési lehetőségei. *Gyakorlati Agrofórum*. 13. 1. 19-22.
- Pépó, P.-Zsombik, L. (2003): Napraforgó termesztéstechnológiai vizsgálatok legújabb eredményei. *Gyakorlati Agrofórum*, 14. 3. 15-16.
- Sinkins, C. A.-Overdahl, C. J. (1982): Fertilizing sunflowers on sandy land. *Better Crops Plant Food* 66: 14-15

AMMONIA FERTILIZATION IN MAIZE PRODUCTION

P. Pepó¹, J. Derzsényi² and L. Zsombik¹

¹University of Debrecen, Faculty of Agronomy

²Agrokemia Co., Polgar, Hungary

Abstract

In maize production the fertilization is one of the biggest cost-factor but parally it is the most efficient agronomic input. Maize has relatively high nutrient demand and it needs not only the nutrients originated from soils but it efficiently utilizes the different fertilizers (mainly N and K, P, microelements). The fertilizer-usage of Hungary reached fairly high level ($\sim 280 \text{ kg/ha}^{-1}$ NPK in arable land) in 1980 years. Hungarian fertilizer usage dramatically dropped (the lowest using was only $\sim 20 \text{ kg/ha}^{-1}$ NPK, and nowadays $\sim 80 \text{ kg/ha}^{-1}$ NPK) because of the economic problems from the early 1990's. In this situation we have to find those ways, which could improve the efficiency of fertilization quantitatively and qualitatively too. Besides the usage of traditional solid mono and complex fertilizers we could use other N-fertilizers. Liquid ammonia has high N-content (82,2 %) and has other advantages (cheaper, easy-handle, environmental friendly material etc).

In sustainable maize production there are several impacts but we have to realize three priorities: agronomic-economic efficiency, quality and environmental protection. In the field of environmental protection the nutrient supply, fertilization are the most important elements.

In large plot experiments ammonia was studied in different agroecological (cropyear, soil), biological (genotypes) and agrotechnical (forecrop etc) conditions to get information about agronomic efficiency and application methods in maize production.

In our research project we studied the phenometrical, agronomic traits of maize, the surface biomass dynamics in vegetation period, the LAI-dynamics, the yield-elements. Our scientific results proved that the efficiency of conventional N-fertilizer (NH_4NO_3) and ammonia (NH_3) was the same in different soil types, genotypes. The efficiency of N-fertilization (NH_4NO_3 and NH_3) depended on cropyear, hybrid and N-doses. The optimum N-doses varied $150\text{-}200 \text{ kg/ha}^{-1}$ in 2001 and 200 kg/ha^{-1} in 2002, respectively (both cropyears were dry with high temperature). The yield-surpluses were $300\text{-}2900 \text{ kg/ha}^{-1}$ in 2001 and $1200\text{-}3800 \text{ kg/ha}^{-1}$ in 2002, respectively.

Our scientific results proved that ammonia fertilizer had same agronomic efficiency comparing with conventional solid N-fertilizers and it has some advantages from economic and environmental aspects in maize production.

Introduction

From the 1940's to the end of the 1980's the agricultural growth focused on yield and yield-increase, so this traditional crop production system needed more and more inputs originating from industrial sectors. It means that during the last 30-40 years, agriculture in the developed countries (we should include Hungary during the last 10-20 years) has become more intensive, mechanised, energy – and chemical – consuming. Although these developments have resulted in large increases in productivity, they have often been accompanied by detrimental side-effects

of environmental and social nature. This development in crop production has decreased biological, agronomical and economical efficiency and has caused a lot of harmful effects in current agricultural practice.

In the “golden period” of Hungarian agriculture (from the 1960’s to the end of the 1980’s) mainly cereal production developed dynamically and reached the level of well-developed West-European and North-American countries. This rapid yield increase was based on the extended use of external industrial inputs, among which fertilization was the most important and determining factor. During the above-mentioned 30 year period fertilizer use in Hungary increased from 15 to 250-300 kg ha⁻¹ NPK. Due to this dynamic fertilizer application – and several other factors (pesticides, fossil energy, machinery hardware, professional knowledge etc) – the yield of different crops (mainly cereals) increased and 2- or 3-times more yield was obtained as compared to the average yields in the early 1960’s. It should be emphasized that these appropriately applied fertilizers and pesticides were not too large amounts in comparison with the crops’ demands, Hungary’s agroecological conditions and with the usage of them in well-developed countries.

In maize cultivation among the agro technological methods and procedures besides crop rotation, tillage and plant density the adequate nutrient supply has a major importance. Maize is such a plant culture, which demands and also utilizes nutrients and so nutrient supply in maize production has an outstanding significance. Besides the amount of nutrients it is also important to choose the right form of nutrient element. Besides the traditional artificial fertilization methods the application of the different forms of nutrients gets a stronger emphasis, so in the case of nitrogen ammonia is one of the alternatives, the application of which is advantageous from the aspect of physiology, efficiency and dispersion technology.

When liquid ammonia is injected into the soil the fixation of ammonia on the organic matters of the soil is relatively high, so this fixed ammonia is more accessible biologically than the soil’s nitrogen (*He et al., 1990*). *Boman et al.*(1995a) on the basis of their many-year-long continuous analysis came to the conclusion that in the case of liquid ammonia treatments the NO₃-N content of the upper soil is significantly higher than in the case of UAN injection, however this difference was not significant in the following years. The movement and dispersion of ammonia in the soil highly depends on the moisture content and the texture of the soil (*Ostapenko et al., 1984*). The acidity of the soil in the examined parcels (pH 4.3) did not change after nine years of ammonia fertilization. The analysis of *Boman et al.* (1995b), however, suggests that the increase of the replaceable Ca- and Mg-content in the soil was characteristic. The liquid

ammonia treatment increased the mineral nitrogen fund of the upper soil and the speed of nitrification in the treated soil was favourable (Muirhead *et al.*, 1985).

The form of dispersed nutrient strongly influences the N-emission from the soil. In the case of liquid ammonia dispersion 129 days after the treatment the measured loss was 12.33kg/ha NO₃-N, 7.33% compared to the full amount of dispersed nitrogen (Thornton *et al.* 1996).

On the basis of the results of the five-year-long comparative examinations we can state that the yield of maize was less in the case of pre-emergence UAN- solution application than in the case of preplanting ammonia injection. The increase of N-dose in the case of UAN could not compensate for the decreasing efficiency. The 158 lb/acre dose of liquid ammonia resulted the highest yield (Gordon *et al.*, 1993).

In the case of pre-emergence ammonia injection in maize cultivation the N-concentration of the leaf and the dry matter content of the plant were higher than in the case of pre-sowing + pre-emergence combined treatment (Randall *et al.*, 1997). When liquid ammonia was dispersed in maize cultivation the nitrogen content of the leaf was in strong correlation with the available nitrogen content of the soil and with the yield as well (Hubert *et al.*, 1993).

Ammonia as a form of nitrogen has its hybrid-specific effects (Tsai *et al.*, 1984). The injection of liquid ammonia into the soil could be a low-expense solution (Roberts *et al.*, 1995).

Material and Methods

In the given publication we wish to report the latest results (2002.) of a many yearlong sequential analysis. The sequential experiments were carried out in two different agro ecological circumstances in Hajdúhadház and Mezőkövesd (both have extensive farming on large parcels). In Hajdúhadház (HH) the soil of the examined area can be physically characterised as sandy-loam soil-type whereas in Mezőkövesd (MK) it is loam with gravel subsoil. At both places maize was cultivated as pre-crop. The maize hybrid examined in Mezőkövesd was *Stira SC*, while in Hajdúhadház it was *PR37M34*. The treatments applied in the experiment are shown in *table 1*.

Table 1: Treatments applied in the experiment

Treatment mark	Form of N	N-dose (kg ha ⁻¹)	Microelement
HH1/MK1	-	-	-
HH2/MK2	solid N-fertilizer	100	Cu+Zn*
HH3/MK3	solid N-fertilizer	150	Cu+Zn*
HH4/MK4	solid N-fertilizer	200	Cu+Zn*
HH5/MK5	ammonia	100	Cu+Zn
HH6/MK6	ammonia	150	Cu+Zn
HH7/MK7	ammonia	200	Cu+Zn

*only in MK treatments

Fertilizer was dispersed in spring in the pre-sowing period. During the vegetation period samples of plants were taken in every four weeks in order to carry out production-biological and assimilation-area examination. We publish the harvested yield results standardized on a 14.5% moisture content.

Results and Discussion

The results of production biological examinations proved the joint impact of habitat, hybrid and N-fertilization differentially at the experimental sites. The maximum values of over ground phyto-weight were between 328-344 g/plant in Hajdúhadház and 241-344 g/plant in Mezőkövesd. The dynamics of dry matter formation in certain parts of the plants showed characteristic specification of the experimental sites (*figure 1.*).

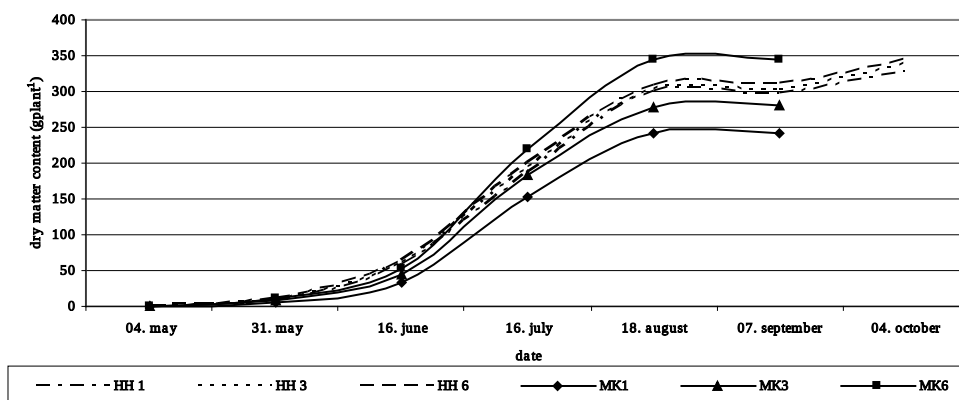


Figure 1: The impact of different N-forms and N-doses on the over ground phyto-weight of maize

In the vegetation period of 2002 the results of assimilation area-experiments proved the complex, join effect of weather conditions and N-fertilization. In the first quarter of the

vegetation period the growth of the assimilation area was moderate. After the intensive growth in June, in mid-July (the period of bloom and fecundation) the stands reached their maximum value of leaf-surface (in mid-July in Hajdúhadház it was 5800-6100 cm² / plant, while the same in Mezőkövesd was 4500-6300 cm² / plant). The measurements at the assimilation site showed moderate leaf-drying till mid-August and then for September-October leaf-drying was rapid (figure 2.).

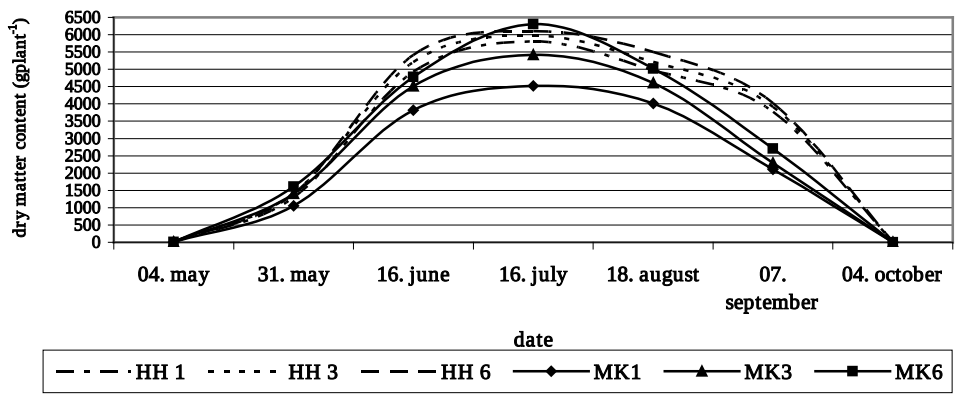


Figure 2: The impact of different N-forms and N-doses on the leaf area of maize

In the vegetation period of 2002 as the result of weather- and habitat conditions and agrotechnological factors yield results were higher than the average. Yield results were modified by N-forms and N-doses to a smaller (Hajdúhadház) or a larger (Mezőkövesd) extent. The yield results of maize were between 8200-9700 kg^{ha}⁻¹ in the Hajdúhadház experiment (figure 3.) while they were between 5600-9400 kg^{ha}⁻¹ in Mezőkövesd.

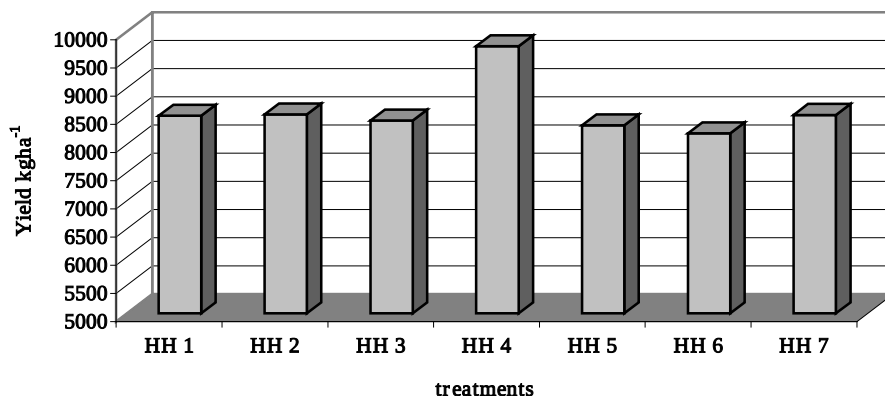


Figure 3: The effect of N-forms and N-doses on the yield of maize (Hajdúhadház, 2002)

The impact of N-doses was moderate in the experiment of Hajdúhadház (the yield increase resulted from the average of N-forms was 624 kg ha⁻¹ compared to the control group), while in Mezőkövesd (*figure 4.*) the yield increase was significantly high (it was 2300-2900 kg ha⁻¹ resulting from the average of N-forms, compared to the control group).

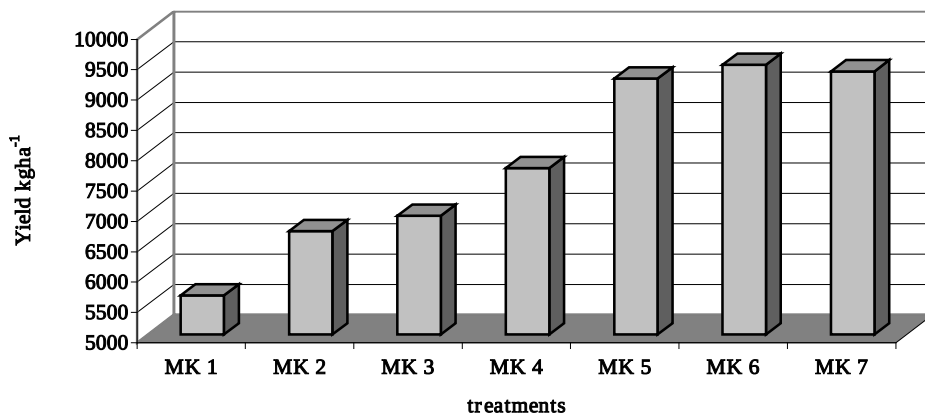


Figure 4: The effect of N-forms and N-doses on the yield of maize (Mezőkövesd, 2002)

In the vegetation period of 2002 due to the dry, droughty weather conditions the nutrient-uptake for maize from the soil or from the dispersed N-fertilizer (solid N, ammonia) became difficult. Because of the unfavourable solubility conditions-in accordance with the law of mass action-higher nutrient concentration could guarantee the adequate nutrient-uptake of the stands. Our

experimental results reflected the same, which means that the optimal N-dose at both experimental sites proved to be 200 kg ha⁻¹ in the average of N-forms (*figure 5*).

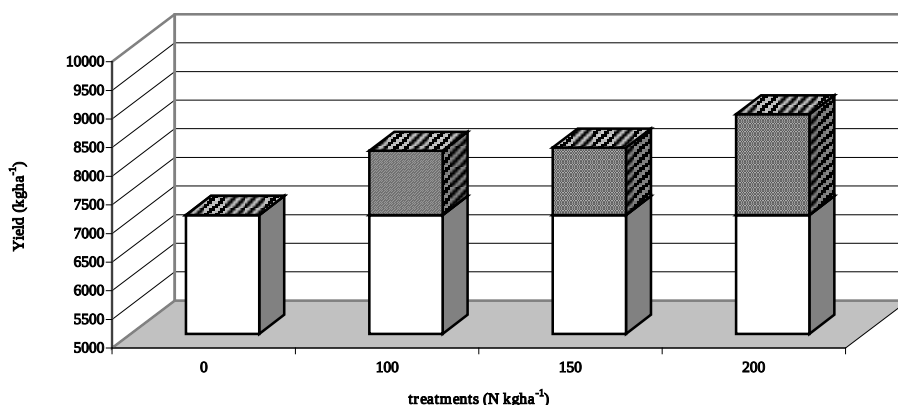


Figure 5: The effect of N-doses on the yield of maize (the average of N-forms, habitats, hybrids)

The efficiency of the examined N-forms differs as the consequence of the specification of the year. In the experiment in Hajdúhadház the achieved yield increase resulting from solid N-fertilization slightly exceeded the yield increase caused by ammonia treatments. Similarly to the results of previous years the yield increase resulting from N-fertilization in Hajdúhadház was rather moderate, which can be explained by the advantageous conditions of nutrient management of the given area (the experiments were carried out at the same place). In the experiment in Mezőkövesd the achieved yield increase resulting from ammonia treatments (the average yield increase was 3692 kg/ha) was twice as much as the yield increase achieved by solid N-fertilization (1491 kg/ha yield increase) and this favourable impact could be observed beside a significantly high yield.

Comparing the yield results of the average of habitats and treatments we can state that this year the yield increase caused by ammonia treatment was two times higher (1767 kg/ha) than the increase resulting from solid N-fertilization (940 kg/ha), which proved the efficiency of this technology or form of nutrient compensation (*figure 6*.)

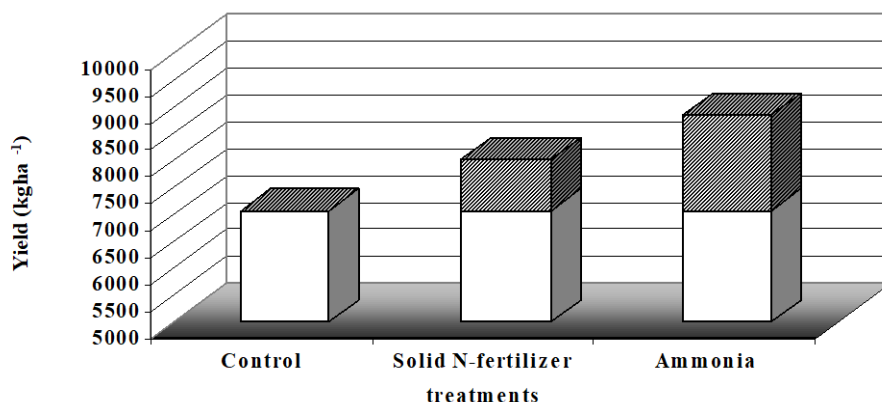


Figure 6: The effect of N-forms on the yield of maize (the average of habitats and hybrids)

References

- Boman, O. T. – Curtin, D. – Cambell, C. A. – Biederbeck, V. O. – Ukrainetz, H. (1995a): Soil acidification from long-term use of anhydrous ammonia and urea. *Soil Science Society of America Journal*. 59. 5. 1488-1494.
- Boman, R. K. – Westerman, R. L. – Raun, W. R. – Jojola, M. E. (1995b): Spring-applied nitrogen fertilizer influence on winter wheat and residual soil nitrate. *Journal of Productoin Agriculture*. 8. 4. 584-589.
- Gordon, W. D. – Whitney, D. A. – Raney, R. J. (1993): Nitrogen managment in furrow irigated, ridge-tilled corn. *Journal of Productoin Agriculture*. 6. 2. 213-221.
- He, X. T. – Mulvaney, R. L. – Stevenson F. J. – Vandem-Heuvel, R. M. (1990): Characterization of chemically fixed liquid anhydrous ammonia in an Illionois Drummer soil. *Soil Science Society of America Journal*. 54. 3. 775-780.
- Huber, D.M. – Sutton, A.L. – Jones, D.D. – Joern, B.C. – Mitchell, J.K. (1993): Nutrient management of manure to enhance crop production and protect the environment. *Integrated resource management & landscape modification for environmental protection. Proceedings of the International Symposium*. Chicago, Illinois, USA. 13-14 December, 1993. 1993. 39-45.
- Muirhead, W. A. – Melhoish, F. M. – White, R. J. G. – Higgins, N. L. (1985): Comparison oy several nitrogen fertilizers applied in surface irrigation systems. II. Nitrogen Transformations. *Fertilizer Research*. 8. 1. 49-65.
- Ostapenko, N. S. – Petrova, Z. N. – Usjarov, O. G. (1984): Dispersion of liquide ammonia in soil. *Agrokimija*. 3. 8-11.
- Randall, G. W. – Iragavarapu, T. K. – Bock, B. R. (1997): Nitrogen application methods and timing for corn after soybean in a ridge-tillage system. *Journal of Production Agriculture*. 10. 2. 300-307.
- Roberts, R. K. – Howard, D. D. – Gerleff, D. C. – Johnson, L. A. (1995): Oeconomic analyzis of nitrogen sources and placement methods in now-tillage corn. *Journal of Productoin Agriculture*. 8. 4. 575-580.
- Thornton, F. C. – Bock, B. R. – Tyler, B. B. (1996): Soil emissions of nitric oxide and nitrous oxide from injected anhydrous ammonium and urea. *Journal of Environmental Quality*. 25. 6. 1378-1384.
- Tsai, C. Y. – Huber, D. N. – Glover, D. V. – Warren, H. L. (1984): Relationship of an deposition to grain yield and N response of three maize hybrids. *Crop Sciense*. 24. 2. 277-281.

INFLUENCE OF FERTILIZATION ON THE YIELD, QUALITY AND STORABILITY OF CARROT

K. Uurman, P. Põldma, U. Moor and A. Merivee

Institute of Horticulture, Estonian Agricultural University, Kreutzwaldi 64, Tartu 51014, Estonia
E-mail: poldma@eau.ee

Abstract

The aim of present research was to find out the influence of different fertilization methods on the yield, quality and keeping quality of carrot. Three-year experiments were carried out with two carrot cultivars Narbonne F1 and Nantes Duke in a commercial farm close to town Tartu, southern part of Estonia. There were two main fertilizers applied in spring and 5 different fertilizers applied as top dressing. Control plots were not fertilized. Carrots were harvested in the beginning of October and the total yield and quality was determined. After storage amount of diseased carrot roots and total weight loss were determined. The content of nitrates, calcium, potassium and phosphorus of roots was designated before storage.

The results of the research showed that the yield of carrots was more influenced by main fertilizer than top dressing. Using Garden Slow Release NPK 13:3:13 enabled to get additional yield for 2.2 kg m⁻² compared to the control variant and 0.8 kg m⁻² compared to the Cropcare 10:10:20. Certain positive effect was noticed when foliar fertilizer was used for carrot cv Nantes Duke. Fertilizing did not significantly influence internal quality parameters of carrots. In storage experiments during 1999 and 2000 storage loss at the end of storage period was highest when ammonium saltpetre was used and the smallest when Ferticare was used. Best cultivar for storage was 'Nantes Duke'. Using main fertilizers did not influence storability.

Introduction

Carrot (*Daucus carota*) is an important vegetable crop in Estonia, according to the Statistical Office of Estonia the total growing area in 2001 was 680 hectares. The average yield of carrot in Estonia varies by statistics from 9 to 17 tons per hectare. In commercial farms the possible yield can extend to 80 tons per hectare, but normally it ranges between 40-60 tons. To achieve higher yield traditionally higher amounts of nitrogen fertilizers are used, but excessive nitrogen fertilization can cause environmental damage. If earlier it was common to use big amount of main fertilizers in autumn then nowadays it is widespread to use main mineral complex fertilizers in spring. Mostly it is not possible to give necessary amount of mineral fertilizers in one application to produce good crop. Therefore it is important to use top dressings during the growing season and provide crop with nutrients when the plant needs them most. Recently, when in water dissolvable fertilizers became available, vegetable growers have started using them as foliar fertilizers what practically means to spray fertilizer solution on top of the plant leaves. Application of foliar applied nutrients is a commonly recommended method of remedying the visual deficiency of nutrients in vegetable crops. It is also recognized that

supplementary fertilization during crop growth can improve the mineral status of plants, increase the crop yield, as well as giving some measure of protection against fungal and bacterial diseases. Results from the field studies have showed beneficial effects of foliar applied nutrients in cabbage, broccoli, brussels sprouts, endive, red beet, leek, tomato, onion and cucumber (Burghardt & Ellering 1986; Kolota & Osinska 2001). The other advantage of foliar nutrition, when compared to soil application, is a lower input of fertilizers due to the better utilization of nutrients and reduced risk of leaching from the soil

The objective of this research was to find out the influence of different main fertilizers and top dressings on the yield, quality and keeping quality of carrot.

Material and Methods.

The field experiment in four replications was conducted during 1999-2001 in a commercial farm close to town Tartu, southern part of Estonia. Two carrot cultivars Narbonne F1 and Nantes Duke were sown early May in one line rows with 50 cm of distance between rows. There were two main fertilizers applied in spring and 5 different fertilizers applied as top dressing. Control plots were not fertilized. Kemira Cropcare 10:10:20 and Garden Slow Release NPK 13:3:13 in fertilization level of N 60 kg ha⁻¹ were used as preplant main fertilizers. For topdressing 5 different fertilizers at rates recommended by fertilizer producer were used:

1. Cropcare NK 13:0:13 (N-13%) at rate of 30 kg ha⁻¹ N;
2. Ammonium saltpetre (N-34.4%) at rate of 30 kg ha⁻¹ N;
3. Calcium nitrate (N-15.5%) at rate of 2% solution;
4. Liquid Fertilizer for Professionals NPK 14:4:7 (N-14%) at rate of 5 l ha⁻¹;
5. Ferticare 14:11:25 (N-14%) at rate of 2% solution.

For top dressing ammonium saltpetre and Kemira Cropcare NK 13:0:13 were applied once during the growing season. Calcium nitrate, Liquid fertilizer for professionals NPK 14:4:7 and Ferticare 14:11:25 were sprayed twice during the period of intensive plant growth at 10 days interval, by using 400 l water solution per hectare.

Carrots were harvested in the beginning of October and the total yield and quality was determined. After harvesting carrots were stored in cool storage room at +2°C and RH 95% for 120 days. After storage amount of diseased carrot roots and total weight loss were determined.

The content of nitrates, calcium, potassium and phosphorus of roots was designated before storage.

Collected data was statistically analysed by ANOVA test at significance level of $P \leq 0.05$.

Results

The average yield of cv Narbonne F1 and Nantes Duke in experiment were 7.03 kg m^{-2} and 7.11 kg m^{-2} respectively. The total yield of 'Narbonne' F1, grown without fertilizers, was 4.7 kg m^{-2} , while the use of main fertilizer without top dressing gave the yield 6.6 kg m^{-2} for Cropcare 10:10:20 and 6.0 kg m^{-2} for Garden Slow Release NPK 13:3:13 (Fig. 1). If the main fertilizer and top dressing both were used the yield was higher. In case of preplant fertilizer Garden Slow Release NPK 13:3:13, the highest yield was achieved when Cropcare NK 13:0:13 (7.8 kg m^{-2}) and Ferticare 14:11:25 (7.6 kg m^{-2}) as top dressing were used. There were no significant differences in total yield between different top dressings in case when Cropcare 10:10:20 was used as main fertilizer. When top dressing was used the average marketable yield (I and II quality classes) of 'Narbonne' F1 was 96%, which was significantly higher compare to experimental variants with only main fertilizers or without fertilizers (89% and 83% respectively).

The total yield of cv Nantes Duke was 7.5 kg m^{-2} when main fertilizer Garden Slow Release NPK 13:3:13 was used, and 6.2 kg m^{-2} when Cropcare 10:10:20 was used (Fig. 2.). When no fertilizers were applied, the yield of 'Nantes Duke' remained 5.9 kg m^{-2} . Using Garden Slow Release NPK 13:3:13 and top dressing together the highest yield was achieved in variant of Cropcare NPK 13:0:13 (8.6 kg m^{-2}) and Ferticare 14:11:25 (8.2 kg m^{-2}). In average of three years of experiment there were no significant differences in total yield between different top dressings in case when Cropcare 10:10:20 was used as main fertilizer. However, in 2000 the highest yield was achieved when plants were sprayed with calcium nitrate and Ferticare 14:11:25 solutions (data not shown). The rate of marketable yield was similar as for 'Narbonne' F1, 93 % in average when with top dressings were used and 90 % in case of main fertilizers. The lowest marketable carrot yield was in case when no fertilizers were used (87%).

The quality of carrot was not affected by use of fertilizers. Dry matter content of carrot roots varied from 10.2 % to 12.6 %. Using Garden Slow Release NPK 13:3:13 the content of dry matter was slightly slower, being in cv Narbonne F1 in average 11.2 % (11.5% for Cropcare 10:10:20) and in cv Nantes Duke 10.5 % (10.9 % for Cropcare 10:10:20).

The content of nitrates in carrot roots depended on the year. It varied from 12 to 210 mg kg⁻¹ on a fresh weight basis. In Estonia the highest permitted content of nitrates is 200mg kg⁻¹. Cultivar Nantes Duke had higher content of nitrates (78.6 mg kg⁻¹) compared to 'Narbonne' F1 (54.8 mg kg⁻¹). In average the content of nitrates was significantly higher when Garden Slow Release NPK 13:3:13 as main fertilizer was used (64.0 mg kg⁻¹). Carrots fertilized with Cropcare 10:10:20 had in average the content of nitrates 44.5 mg kg⁻¹. Top dressing did not affect the content of nitrates in carrot roots. There was noticed that only the use of ammonium saltpetre resulted with higher content of nitrates (164 mg kg⁻¹). In 2000 the content of nitrates was higher then in 1999 and 2001. Uptake of nitrates is favored by higher amount of precipitation in growing season and that resulted also higher accumulation of nitrates in 2000. Similar result has been reported also by Prabhakar *et al.* (1991).

There were no significant differences in content of calcium, phosphorus and total sugars in carrot roots. The use of Cropcare 10:10:20 affected positively the content of carotene, where the content of carotene was in average 2.5 m%. The content of carotene in carrot was 2.0 m% when Garden Slow Release NPK 13:3:13 was used. Top dressing did not affect the content of carotene in carrot roots.

The storage loss was highest when ammonium saltpetre and lowest when Ferticare 14:11:25 as top dressing were used. The use of main fertilizers did not influence storability of carrot. Cultivar Nantes Duke had better storability compared to 'Narbonne' F1.

Conclusion

The results of the research showed that the yield of carrots was more influenced by main fertilizer than top dressing. Using Garden Slow Release NPK 13:3:13 enabled to get additional yield for 2.2 kg m⁻² compared to the control variant and 0.8 kg m⁻² compared to the Cropcare 10:10:20. Certain positive effect was noticed when foliar fertilizer was used for carrot cv Nantes Duke. Fertilizing did not influence internal quality parameters of carrots.

References

- Burghardt, H. & Ellering, K. 1986. Verträglichkeit und Wirkung von Blattdüngungsmassnahmen bei Gemüsekulturen. *Gartenbauwissenschaft* 51 (2):58-62.
- Kolota, E. & Osinska, M. 2001. Efficiency of foliar nutrition of field vegetables grown at different nitrogen rates. *Acta Horticulturae* 563: 87-91.
- Prabhakar, M., Srinivas, K., Hedge, D.M. 1991. Effect of irrigation regimes and nitrogen fertilization on growth, yield, N uptake and water use of carrot (*Daucus carota* L.). *Gartenbauwissenschaft*, 56 (5). S. 206-209.

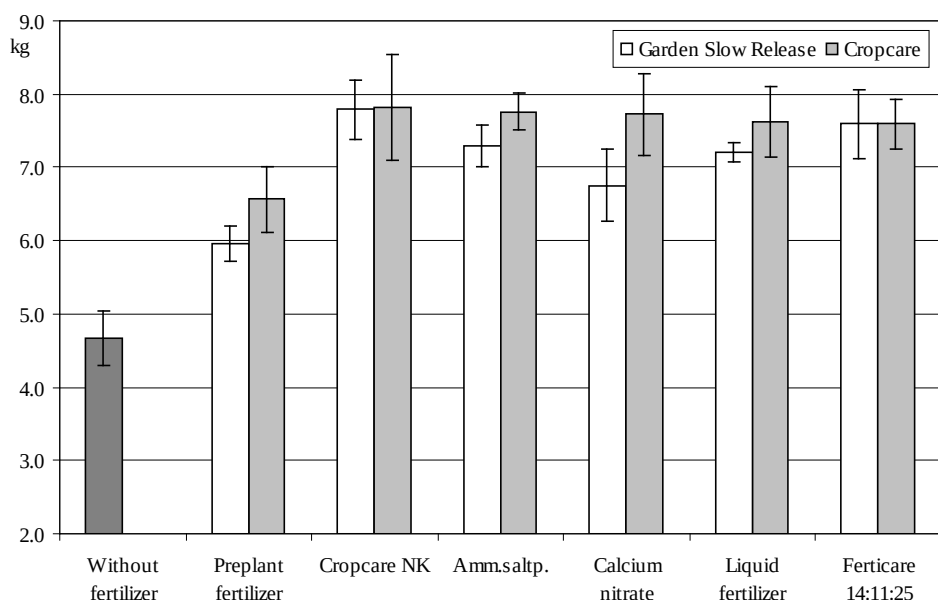


Figure 1: Total yield (kg m⁻²) of carrot cultivar Narbonne F1 dependent of preplant fertilizing and top dressing (means, STDEV).

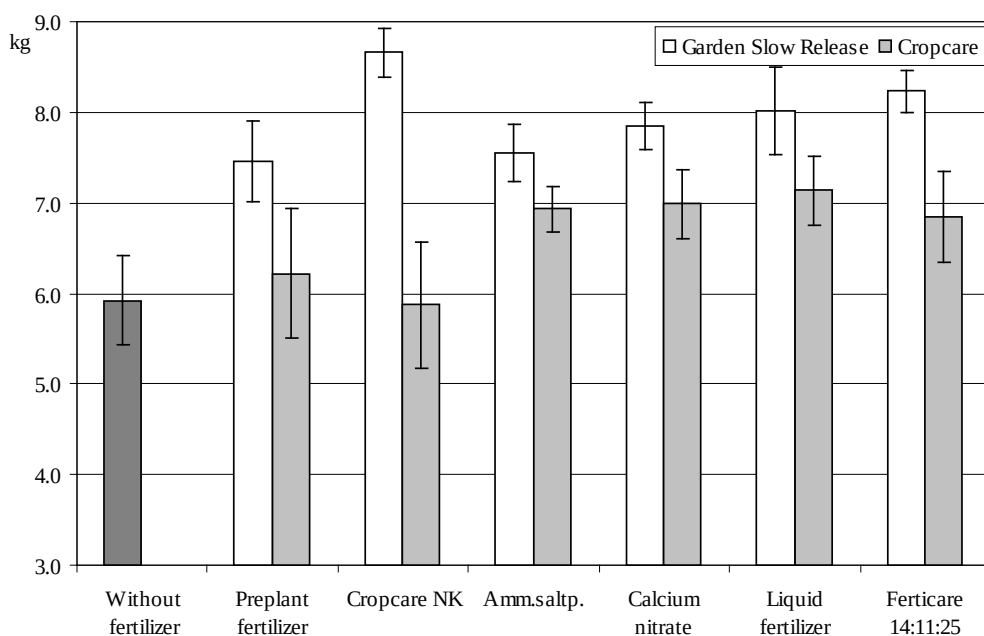


Figure 2: Total yield (kg m⁻²) of carrot cultivar Nantes Duke dependent of preplant fertilizing and top dressing (means, STDEV).

CALCIUM, MAGNESIUM AND SULPHUR CONTENT OF YOUNG PLANTS AS AFFECTED BY DIFFERENT FERTILIZERS AND SOIL PROPERTIES

K. Sárdi¹ and F. Éri²

¹University of Veszprém, Georgikon Faculty of Agriculture, Keszthely, Hungary
email:sardi@georgikon.hu

²TRANSCENTER Fertilizers Ltd, Peremarton, email: erif@transcenter.hu

Introduction

Recently, balanced fertilization strategies pay increasing attention to the supply Ca, Mg and S. These three macronutrients are referred frequently also „secondary nutrients”. Calcium, magnesium and sulphur as essential nutrients play a significant role in both yield levels and in the yield quality of crops. The importance of Ca can be seen from the fact that in many crop species, Ca is required in higher amounts than P (Tisdale et al. 1993). For optimum yields, magnesium and sulphur are needed by plants also in relatively high concentrations.

Results of experiments show that crop responses in both yield surpluses and quality improvement may be directly related to the level of bioavailability in these macro- and micronutrients and to important site characteristics such as soil pH. Recently, the importance of Ca, Mg and S nutrition in various cropping systems is increasing in Hungary and related questions are involved in production development strategies of fertilizer producers. Among new formulations, Ca, Mg and S as „secondary nutrients” are often added to „primary nutrient fertilizers” containing NPK to meet the requirement of plants for sufficient yields. Corn and sunflower are known to be highly Mg responsive.

Nutrient ratios have been widely used by many researchers for diagnosing nutrient imbalances in crops (Sumner, 1978), Sardi and Csitari 1997 etc.). Nutritional status of crops may have also an influence on nutrient interactions (Bergmann 1992, Sardi et al. 2000). It was found by several authors that these ratios such as N/S, N/P, K/Mg, K/Ca etc. correlate well with yields (Black 1993, Jones 1998 etc.).

Materials and Methods

A pot experiment was carried out under greenhouse conditions for studying the effects of several fertilizers having variable rates of NPK and secondary elements. Three fertilizer products of the TRANSCENTER Ltd. (TC 14:7:21 + 2, TC 18 :12:10 and TC 0: 10:28) were tested and compared to 3 other fertilizer products having similar NPK rates produced by an

international fertilizer company recently introduced and commercialized in Hungary (labeled by B1, B2 and B3, respectively).

Corn (*Zea mays* L., DK 537 variety) and sunflower (*Helianthus annuus* L., PR 63 A 90 variety) were grown for 35 days after emergence, (DAE) in pots containing 2 kg of air dried soil.

Two typical soil types from South-West Hungary were selected for the experiment: a calcareous chernozem brown forest soil, Calcic phaeosem by FAO taxonomy ($\text{pH}_{\text{KCl}} = 7.04$) and a lessivated brown forest soil, a Haplic luvisol ($\text{pH}_{\text{KCl}} = 6.64$), having adequate levels of N supply but low levels of available P and K. Main characteristics of experimental soils are summarized in Table 1. Soil moisture was kept on 70 % WHC by daily watering. Fertilizers were applied at two rates, N1 =100 mg N plus P and K depending on the ratios of NPK, and N2 = 200 mg N plus P and K (Table 2). Ca, Mg and S contents of fertilizers are given in Table 3.

At the harvest, DM production, macro- and microelement content of plants were determined. Multielement determinations (12 elements) were made by using ICP-AES.

Table 1: Main characteristics of the experimental soils

Location	Soil type	FAO taxonomy	Humus %	$\text{pH}_{\text{H}_2\text{O}}$	pH_{KCl}	CaCO_3 %	AL P_2O_5 mg/kg	AL K_2O mg/kg	$\text{N}_{\text{min.}}$
Enying	Chernozem brown forest soil	Calcic phaeosem	3.08	7.18	7.04	3.09	19	142	153.4
Nagyrecse	Lessivated brown forest soil	Haplic luvisol	2.87	6.78	6.64	0	21	113.4	121.2

Table 2: Treatments used in the experiment

Num- ber	Fertilizer	N	P ₂ O ₅	K ₂ O	Label
		mg/kg soil			
1	Unfertilized control	0	0	0	N ₀ P ₀ K ₀
2	TC (14:7:21+2) N1	100	50	150	N ₁₀₀ P ₅₀ K ₁₅₀
3	TC (14:7:21+2) N2	200	100	300	N ₂₀₀ P ₁₀₀ K ₃₀₀
4	B ₁ (16:9:14) N1	100	69	87	N ₁₀₀ P ₆₉ K ₈₇
5	B ₁ (16:9:14) N2	200	138	174	N ₂₀₀ P ₁₃₈ K ₁₇₄
6	TC NPK (18:12:10) N1	100	67	56	N ₀ P ₀ K ₀

7	TC NPK (18:12:10) N2	200	134	112	N ₂₀₀ P ₁₃₄ K ₁₁₂
8	B ₂ (22:8:8) N1	100	36	36	N ₁₀₀ P ₃₆ K ₃₆
9	B ₂ (22:8:8) N2	200	72	72	N ₂₀₀ P ₇₂ K ₇₂
10	TC PK (0:10:28) N1	0 + 100 from NH ₄ NO ₃	50	70	N ₀₊₁₀₀ P ₅₀ K ₇₀
11	TC PK (0:10:28) N2	0 + 200 from NH ₄ NO ₃	100	140	N ₀₊₂₀₀ P ₁₀₀ K ₁₄₀
12	B ₃ (4:20:20) N1	14 + 86 from NH ₄ NO ₃	69	69	N ₁₄₊₈₆ P ₆₉ K ₆₉
13	B ₃ (4:20:20) N2	28 + 172 from NH ₄ NO ₃	138	138	N ₂₈₊₁₇₂ P ₁₃₈ K ₁₃₈

Table 3: Ca,Mg and S contents of fertilizers used in the experiment

Fertilizer	Ca	Mg	S
TC NPK (14:7:21+2)	0.6	0.07	11.7
B1 (16:9:14)	1.8	0.9	4.8
TC NPK (18:12:10)	1.5	0.43	7.6
B2 (22:8:8)	0.2	0.018	9.9
TC PK (0:10:28)	5.0	0.1	4.5
B3 (4:20:20)	3.3	0.5	5.3
NH ₄ NO ₃	0.17	0.09	0

Results and Discussion

From the results of our experiment it was evident that both DM production and nutrient concentrations (NPK and Ca, Mg, S contents) of young plants significantly responded to

- crop species
- fertilizer rates
- soil characteristics

Highly significant differences in Ca, Mg and S concentrations were observed among the plants grown in the unfertilized control pots, strongly influenced by soil type (Figures 1-6). In the Calcic phaeosem, Ca concentration was increasing with the higher rate in most treatments while in the higher rate it was lower in corn plants grown in the Haplic luvisol.

Changes in Ca content of sunflower showed similar tendencies for the two soil types.

Differences in Mg concentrations of test plants were significant both among soils and treatments. Sulphur concentrations of corn plants grown in the Calcic phaeosem were

Figure 1 Ca content (Ca %) of corn (35 DAE)

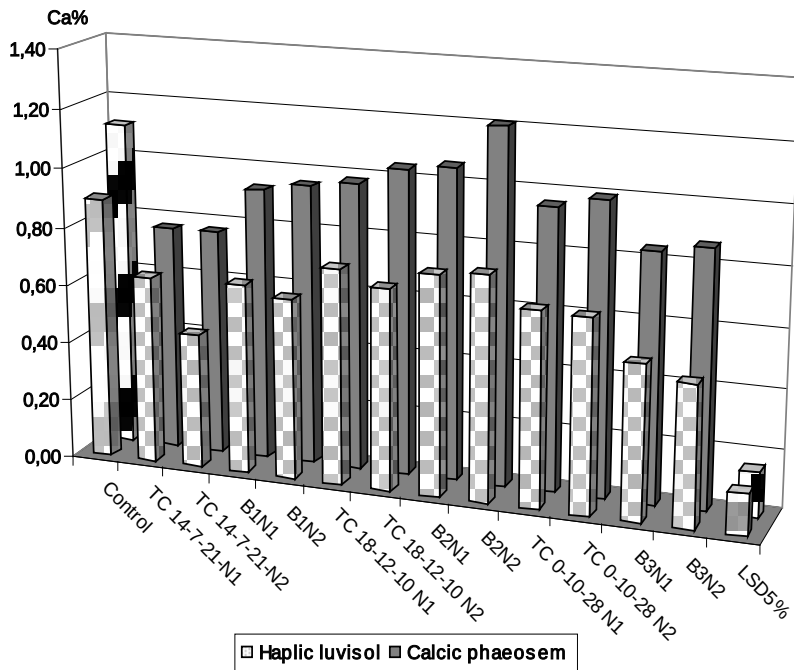


Figure 2 Ca content (Ca %) of sunflower (35 DAE)

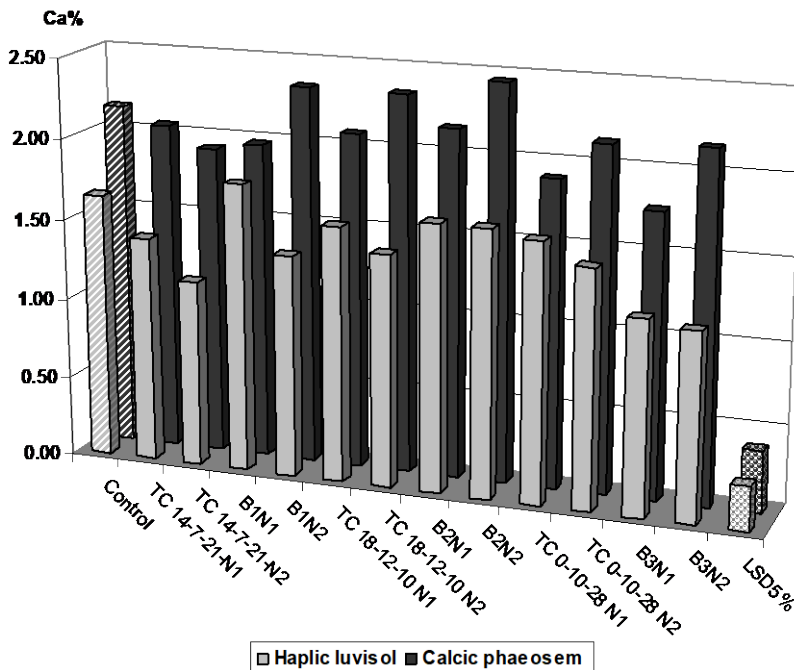


Figure 3 Mg content (Mg %) of corn (35 DAE)

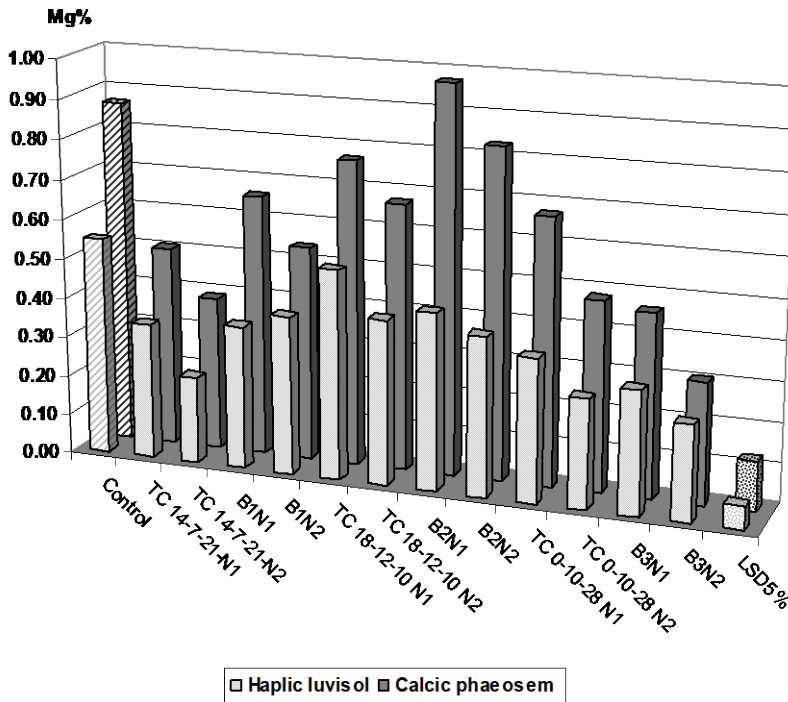


Figure 4 Mg content (Mg %) of sunflower (35 DAE)

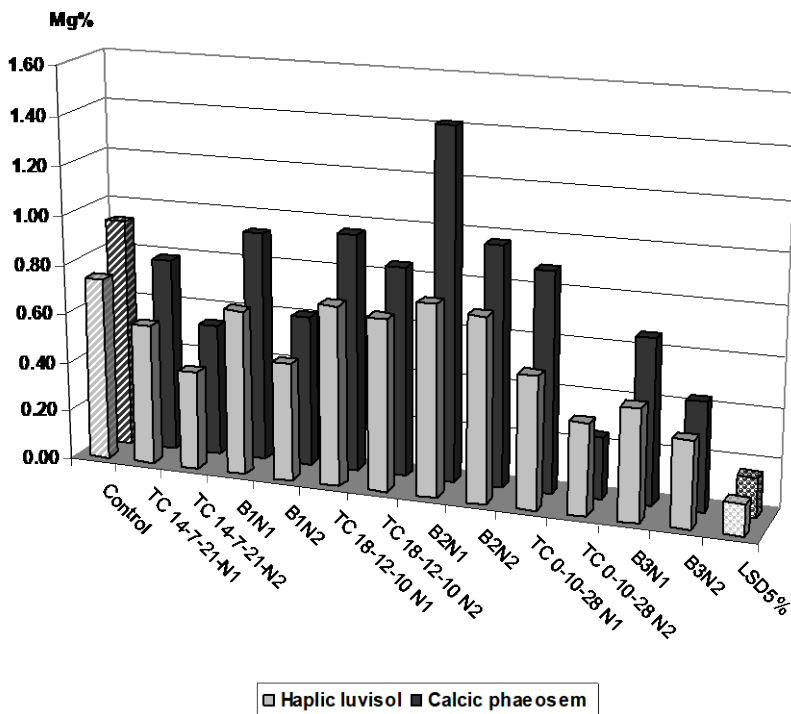


Figure 5 S content (S %) of corn (35 DAE)

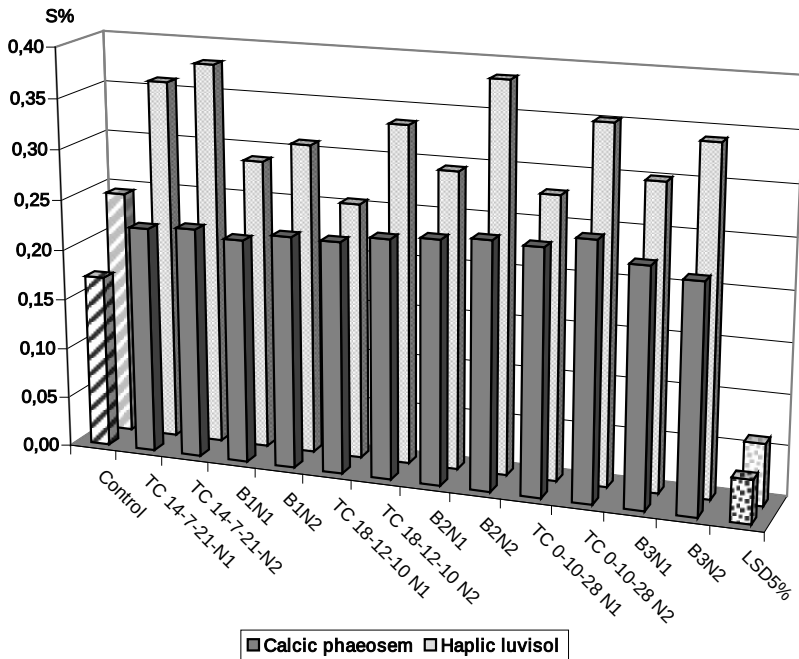
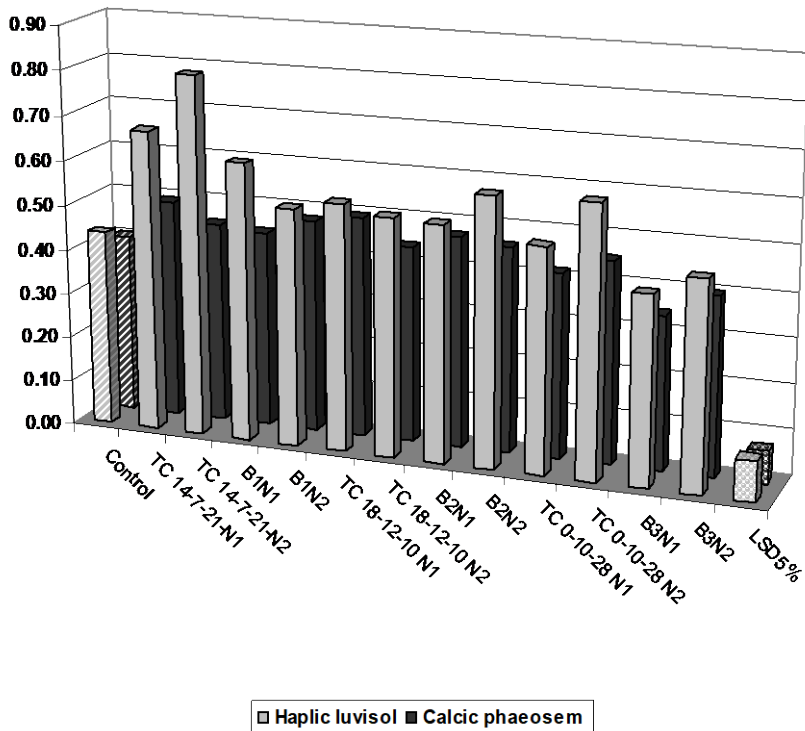


Figure 6 S content (S %) of sunflower (35 DAE)



significantly higher in all treatments compared to the unfertilized control. On the other hand, only very small differences could be observed among the treatments in this soil. Interestingly, S concentrations of corn grown in the Haplic luvisol were higher. Increases with higher rates of fertilizers were significant in most treatments.

Relationships between DM production of plants and amounts of nutrients taken up per pot were also evaluated. For the Calcic phaeosem, closest relationships were described by exponential equations whereas in the Haplic luvisol, both exponential and quadratic equations were obtained. R2 values were ranging between 0.328 and 0.931 (Table 4).

Table 4: Relationships (R^2 values) between DM production of plants and amounts of Ca, Mg and S nutrients taken up (mg pot^{-1})

Soil type	Calcic phaeosem		Haplic luvisol	
Location	Enying		Nagyrecse	
		n = 52		
	type of equation		type of equation	
DM-Ca uptake	Corn exp.	0.837	exp.	0.844
	Sunflower exp.	0.885	quad.	0.931
DM-Mg uptake	Corn exp.	0.481	quad.	0.649
	Sunflower exp.	0.328	quad.	0.852
DM-S uptake	Corn exp.	0.821	exp.	0.863
	Sunflower exp.	0.852	exp.	0.865

From the results of nutrient concentration determinations, nutrient ratios were calculated (Table 5) and compared to sufficiency ranges (Table 6).

Table 5: Nutrient ratios in test plants (35 DAE)

CORN				
	K/Ca	Ca/P	Mg/P	N/S
Calcic phaeosem	1.73-7.01	2.91-9.27	1.13-7.23	13.1-21.71
Haplic luvisol	3.29-12.2	1.02-5.27	0.51-3.23	8.86-15.28
SUNFLOWER				
Calcic phaeosem	1.50-4.29	5.38-12.6	1.04-6.17	6.98-11.32
Haplic luvisol	2.03-5.26	3.23-11.77	0.97-5.29	4.93-7.88

Table 6: Sufficiency ranges of Ca, Mg and S and sufficient nutrient ratios in test plants, 35 DAE (Reuter and Robinson 1986, Bennett 1993, Kádár 1992)

Crop species		Critical	Adequate
	Ca %		0.3-0.7 0.9-1.6*
CORN	Mg %		0.3-0.8
	S %	0.08	0.2-0.3
	Ca/P		1.0-1.4 ⁺
	Mg/P		0.7-1.2 ⁺
	N/S	16	
SUNFLOWER	Ca %		1.6-1.9
	Mg %		0.27-0.68
	S %	0.43	

*Adequate range given by Bennett (1993)

⁺Sufficient ratio given by Kádár (1992)

Conclusions

From the results of our experiment, it was evident that increasing rates of NPK fertilizers containing no „secondary elements”, cation balances may change and therefore amounts and ratios of Ca, Mg and S may be unfavorable.

With higher rates of NPK fertilizers free of either Ca, Mg and S, nutrient concentrations of plants in these elements will be considerably decreasing in the early vegetative period. It may result in reducing yield stability and quality. Maintaining sufficient levels are of outstanding importance for plants having higher requirements of these nutrients and in soils with unfavorable conditions for availability.

References

- Bennett W.F. (1993): Nutrient Deficiencies & Toxicities In Crop Plants. APS Press Chapter 2 Corn. pp. 11-14.
- Bergmann, W. (1992): Nutritional Disorders of Plants. Gustav Fischer Verlag Jena-Stuttgart-New York. pp. 343-360.
- Black, Ch.A. (1993): Soil Fertility Evaluation and Control. Chapter 3. Plant Testing and Fertilizer Requirement. Lewis Publishers USA pp. 155-269.
- Jones, J.B. (1998): Plant Nutrition Manual CRC Press Boca Raton.
- Kádár, I. (1992): Principles and methods of plant nutrition. (A növénytáplálás alapelvei és módszerei). MTA TAKI Akaprint Budapest.
- Reuter, D.J. and J.B.Robinson (1986): Plant Analysis. Inkata Press Melbourne. pp. 1-217.
- Sardi, K. –Győri, Z. –Lukács, P. and Pék, I. (2000): Influences of crop N and S nutrition on the micronutrient interactions. 3rd International Crop Science Congress, 17-22 August 2000, Hamburg. Book of abstracts p. 163.
- Sárdi, K. and Csitári, G. (1997): Responses of Corn and Sunflower to Nutrient Stress. 11th International World Fertilizer Congress. Spet. 7-13, 1997, Gent. Proceedings Vol. 1. pp. 626-533.
- Sumner, M. E. (1978): Interpretation of Nutrient Ratios In Plant Tissue. Commun. in Soil Science and Plant Analysis, Vol. 9 No. 4, pp. 335-345.
- Tisdale, S.L., W.L. Nelson, J.D. Beaton and J.L.Havlin (1993): Soil Fertility and Fertilizers. Fifth Edition. Chapter 8 Soil and Fertilizer Sulfur, Calcium and Magnesium. Macmillan Publishing Company New York pp. 266-303.

EFFECT OF FERTILIZATION ON SOIL PH AND GROWTH OF LOWBUSH BLUEBERRY (*VACCINIUM ANGUSTIFOLIUM* AIT.)

M. Starast^{1,2*}, K. Karp¹, U. Moor¹, E. Vool¹ and T. Paal³

¹ University of Tartu, Institut of Botany and Ecology, Lai St. 40, 51005 Tartu, Estonia, E-mail: starast@eau.ee

² Estonian Agricultural University, Department of Horticulture

³ Estonian Agricultural University, Forest Research Institut, Kreutzwaldi St. 64, 50412 Tartu, Estonia

Abstract

Lowbush blueberry (*Vaccinium angustifolium* Ait.) has specific soil requirements, they do best when the pH_{KCl} of the soil is between 4.5 and 5.5. In the Department of Horticulture at the Estonian Agricultural University the trial work with lowbush blueberry began in 1999 to investigate the effects of fertilizers and elemental sulfur on soil pH. The aim of the research was to find out weather the suggested doses of fertilizers are sufficient to ensure necessary pH value for blueberry in the soil. Experimental fields were situated in different soils. Sulphur and mineral fertilizers ammonium sulfate + potassium sulfate + superphosphate were used in both fields. In one field complex fertilizers Kemira Cropcare 2-11-22 and Kemira Cropcare 6-14-23 were also used. Fertilizers were used according to the content of nutrients in the soil.

The results of the research showed that for changing soil pH from pH_{KCl} 6.0 to the suitable one for blueberry (below 5.5), it takes two years if using sulphur + fertilizers and it takes three years if to use only fertilizers. The results from second experimental field showed that if the pH_{KCl} of the soil is 5.5, then the acidity of the soil during two years is significantly changed by acidic mineral fertilizers and complex fertilizer, which has higher nitrogen content. In present experimental conditions there was a weak relation between soil pH and content of nutrients in blueberry leaves. Using sulfur and fertilizers influenced the growth of the plants. According to the research results we may say that concerning prevalent soils in Estonia the suggested doses of fertilizers for blueberry are sufficient to ensure necessary pH value in the soil.

Keywords: wild berry, sulphur, complex fertilizer, nutrient content

Introduction

Lowbush blueberry (*Vaccinium angustifolium* Ait.) is a low-growing plant, 35 cm has been measured to be the height of the plant in natural habitats. Natural growing area for lowbush blueberry is situated in north-east of North America (Vander Kloet, 1988). Growing as half-cultivated plants together with other blueberry species *Vaccinium angustifolium* forms considerable amount of berry production in USA and Canada (Eck, 1989; Sibley, 1994).

The success of blueberry growing is greatly dependent on soil conditions. Most suitable soils are mentioned to be well aerated sandy-clay soils, which would be rich in organic matter and with light texture. The most important factor is considered to be the reaction of the soil; optimum is pH_{KCl} 4.5...5.5 (Vander Kloet, 1988; Paasisalo et al., 1994). In production fields with mineral soils sulfur is widely used to change soil's acidity in USA and Canada (Spiers,

Braswell 1992). Soil's pH and texture should be taken into consideration when finding suitable amounts of sulfur (Hanson, Hancock, 1996).

Blueberry plants are very sensitive to excessive fertilization, but in production conditions optimal fertilization is needed in order to gain higher yields. If the soil pH is somewhat high (above 5.0), ammonium sulfate is the best fertilizer. Ammonium sulfate is acidic and it tends to decrease soil pH (Hanson, Hancock, 1996; Lehmushovi et al., 2000).

The experimental work with blueberries in the Department of Horticulture at the Estonian Agricultural University began in 1997. Experiments have shown, that due to good winter-resistance species of lowbush and half-highbush blueberry could be perspective berry – cultures in Estonia (Starast et al., 1999; Karp et al., 2000). At the same time there is a lack of soils in Estonia, which would have suitable Ph. The aims of the present research were to find out:

- whether the suggested fertilizers and their doses are sufficient to ensure necessary pH value for blueberry growing;
- how fast the influence of mineral fertilizers and sulfur appears;
- the influence of mineral fertilizers and sulfur on vegetative growth of lowbush blueberry.

Material and Methods

The blueberry experiment were carried out in Tartu County, South Estonia (hereafter Tartu experiment) and in island Saaremaa, West Estonia (hereafter Saaremaa experiment). Trial fields were established with one-year old lowbush blueberry (*Vaccinium angustifolium* Ait.) seedlings in 1999. The gap between the plants was 0.8 m and the space between two rows was 1.0 m. Soil elemental contents was analyzed before plantation in 1999 (table 1).

Table 1: Soil elemental content in Taru and Saaremaa trials before plantation in 1999.

Location, year, treatment	pH _{KCl}	P mg/kg	K mg/kg	Ca mg/kg	Mg mg/kg	% Org. matter
Island Saaremaa	6,0	8	0	1300	280	2,6
Tartu County	5,9	176	288	1706	110	4,7

Variants of fertilization in Tartu experiment:

1. without sulphur and fertilizers (control);
2. ammonium sulfate 5 g/m² + potassium sulfate 10 g/m² + superphosphate 17 g/m²;
3. Sulphur 100g/m²;
4. Sulphur 100g/m² + ammonium sulfate 5 g/m² + potassium sulfate 10 g/m² + superphosphate 17 g/m²
5. Sulphur 100g/m² + complex fertilizer (N-11%; P-5%; K-18% + microelements) 20 g/m².

Referred fertilization scheme was used in spring 2000. In spring 2001 only ammonium sulfate was used with dose 12 g/m² in variants, where ammonium sulfate was also used in last year (variants 2 and 4). In 2002 fertilizers were not used, because soil analysis showed that P and K levels in the soil were high.

Variants of fertilization in Saaremaa experiment:

1. without sulphur and fertilizers (control)
2. ammonium sulfate 12 g/m² + potassium sulfate 15 g/m² + superphosphate 20 g/m²
3. Kemira Cropcare 2-11-22 - (N 2%, P 5%, K 18%, + microelements) 20 g/m²
4. Kemira Cropcare 6-14-23 - (N6%, P 6%, K 19%, + microelements) 20 g/m²
5. Sulphur 100g/m²
6. Sulphur 100g/m² + ammonium sulfate 12 g/m² + potassium sulfate 15 g/m² + superphosphate 20 g/m²
7. Sulphur 100g/m²S+Kemira Cropcare 2-11-22 20 g/m²
8. Sulphur 100g/m²S+Kemira Cropcare 6-14-23 20 g/m²

According to previous variants fertilization was carried out in spring 2001 and 2002.

Powdery elemental sulphur (S 100%) was used in the experiments. The doses of fertilizers were estimated using suggested amounts given by Finnish scientists Lehmuhovi et al. (1999) and Paasisalo (1994) , and for doses of sulphur amounts suggested by Hanson and Hancock (1996) according to soil's texture, acidity and content of nutrients. pH_{KCl} of the soil samples, from the depth of 0-20 cm was measured with Evikon pH Meter E 6115 in September 2002.

In the autumn (2002), height of blueberry plants was measured and number of long shoots (longer than 15 cm) was counted.

The nutrient content of blueberry leaves was measured at the beginning of harvesting period (August 2002) using N- tester Spad 400, Minolta.

Data were analyzed by ANOVA table and regression analyze. Significant (LSD 95%) differences from the control were marked by asterisk (*) in figures.

Results

At the time of planting the average pH_{KCl} of the soil in the experimental area in Tartu was 6.0 and it did not change significantly during first summer after fertilization (Fig. 1). By autumn in the second year (2001) the reaction of the soil had significantly changed in variants, where sulphur was used together with acidic or complex fertilizers (variants 4 and 5). Sulphur powder without fertilizers had no effect.

The influence of sulphur appeared in third year. The reaction of the soil had raised to the level which was appropriate for blueberries in variants where sulphur and fertilizers together with sulphur was used (variants 3,4,5).

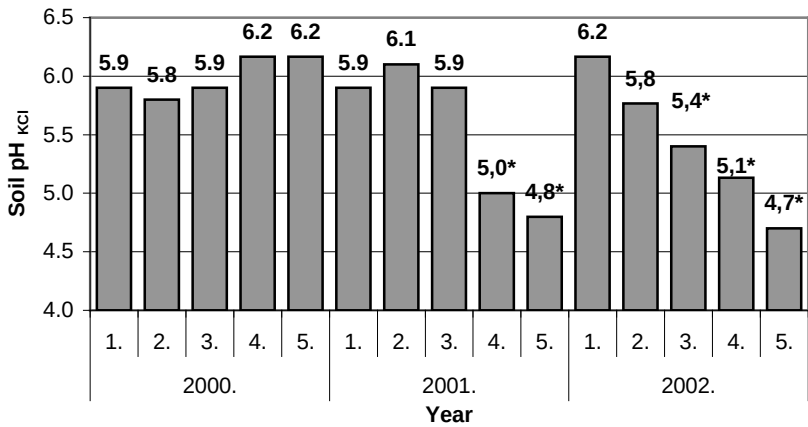


Figure 1: pH_{KCL} of the soil depending on fertilization in spring 2000 in Tartu experiment.

1- Control; 2- Ammonium sulfate + potassium sulfate + superphosphate; 3- Sulfur;
4- Sulfur + complete fertilizer; 5- sulfur + ammonium sulfate + potassium sulfate + superphosphate

*significant difference 95%

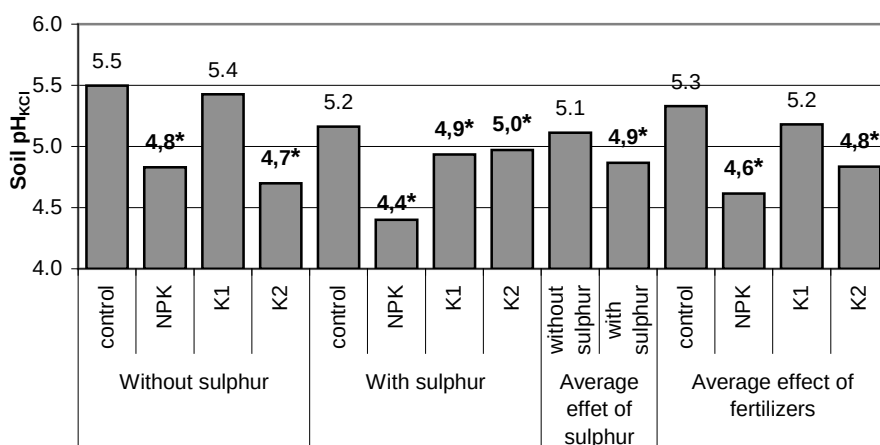


Figure 2: pH_{KCL} of the soil depending on fertilization in spring 2002 in Saaremaa experiment.

NPK - ammonium sulfate + potassium sulfate+ superphosphate; K1 - Kemira Cropcare 2-11-22; K2 - Kemira Cropcare 6-14-23

*significant difference 95%

The acidity of the soil in Saaremaa before establishing plantation was pH_{KCl} 5.9 (Table 1). pH_{KCl} was a bit lower than in Tartu, but still remained outside the recommended values for blueberries. In this experiment significant influence of sulphur and fertilization appeared already in second year after fertilization (Fig. 2). In 2002 the reaction of the soil had significantly changed as a result of acidic fertilizers and Kemira Cropcare 6-14-23, which is richer in nitrogen. The average effect of these fertilizers was also significant. Together with sulphur another complex fertilizer also had significant effect. As an average of the experiment, the acidity of the soil in variant without sulphur was 5.1, in variant with sulfur the soil was more acidic, having pH_{KCl} value 4.9.

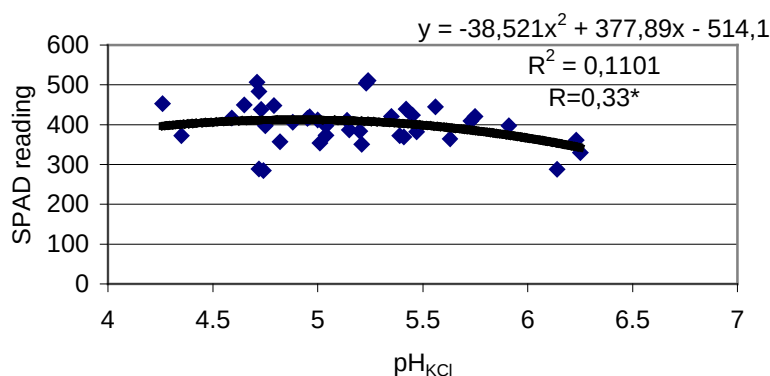


Figure 3: Nutrient content of blueberry leaves depending on soil's pH_{KCl} value in August 2002.

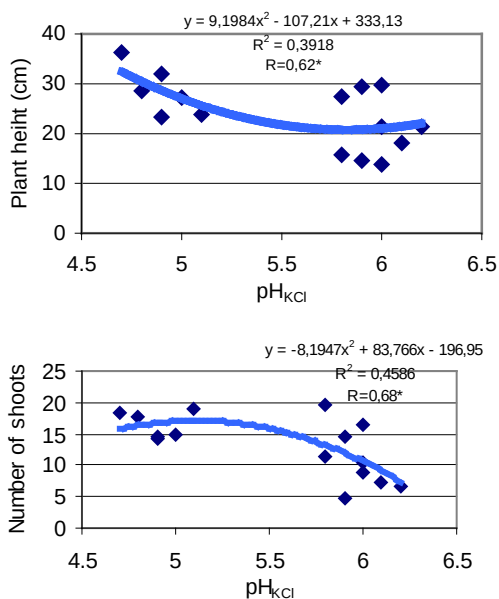


Figure 4: Growth of blueberry plants depending on soil's pH_{KCl} value in 2002.

The influence of soil reaction on assimilation of nutrients by blueberry plants was relatively low, only 11% (Figure 3). In our experiment there was a weak relationship between pH of the soil and nutrient content of blueberry leaves, which indicates that assimilation of nutrients by the plants is influenced by soil acidity, but not much. At the same time relationship between growth of the plants and reaction of the soil was stronger (Figure 4). Thus we may conclude that in given pH interval plants do not suffer from lack of nutrients, but growth of the plants is better with more acidic soil, which also has been fertilized.

Discussion

Plantation of lowbush blueberry will give yield 3...4 years after establishing. During first growing years it is important to create optimal conditions for vegetative growth of plants to ensure high yield in future. The reaction of the soil is considered to be very important. Optimal acidity for growing media of blueberries is found to be pH_{KCl} 4.5...5.5 (Vander Kloet, 1988; Paasisalo et al., 1994). Spiers (1984) made experiments with rabbitey blueberry and claimed pH 3.9...6.1 to be the best for ensuring good growth and high yield. To regulate acidity of the soil, sulphur or physiologically acidic fertilizers are recommended (Hanson, Hancock, 1996). Spiers and Braswell (1992) have explained that in soils with low acidity using acidic fertilizers is not enough to reach the desired pH value. In present experiments added sulphur did not change the reaction of the soil in first year after fertilization. Elemental sulphur dissolves poorly in the water and therefore its effect appears slowly. Hanson and Hancock (1996) have also mentioned in their work that sulphur needs time to have an effect and therefore they recommend to give sulphur the year before establishing blueberry plantation. The influence of sulphur and fertilizers in current experiment appeared in second and third year.

The results of the research showed also that after establishing blueberry plantation, ammonium sulfate + potassium sulfate + superphosphate or Kemira Cropcare 6-14-23 are suitable for changing soil's pH . High amounts of fertilizers are not needed, doses which are worked out and recommended by Finnish scientists, are sufficient for blueberries in Estonia. Fertilization after establishing the plantation increases growth of blueberry plants and thus creates good preconditions for gaining high yields.

Acknowledgements

This research was financed by Estonian Science Foundation (Grant No. 4726), and Enterprise Estonia for which we are sincerely grateful.

References

- Eck, P. 1989. Blueberry culture. - Rutgers University Press, New Brunswick, London, 3-14.
- Hanson, E., Hancock, J. 1996. Managing the Nutrition of Highbush Blueberries. Extension Bulletin E-2011, Major Revision, 13 p.
- Karp, K., Sarast, M., Tiido, T. 2000. Frost damages of arctic bramble (*Rubus arcticus*) and half-highbush blueberry (*Vaccinium corymbosum* x *Vaccinium angustifolium*) depend on cultivation methods. - Proceedings of the International Conference: Fruit Production and Fruit Breeding. Tartu, 244-247.
- Lehmushovi, A., Ylämäki, A. 1999. Pensasmustikkaakin on osattava viljellä. - Puutarha & Kauppa. 11: 6-7. (in Finnish)
- Lehmushovi, A., Ylämäki, A., Tahvonen, R. 2000. Näin se tehdään oikein: pensasmustikkaviljelys. - Puutarha & Kauppa. 25-26: 8-9. (in Finnish)
- Paasisalo, S., Kokko, H., Kärenlampi, S. 1994. Pensasmustikka marjantuotannossa: kasvatus- ja hoitoohjeita. - Muuruvesi, 31 s. (in Finnish)
- Sibley, J.D. 1994. Growing lowbush blueberries in Nova Scotia. - Department of Agriculture and Marketing. Nova Scotia, Canada, 12p.
- Spiers, J.M. 1984. Influence of lime and sulphur soil additions on growth, yield, and leaf nutrient content of rabbiteye blueberry. J. Amer. Soc. Hort. Sci. 109 (4): 559-562.
- Spiers, J.M., Braswell, J.H. 1992. Soil-applied sulfur affects elemental leaf content and growth of 'Tifblue' rabbiteye blueberry. - J. Amer. Soc. Hort. Sci. 117, (2): 230-233
- Starast, M., Karp, K., Tasa, T. 1999. Poolkõrge mustika sortide 'Northblue' ja 'Northcountry' talvekindlus. - Eesti Põllumajandusülikool. Teadustööde kogumik. 203: 162-163. (in Estonian)
- Vander Kloet, S.P. 1988. The Genus *Vaccinium* in North America. - Minister of Supply and Services, Canada, 201p.

SPATIAL ANALYSIS OF POINT DATASETS TO EXPLORE SUGAR BEET VARIABILITY

J. Tamás¹ and I. Buzás²

* University of Debrecen, Hungary

**Kecskemét College, Hungary

Abstract

The sugar beet is very sensitive for the soil characteristics of the cultivated land. This demand is supplied by strictly and highly industrialised cultivation technology. The technology has to be applied in a site-specific way, obviously. Thus, it is important to use an effective and representative soil and plant sampling method. Our study was carried out at a sugar beet farm having moderately heavy clay soil at the Small Plain in Hungary. In addition to the classic soil and plant analysis, the necessary and the toxic microelement contents were also examined. The applied 20 x 20 m high density grid sampling technique supported the geo-statistical analysis of the soil – plant relationship.

Spatial agrochemical data are sensitive to scales and scales of measurement. We provide our implementation of integrating spatial statistical analysis with GIS highly contributes to the description of the spatial correlation of certain parameters and the spatial directions and extents of their effects. Analogous to the traditional statistical parameters were introduced to spatial analyses such as mean centre, weighted mean centre, standard distance and standard ellipse of deviation were calculated based on some representative attribute data sets of points. In addition to the analysis of those parameters considerable from industrial point of view and the mathematical interpolations, the optimal sampling number and the sampling points were determined. The data were integrated to a geographical information system. The developments in Geographic Information Systems allow local and regional variations in crop performance to be more readily explored through co-mapping with data for soil and other factors. This offered the possibility of refining the use of both factory records and crop models.

Introduction

Quality parameters of sugar beet change according to production sites. Decreasing of variability is exceptionally important from the point of view of the sugar industry. Accurate spatial determination of the site and fluctuation of this variability is considered to be the base of this work. Standardisation of field sampling and comparability of studies were subjects of several studies (Kádár and Kiss, 2000). These studies assumed that the number of repetitions is steady in space, but the randomly made sampling technique can keep the sampling errors under an acceptable level. However in this manner the sampling sites and their spatial locations can not be evaluated / retrieved in the future. The differences in plant states can be evaluated with accurate co-ordinates on the basis of DGPS and other real-time corrections. The precision agricultural technologies building on this technical possibility perform rate application input material output (Tamás 2000). The technology in its present state provides more information for the producer than before. However the digital soil map determined by such way do not give

direct information on the relationship between the measurement data and the true data. Conditions of data production, for example the form of estimation or its spatial uncertainty, are not known. Particularly handling of randomly occurred extreme data could cause problems. A yield peak can happen in the sensor of a harvester due to actual yield increase because of local weeding or errors in fertiliser spreading. The secondary data processing based on these data, where at first on the basis of the sample taking points a yield surface is made, then according to the spreading width of the cultivating machines are classified to zones considered to be homogeneous, can make both types of error. Namely they at first faulty evaluate the yield in space due to local error then because of generalisation this error is spread globally to the homogenised zone. We have also no information on the direction and volume of the error propagation happened meanwhile. Some researchers offer the automatic ignorance of the extreme data, whose volume and influence can also difficult to be assessed. The traditional statistic indexes: average, deviation, t, f, chi test; do not take into consideration the locations of the samples compared to each other. In our examinations spatial variability examinations were performed on sugar beet test plant, the application conditions of the estimation methods were evaluated and such statistical analogues that can spatially be interpreted were sought, which meet the traditional statistical indexes.

Material and Methods

The examinations were made in a sample area located in north-western Hungary with sugar beet test plant. According to the traditional sample taking procedure N=60 samples were taken in regular 20 x 20 m grid, where besides the plant micro- and macro elements, the sugar industrial quality parameters the agro-chemical examination of soils were performed as well. The spatial relations of the sample values are shown mainly on the basis of the average yield. Data were pictured digitally in ± 1 m spatial accuracy, the database was supplemented with a 1:10,000 scale topographical map. The integrated geographical information system was made under 8.2 version of ArcMap. For statistical examinations Geo-statistical Analyst (ESRI), Genstat 6.0 and Variowin 2.2 softwares were used. On the basis of the point database five interpolation methods were compared to each other. Cross-correlation calculation was made with 31 examination parameters for the Pearson-values. For its spatial analogy an application for cokriging was shown. Description of this method is available for example in the works of Isaaks, E. H.; Srivastava (1989); Cressie (1990); Wackernagel (1995).

In case of the statistical analogues of the traditional statistical indexes solutions applied for description of space in geometry were utilised. Monmonier (1993) calls attention to the fact that

in this case the co-ordinate system needs to be carefully structured data source so that it orients to proper direction for GIS project, it situates with proper arbitrary origin, and it uses suitable measurements unit and interpretation scale. With a co-ordinate system defined, the mean centre can be calculating as follows (1.equation).

$$(\bar{x}_{mc}, \bar{y}_{mc}) = \left(\frac{\sum_{i=1}^n x_i}{n}, \frac{\sum_{i=1}^n y_i}{n} \right), \quad (1.equ)$$

where $\bar{x}_{mc}, \bar{y}_{mc}$ = are co-ordinates of mean centre, x_i, y_i are co-ordinates of point i , and n is the number of points.

The weighted mean centre of distribution can be found by multiplying the x and y co-ordinates and mean of each point by weights (measured values) assigned to them (2. equation).

$$(\bar{x}_{wmc}, \bar{y}_{wmc}) = \left(\frac{\sum_{i=1}^n w_i x_i}{\sum_{i=1}^n w_i}, \frac{\sum_{i=1}^n w_i y_i}{\sum_{i=1}^n w_i} \right), \quad (2.equ)$$

where $(\bar{x}_{wmc}, \bar{y}_{wmc})$ defines the weighted mean centre and w_i is the weight at i measured point

Standard distance is the spatial analogy of standard deviation in descriptive statistics. While standard deviation indicates how observations deviate from mean, standard distance indicates how points in a distribution deviate from mean centre. Attribute values can be used as weights when calculating their mean centre and also possible to weight when calculating the weighted standard distance as following (3. equation):

$$SD = \sqrt{\frac{\sum_{i=1}^n f_i (x_i - x_{mc})^2 + \sum_{i=1}^n f_i (y_i - y_{mc})^2}{\sum_{i=1}^n f_i}} \quad (3.equ)$$

$\bar{x}_{mc}, \bar{y}_{mc}$ = are co-ordinates of mean centre, x_i, y_i are co-ordinates of point i , and n is the number of points and f_i is the weight for x_i, y_i point.

Results

The traditional statistical measurement is not able to take into consideration the spatial locations of number = N sample taking points. Spatial relations between the x-value characteristic (i.e. sugar content and signed as $z(x)$) of the plant defined by x_1, y_1 co-ordinates in the given z

measuring point and described with given h distance vector and the same characteristic of a plant defined x_2, y_2 co-ordinates being in the point of $z(x+h)$ can't be evaluated. The work hypothesis of exact field trials is that providing the repetition number of the trial treatment plots situated randomly in space the treatment data of each plot differentiate from the others in space and the results exceeding a given certainty limit value depends on significantly on the treatment. Basis of the work hypothesis of the geo-statistical examinations is the so-called Tobler law that says the characteristics of the objects (sample taking points) located nearer to each other are more similar than of the point located farther in space. The spatial variance of the closer sample taking points is smaller and their auto-correlation is bigger than of the farther points. This γ (h variability) grows with distance, while the auto-correlation decreases and in case of a given range the variability stabilises at given sill value and the correlation approaches to 0 at this same place.

The variogram is sensitive to local and global outliers. Local outlier means an attribute value of the sampling point exceeds its neighbourhood, while the global outlier exceeds the means of the examined area. Each observed $z(x)$ can contribute to several estimates of $\gamma(h)$. So one exceptionally large or small measured value $z(x)$ will tend to swell $\gamma'(h)$ whenever it is compared with other values. The result is to inflate the average. But the effect is not general. The point that is closer to the edge of the examination area contributes less, than the one is closer to the centre. If the sample points along a regular line would be taken into consideration, the initial and end points act only one time in each lag, while the others inside the line more times. If the points are scattered in space the effect of the extreme data can lesser be estimated. In the database of the average yields distributed near normally a similar case can be found in the NW space, if the biggest and smallest values are close to each other in space. Thus their effect succeeds less than of the high yield values located in the centre of the examination space. At the same time the surface estimation made by ordinary kriging under- and overestimated these spaces (Figure 1.).

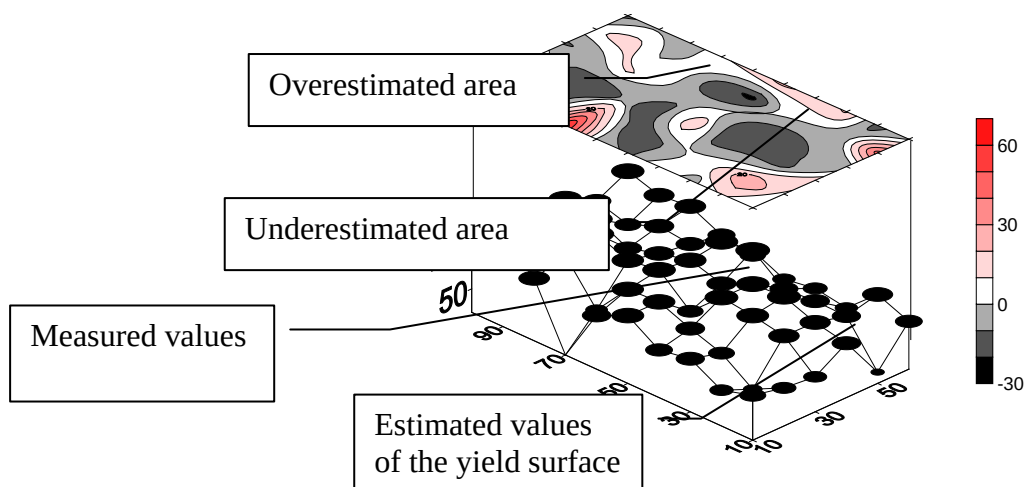


Figure 1: Spatial distributions of residual data of the measured values and the surface calculated by kriging.

Exceptional contributions to the semi-variance can be identified by drawing an h-scattergram surface or scatter diagram for each lag, h . An h-scatter diagram is a graph in which the $z(x)$ are plotted against the $z(x+h)$ with which they are compared in computing $\gamma'(h)$. The closer the points lie to the diagonal line with gradient 1, the stronger is. In the figure in the upper part the variogram fitted onto the value pairs can be seen, while in the lower part the average yield h-scattergram surface and the seeking directions can be seen.

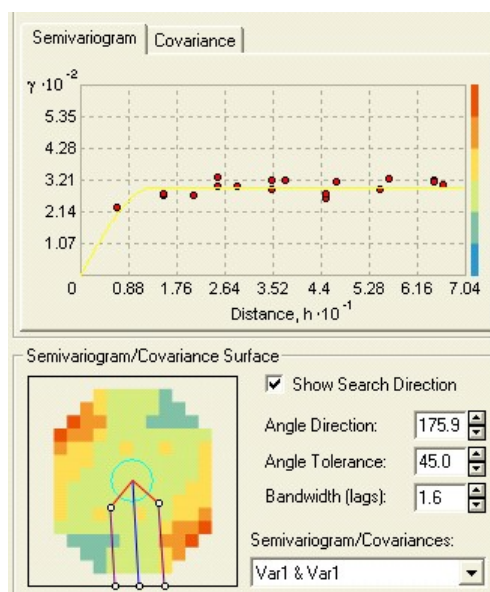


Figure 2: Semi-variogram and h-scattergram surface of sugar beet yield samples

On the figure 2. can be observed that the yield samples showed the smallest variance in N-S direction. The fitted model function is $\gamma'(h) = 296.4 * \text{spherical}(17.3)$. The experimental sample taking distance, which was 10 m originally, can be grown to near twofold but keeping the variance level. The variogram function was used during Ordinary Kriging interpolation. Effects of other interpolators to the same yield data were analysed as well, which were the follows: Global Polynimonal (GP), Local Polynominal Interpolation (LP) are quick deterministic interpolators that are smooth (inexact), Inverse Distance Weighted (IDW), Radial Basis Functions (RBF) methods are a quick deterministic interpolator that is exact. In case of each of all methods the cross-validation was performed as well residual values were calculated to all (N=60) measurement sites, their average and deviation to each method (Table 1.).

Table 1: Residual Results of Different interpolation methods

	Measured yield t/ ha ⁻¹	LP Error	RBF Error	IDW Error	GP Error	Ordinary kriging
Mean	84.16	-0.93	-0.10	0.17	0.07	0.08
Standard deviation	17.83	16.54	14.88	15.39	17.04	14.97

A residual is the difference between the Z value of a point in a data file and the interpolated Z value at the same XY location on a grid surface. Residual values are reported as either positive or negative values. If the Z value in the data file is greater than the Z value derived from the grid surface, the residual value is positive. A negative residual value indicates that the Z value from the data file is less than the interpolated Z value at that point. On the basis of the residual maps and their statistical values it can be ascertained, that the GP can be used successfully in that case if the surface changes slowly and gradually. The data located in the edges can play an important role in surface formation. Local Polynomial Interpolation (LP) is more flexible than the global polynomial method, but there are more parameter decisions, but it is less flexible and more automatic than kriging. Inverse Distance Weighted (IDW) can be a good way to take a first look at an interpolated surface.

Radial Basis Functions (RBF) provides prediction surfaces that are comparable to the exact form of kriging, making it less flexible and more automatic than kriging.

Kriging is a moderately quick interpolator that in this case was exact because it was not involved measurement error model in variogram. Kriging assumes the data come from

stationary stochastic process and used ordinary kriging methods assume normally distributed data.

Not only spatial distribution of yield must be determined in practice but its correlation to other parameters and soil examination values needed for sugar industry. The Pearson correlation values were calculated for 31 parameters. From the correlation matrix received in such way the values $-1 \leq -0,5$ and $0,5 \leq 1$ were kept (2. Table).

Table 2: The Pearson correlation values of the yield and the soil pH.

	Mean of yield t ha ⁻¹		pH (KCl)
net sugar beet yield t ha ⁻¹	0.97	Carbonic chalk m/m%	0.83
raw sugar yield t ha ⁻¹	0.91	Humus m/m%	-0.75
white sugar yield	0.87	Cu mg/kg	-0.69
thick juice purity quotient %, (: Q%,)	0.96	Mn mg/kg	-0.74
		Fe mg/kg	-0.72
		Al mg/kg	-0.74
		Cd mg/kg	-0.78
		Co mg/kg	-0.72
		Pb mg/kg	-0.76

Parameters of the table were calculated as follows:

-raw sugar yield: net sugar beet yield t/ha x digestio %/100

-white sugar yield t/ha, : net yield sugar beet t/ha x white sugar content of the sugar beet %/100,
where

white sugar content of the sugar beet % = digestio % - [0,343(K+Na)+(0,094N)+0,2]

K = K content of the sugar beet, mmol/100g sugar beet

Na = Na content of the sugar beet, mmol/100g sugar beet

N = alfa-amino-N content of the sugar beet, mmol/100g sugar beet.

-thick juice purity quotient Q%, :=99,36 – 1,427(K'+Na'+N')/digestio%,

where K'=K content of the sugar beet, mmol/kg sugar beet

Na'=Na content of the sugar beet, mmol/kg sugar beet

N'=alfa-amino-N content of the sugar beet, mmol/kg sugar beet.

The statistical examination above does not take the places and spatial values of the sample into consideration. As analogy in this case the spatial effect of cokriging was analysed. Cokriging jointly analyses the spatial variance of the two variables. On its basis spatial variance with less number of samples can be calculated on the basis of the variogram defined to bigger sample number.

Cokriging uses statistical models that allow a variety of map outputs. Cokriging assumes the data come from a stationary process, and used methods assume normally distributed data.

From amongst the results maps of copper and pH are shown here. (Figure3.).

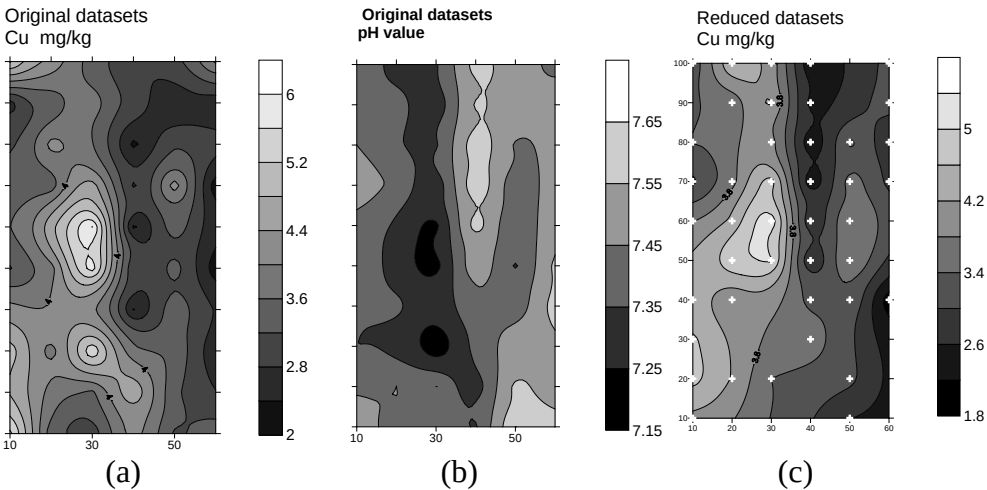


Figure 3: Sample taking areas of copper and pH of original sample numbers (a-b) as well as spatial distribution of copper with reduced sample points estimated by pH variogram (c)

Copper and pH show a negative spatial correlation, i.e. increasing several decimal pH level already detects less micro element content and distribution. In both cases the cokriging functions make decrease of number of samples possible. In the model the number of the regular sample grid were randomly decreased to 70% (signed with white cross). pH and Cu $r=-0,69$ showed medium values, which were signed by the opposite meaning spatial pattern of the above figure. On the basis of the co-variogram the spatial pattern of Cu was re-estimated by ordinary kriging in the 30% reduced database, where the standard error was 12% between the original and reduced number of sample estimation. Since the Fe, Mn, Al, Cd, Co, Pb showed a closer correlation with the pH, at the same error level further decrease in the number of samples and in case of same number of samples further decrease in uncertainty can be reached. In practice the parameter that can be measured cheaper can decrease the measurement costs of several spatially well correlating elements.

On the basis of the equations No. 1.-3. of chapter Material and Methods the spatial weighted mean and standard distance values were calculated for the different parameters (table). For the examination area the geometrical spatial mean is x(35), y(55) and the standard distance is 33,41(Table 3.).

Table 3: Spatial weighted mean and standard weighed distance of sugar beet and soil data

	Spatial mean (X)	Spatial mean (Y)	Standard distance	Weighted mean		
1. Measuring point	35	55	33,41	sum of Weighted (x)	sum of Weighted (y)	sum of weight
2. Average yield tha^{-1}	34.7785	57.5187	33.0611	175607	290429	5049.3
3. pH(KCL)*	35.1054	54.9917	33.456	15648.6	24513.1	445.76
4. saturation percentage*	33.8719	55.5688	33.4	70860	116250	2092
5. Total salt (m/m%)*	20	10	0	1.4	0.7	0.07
6. CaCO_3 (m/m%)*	39.4189	50.8959	33.9	16280	21020	413
7. Humus (m/m%)*	34.1157	55.8579	33.016	4268.9	6989.5	125.13
8. Contamination of the sugar beet (mmol/kg)	33.9164	58.4595	32.89	12990	22390	383
9. Digestio %r	34.8487	57.4433	33,096	165880	273430	4760
10. Net sugar beet yield yield t ha^{-1}	35.4976	54.4539	33.2421	29250	44870	824
11. Raw sugar yield yield t ha^{-1}	35.2549	57.1895	32.9375	26970	43750	765
12. White sugar yield yield t ha^{-1}	35.3988	56.6718	32.9546	23080	36950	652
13. Q%	35.351	54.7311	33.295	34074.1	52754.2	963.88
14. K-content of the sugar beet mmol/kg	34.7532	55.7278	33.5336	92996	149122	2675.9
15. Na content of the sugar beet mmol/kg	33.9698	56.7187	33.3717	21119	35262	621.7
16. alfa-amino N content of the sugar beet mmol/kg	35.1002	54.9235	33.396	192630	301420	5488
17. $\text{NO}_3\text{-N}+\text{NO}_2\text{-N}$, 1 mol KCl soluble mg/kg soil	30.0307	62.2761	33.8225	9790	20302	326
18. P_2O_5 soluble, mg/kg soil	34.3553	53.0497	33.2863	428410	661530	12470
19. K_2O soluble, mg/kg soil	33.9419	56.2672	33.6628	532480	882720	15688
20. Na soluble, mg/kg soil	34.6702	57.9553	33.2343	162950	272390	4700
21. Mg 1 mol KCl soluble, mg/kg soil	34.3305	56.2369	33.33	226890	371670	6609
22. Zn*	33.9291	54.4593	33.8873	2739.1	4396.5	80.73
23. Cu*	32.8236	53.634	33.3894	7055.1	11528.1	214.94
24. Mn*	30.099	59.5723	30.1001	62916	124524	2090.3
25. Fe*	33.2593	55.8289	32.4939	18276	30678	549.5
26. Mo*	34.0116	40.5814	30.7535	58.5	69.8	1.72
27. Al*	31.6297	58.3228	31.5015	9995	18430	316
28. B*	32.2859	56.3163	32.764	614.4	1071.7	19.03
29. Cd*	32.0963	55.6118	32.7386	103.35	179.07	3.22
30. Cr*	34.1549	55.1698	33.6255	89.52	144.6	2.621
31. Co*	28.6805	59.2803	29.5924	263	543.6	9.17
32. Pb*	31.4789	56.6745	32.4218	2937.3	5288.3	93.31

Remarks: 3-7 rows – soil; 22-32 rows -0,05mole EDTA+0,1 mole KCl soluble, mg/kg soil*

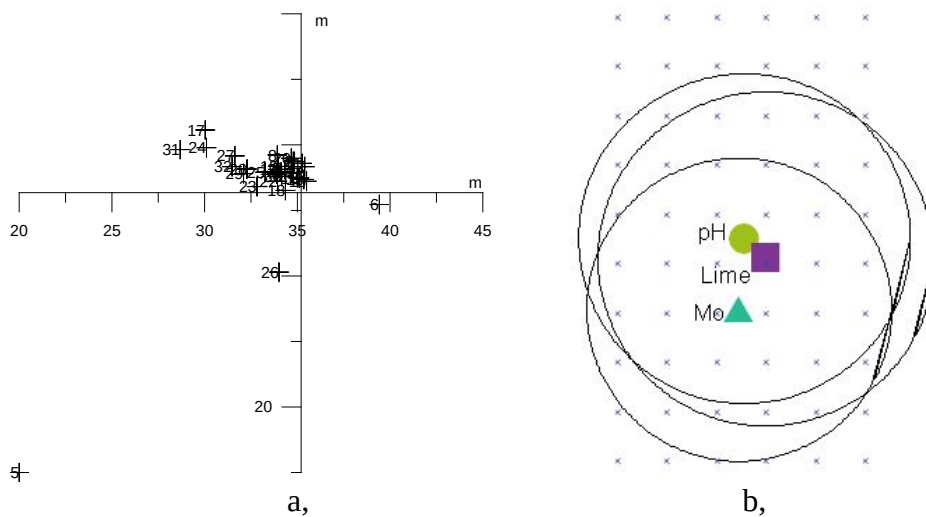


Figure 4: Spatial mean of analysed data and visual methods of mapping

The origin of the above figure 4.a, is in the geometrical centre of the examination area. The co-ordinates of the parameters are displayed correctly according to the serial number of the figure. Distribution of the density values shows the relative homogeneity of the examination area. Excluding the pH, lime and Mo content the spatial mean values of the examined characteristics moved to the N-W direction. To the spatial average its dispersion value can be added, as the radius value of the circle drawn into the origin of the spatial average. They can be jointly mapped in co-ordinate spaces.

Similarly to our results, Lee and Wong (2001) declare based on population data that a weighed mean centre provides a better description of the central tendency than a mean centre when points or locations have different frequencies or occurrences of the phenomena studied. In this case, standard distance is usually used as the radius to draw a circle around the mean centre to give the extent of spatial spread of the point distribution it is based on. This can provide visual comparison of extent of spread among different types of measured data.

Conclusion

In a 20 X 20 m sample grid 31 soil- and plant parameters were examined in case of sugar beet sample plant. For analysing the spatial distribution of yield data 3 exact and 2 smooth interpolators were tested. The spherical model used in case of ordinary kriging interpolation provided good result. The about 17 m grid-distance still estimates the spatial variance well.

Approach of the extreme values at the edges of the examination areas provided higher spatial uncertainty. The pH distribution of the soil in case of a several decimal deviation already showed negative correlation to the examined microelements. Cokriging significantly improved the estimation of the less examined microelement, if spatial correlation made it possible. The spatial weighted mean and spatial weighted deviation values were established for characterisation of the examination space. They are available for visual mapping, thus can show the location of the parameters co-ordinate-correctly in the examination space..

References:

- Cressie, N. A. C. Statistics for Spatial Data; John Wiley and Sons, New York, 1991; 900.
- Isaaks, E. H.; Srivastava, R. M. An Introduction to Applied Geostatistics, Oxford University Press, New York, 1989; 561.
- Kádár, I.; Kiss, E. Mineral fertilisation of sugar beet (*Beta vulgaris* L.) on calcareous loamy chernozem soil, *Növénytermelés*, 2000; 49.677-690.
- Lee, J., Wong, S. W, Statistical analysis with ArcView GIS. John Wiley and Sons, New York, 2001; 1-191.
- Monmonier, M. Mapping out. Chicago: University of Chicago Press. 1993
- Tamás, J, *Precíziós Mezőgazdaság, Mezőgazdasági Szaktudás Kiadó*, Budapest, 2001; 1-160.
- Wackernagel, H. Multivariate Geostatistics, Springer, Berlin, 1995; 251.

THE EFFECT OF NITROGEN FERTILIZATION AND WATER SUPPLY ON THE NITROGEN UPTAKE OF *LOLIUM PERENNE*

I. Vágó¹, J. Kátai² and P. T. Nagy¹

Debrecen University, Centre for Agricultural Sciences, Agricultural Faculty, Hungary

¹Department of Agricultural Chemistry, Hungary

²Department of Soil Science and Microbiology, Hungary

Abstract

Besides the genetically coded productivity of plants, other factors also determine the quality and the quantity of yield (*Liebig, 1876; Mengel, 1976; Loch & Nosticzius, 1992*). Among these, nitrogen and water supply are the most decisive ones. We have to reckon that these factors influence the effect of each other (*Debreczeni, 1975; Kiss, 1978*). The nitrogen and the water supply significantly effects the dynamics of nutrient uptake at the different feedcrops (*Borchmann, 1963*), among others winter wheat (*Kincses, 2001*) and maize (*Kincses et al., 2002*). It should be noted, however, that there are significant differences in the plant species' ability to take up nutrients (*Eichler et al., 1997*).

The same nitrogen and water supply has a different effect on soil types. Therefore, a pot-experiment was set up on three extremely different soil types near Debrecen with ryegrass (*Lolium perenne* L.) as a test plant in 2001. In the experiment, we examined the effect of nitrogen and water supply on the plant's dry matter production and its dynamics. The nitrogen concentration of the yielded grass was measured in percentage and the amount of nitrogen extracted from the soil by the plant was calculated for the different cuts and for the whole experiment. The results were evaluated by a three-variate analysis of variance.

Material and Methods

The basic parameters of the three untreated soils from the vicinity of Debrecen used in the pot experiment are included in Table 1. Calculated for air-dry state, 2,5 kg of brown forest soil, 2,5 kg of chernozem soil and 2,0 kg of marshy meadow soil were put separately into pots of 2,0 dm³ volume.

The standard treatment of pots was a joint solution of 40 mg/kg P₂O₅ and 40 mg/kg K₂O, in 10 cm³ KH₂PO₄ and K₂SO₄.

The combinations of treatments applied on the three soils are shown in Table 2. Each treatment was carried out in four replications.

The water supply level set up in the treatment plan was ensured by daily irrigation to a specific weight. At high vegetative mass, plants were irrigated in the afternoon also on hot days to avoid wilting.

Plants were cut three times, on 28 June, 19 July and 9 August 2001, the grass yield was dried at 60 °C until reaching constant mass in a desiccator and the dry matter production per pot was measured.

After the first and second cuts, a nutrient solution of 20 mg N/kg soil (NH_4NO_3) was applied to each pot. N treatment is inevitable after cuts, because the low soil mass the available N stock can reduce to such an extent, that no considerable grass will be yielded.

The nitrogen content of dry matter was measured with a Kjel-Foss analyzer operating on the principle of the Kjeldahl method. From the mass and the nitrogen content, the amount of nitrogen extracted from the soil per cutting was determined. Finally, the total amount of nitrogen extracted was calculated. The obtained results were evaluated by a three-variate analysis of variance on the basis of Sváb's method.

Table 1: Parameters of untreated soils

Soil parameter	Soil site		
	Pallag	Látókép	Dombos
Soil type	Brown forest soil with „kovárvány” *	Calcareous chernozem	Marchy meadow soil
Plant	Orchard	Winter wheat	Grassland
Soil texture	Sand	Loam	Clayey loam
K _A	28	46	58
pH-H ₂ O	5,38	6,13	7,60
pH-KCl	4,04	5,45	7,27
pH-CaCl ₂	4,62	5,91	6,98
y ₁	8,16	7,85	-
CaCO ₃ (%)	-	-	26,7
Salt (%)	0,002	0,039	0,022
Total C content (%)	0,34	1,93	7,20
Total N content (%)	0,043	0,206	0,473
C/N ratio	7,97	9,35	15,24
Organic C (%)	0,26	0,97	1,75
Organic/total C ratio	76,5	50,3	24,3
0,01 M CaCl ₂ extractable (mg/kg)			
NO ₃ ⁻ -N	0,51	4,95	3,44
NH ₄ ⁺ -N	0,31	3,67	0,56
Inorganic N	0,82	8,62	4,00
Organic N	0,14	0,59	1,46
Total soluble N	0,96	9,21	5,46

*brown forest soil with alternating thin layers of clay substance ("kovárvány")

Table 2: Combinations of treatments

Number of combination	N treatment (mg/kg)	Water supply W.c. (%)
1.	0	50
2.	40	50
3.	80	50
4.	0	75
5.	40	75
6.	80	75

In the analysis of variance, F and SD 5 % values were calculated for each factor and for each double and triple interaction, then the significance levels were determined.

Results

Dry matter production

The dry matter production of plants reduced with time (main average: 1st cut: 4,02; 2nd cut 2,04; 3rd cut: 1,78/pot). The reasons for this are the nutrient-deficiency originating from low soil mass and the ageing of grasses. It can be stated that the nutrient supply of soils heavily influenced the dry matter production of plants at all cuts. In the average of treatments, for each cut (and in total also) the calcareous chernozem was the most productive (P= 0,1 %), while the productivity of the brown forest and the marshy meadow soil was similar (Table 3 and Table 4).

Table 3: Dry matter production of perennial ryegrass (g/pot)

1st cut

W.c. (%)	Soil site	N supply (mg/kg) (A)			
(C)	(B)	0	40	80	Average
50	Pallag	1,13	4,47	6,45	4,02
	Látókép	3,05	4,00	6,57	4,54
	Dombos	2,40	3,45	4,00	3,28
	Average	2,19	3,98	5,67	3,95
75	Pallag	1,02	2,63	4,03	2,56
	Látókép	2,70	5,45	8,67	5,61
	Dombos	3,05	4,10	5,18	4,11
	Average	2,26	4,06	5,96	4,09
Average	Pallag	1,08	3,55	5,24	3,29
	Látókép	2,88	4,72	7,62	5,07
	Dombos	2,73	3,78	4,59	3,70
	Average	2,23	4,02	5,82	4,02

Table of variance

Factor	FG	MQ	F		SD 5%
A	2	77,40	158,4	***	0,40
B	2	21,06	43,1	***	0,40
A*B	4	5,25	10,7	***	0,70
C	1	0,38	0,8		0,33
A*C	2	0,09	0,2		0,57
B*C	2	11,65	23,8	***	0,57
A*B*C	4	3,13	6,4	***	0,99
Error	51	0,49			

*** Significant at P=0,1 % level

The effect of nitrogen treatment was reflected in the amount of yield at the first and second cut ($P=0,1\%$). At the third cut, the effect of the original nitrogen treatments was not detectable. The obvious reason for this is the fact, that after each cut a solution containing 20 mg nitrogen /kg soil was applied to each pot to ensure the survival of plants.

On the basis of the total dry matter production of each pot, it can be stated that the treatment effects were similar to those of the first two cuts. The reduction in the effect of nitrogen at the third cut could not be detected in this case. The explanation of this is that on average the dry matter yield of the third cut was only 22 % of the total production mass.

The yield increase due to the nitrogen treatment varied for the different soils. This is supported by the fact, that the A*B (N dose*soil type) interaction is highly significant (in most cases $P=0,1\%$). The 80 mg/kg nitrogen doubled the yield on the brown forest and the calcareous chernozem soil, while on the marshy meadow soil with high organic matter content the increase was also significant, but smaller.

The higher level of water supply increased the yield at every cut, but it was not significant in each case. The fact that the B*C (soil*water capacity) interaction was significant ($P=0,1\%$) proves that the highest yield can be achieved by 75 % water dose on calcareous chernozem and marshy meadow soil and by 50 % water dose on brown forest soil. It can be stated that the effect of nitrogen fertilization was not modified by the water supply.

Table 4: Dry matter production of perennial ryegrass (g/pot)

Sum of 1st, 2nd and 3rd cuts

W.c. (%)	Soil site	N supply (mg/kg) (A)			
(C)	(B)	0	40	80	<i>Average</i>
50	Pallag	4,38	7,43	10,53	7,44
	Látókép	6,92	8,75	11,57	9,08
	Dombos	5,10	6,60	7,27	6,32
	<i>Average</i>	5,47	7,59	9,79	7,62
75	Pallag	4,40	5,80	6,73	5,64
	Látókép	7,33	10,82	14,43	10,86
	Dombos	6,48	7,70	8,85	7,68
	<i>Average</i>	6,07	8,11	10,00	80,6
Average	Pallag	4,39	6,61	8,63	6,54
	Látókép	7,13	9,79	13,00	9,97
	Dombos	5,79	7,15	8,06	7,00
	<i>Average</i>	5,77	7,85	9,90	7,84

Table of variance

Factor	FG	MQ	F		SD 5%
A	2	102,30	117,6	***	0,54
B	2	83,18	95,6	***	0,54
A*B	4	6,68	7,7	***	0,94
C	1	3,51	4,0	*	0,44
A*C	2	0,26	0,3		0,77
B*C	2	22,88	26,3	***	0,77
A*B*C	4	5,18	6,0	***	1,33
Error	51	0,87			

*** Significant at P=0,1 % level

* Significant at P=5,0 % level

The nitrogen content of plants

The average nitrogen content of ryegrass was almost constant during the vegetation period (~ 2%), because the nitrogen extracted by the plant was (partially) supplemented after each cut. In spite of this, the effect of nitrogen treatments was detectable in the dry matter content of plants at each cut (P=0,1 %).

The results demonstrate that the nitrogen uptake of plants is the highest (2,81 %) on marshy meadow soil (P=0,1 %), while on brown forest soil and calcareous chernozem the nitrogen content of ryegrass was lower, 1,34 % and 1,91 %, respectively. The tendency is in accordance with the original total nitrogen contents of the soils.

The higher water supply decreased the nitrogen content of plants in almost every treatment and soil combination (P=1,0 % or 5,0 %)

Table 5: Nitrogen content (%) of perennial ryegrass, 1st cut

W.c. (%)	Soil site	N supply (mg/kg) (A)			
(C)	(B)	0	40	80	<i>Average</i>
50	Pallag	1,13	1,27	1,83	<i>1,41</i>
	Látókép	1,38	2,00	2,52	<i>1,97</i>
	Dombos	1,85	2,90	3,72	<i>2,83</i>
	<i>Average</i>	<i>1,45</i>	<i>2,06</i>	<i>2,69</i>	<i>2,07</i>
75	Pallag	1,00	1,27	1,52	<i>1,27</i>
	Látókép	1,35	1,78	2,45	<i>1,86</i>
	Dombos	2,10	2,75	3,55	<i>2,80</i>
	<i>Average</i>	<i>1,48</i>	<i>1,93</i>	<i>2,51</i>	<i>1,98</i>
Average	Pallag	1,06	1,27	1,67	<i>1,34</i>
	Látókép	1,36	1,89	2,49	<i>1,91</i>
	Dombos	1,97	2,83	3,64	<i>2,81</i>
	<i>Average</i>	<i>1,47</i>	<i>2,00</i>	<i>2,60</i>	<i>2,02</i>

Table of variance

Factor	FG	MQ	F		SD 5%
A	2	7,72	291,5	***	0,09
B	2	13,27	501,0	***	0,09
A*B	4	0,56	21,1	***	0,16
C	1	0,15	5,71	*	0,08
A*C	2	0,08	2,85	+	0,13
B*C	2	0,02	0,82		0,13
A*B*C	4	0,05	1,99		0,23
Error	51	0,03			

*** Significant at P=0,1 % level

* Significant at P=5,0 % level

+ Significant at P=10,0 % level

The amount of nitrogen extracted by plants

In the mean of the experiment, the amount of nitrogen extracted per pot reduced with time (1st cut: 87,7; 2nd cut 42,8 and 3rd cut: 37,2 mg N/pot). The total amount of nitrogen extracted by the three cuts is also considerable with 167,7 mg/pot. The decrease in the amount of nitrogen extracted can be explained by the gradually decreasing yield.

The nitrogen uptake corresponds with the increasing nitrogen supply: the amount of extracted nitrogen at the first cut was 34,9; 80 and 148,2 mg N/pot in the average of control treatments, at 40 mg/kg and at 80 mg/kg N doses, respectively (Table 6).

Table 6: Nitrogen uptake of perennial ryegrass (mg/pot), 1st cut

W.c. (%)	Soil site	N supply (mg/kg) (A)			
(C)	(B)	0	40	80	<i>Average</i>
50	Pallag	12,3	57,0	117,8	62,3
	Látókép	41,9	80,1	165,2	95,7
	Dombos	44,3	100,1	148,9	97,8
	<i>Average</i>	32,8	79,1	143,9	85,3
75	Pallag	10,3	33,4	61,3	35,0
	Látókép	36,4	96,9	213,3	115,5
	Dombos	64,3	112,7	182,8	119,9
	<i>Average</i>	37,0	81,0	152,4	90,1
Average	Pallag	11,3	45,2	89,5	48,7
	Látókép	39,1	88,5	189,2	105,6
	Dombos	54,3	106,4	165,8	108,8
	<i>Average</i>	34,9	80,0	148,2	87,7

Table of variance

Factor	FG	MQ	F		SD 5%
A	2	78087,7	283,1	***	9,63
B	2	27512,1	99,7	***	9,63
A*B	4	2985,4	10,8	***	16,69
C	1	426,8	1,5		7,87
A*C	2	66,9	0,2		13,63
B*C	2	4679,6	17,0	***	13,63
A*B*C	4	1558,9	5,7	**	23,60
Error	51	275,8			

*** Significant at P=0,1 % level

** Significant at P=1,0 % level

The tendency was the same for the total sum of the three cuts: the amount of the nitrogen extracted was 97,2; 159,4 and 246,5 mg N/pot in the average of control treatments, at 40 mg/kg and at 80 mg/kg N doses, respectively (Table 7).

The amount of nitrogen extracted was dependent on the soil (P=0,1 %). The chernozem and the marshy meadow soil supplied the grass with approximately the same amount of nitrogen, which can be explained by the fact that the higher grass yield on the chernozem soil and the higher nitrogen content of plants on marshy meadow soil offset each other. However, plants extracted only 110 mg N/pot from the brown forest soil.

In spite of the fact, that water dose had an effect both on yield quantity and the nitrogen content of plants, the level of water supply did not influence the amount of nitrogen uptake significantly. The reason for this was that while yield increased paralelly with the water supply,

the nitrogen content decreased. These two counter-effects balanced each other in the nitrogen uptake of plants.

Table 7: Nitrogen uptake of perennial ryegrass (mg/pot)

Sum of 1st, 2nd and 3rd cuts

W.c. (%)	Soil site	N supply (mg/kg) (A)			
(C)	(B)	0	40	80	<i>Average</i>
50	Pallag	61,6	113,3	206,2	127,0
	Látókép	113,8	169,4	276,4	186,5
	Dombos	112,8	189,7	248,9	183,8
	<i>Average</i>	96,1	157,5	243,8	165,8
75	Pallag	60,0	95,7	125,0	93,6
	Látókép	98,7	186,2	330,5	205,1
	Dombos	136,4	202,2	292,1	210,2
	<i>Average</i>	98,3	161,4	249,2	169,9
Average	Pallag	60,8	104,5	165,6	110,3
	Látókép	106,3	177,8	303,4	195,8
	Dombos	124,6	196,0	270,5	197,0
	<i>Average</i>	97,2	159,4	246,5	167,7

Table of variance

Factor	FG	MQ	F		SD 5%
A	2	134992,9	295,5	***	12,40
B	2	59348,8	129,9	***	12,40
A*B	4	4742,3	10,4	***	21,48
C	1	265,3	0,6		10,13
A*C	2	14,1	0,0		17,54
B*C	2	6361,1	13,9	***	17,54
A*B*C	4	3207,4	7,0	***	30,38
Error	51	344,0			

*** Significant at P=0,1 % level

Summary

Beside the genetically coded productivity of plants the ecological and agritechnical factors effect on the quality and quantity of crop too. Among these factors the nitrogen and water supply is very important. We have to reckon that these factors influence the effect of each other.

The same nitrogen and water supply has different effect in soil types. So that pot-experiment was carried out on three extremely different soil types near Debrecen with ryegrass (*Lolium perenne* L.) as test plant in 2001. The effect of nitrogen (0, 40, and 80 mg/kg N) and water (W.c.: 50 and 75%) supply on the dry matter production of grass was examined. The nitrogen

concentration of ryegrass was measured and the nitrogen content was calculated extracted from the soil by plant. The results were evaluated by three-variate analysis of variance.

The dry matter production of plants reduced during the experiment (main average: 1. cut: 4,02, 2. cut: 2,04, 3. cut: 1,78 g/pot). The reason of that is the nutrient-deficiency of small soil mass and the ageing of grasses. Could be stated that the dry matter production of plant is considerable influenced by the available nutrient supply of soils. At cuts according to the mean of treatments the calcareous chernozem was the most productive, while the productivity of brown forest soil and marshy meadow soil was similar.

By the nitrogen doses the increase of crop was various in different soil types. The 80 mg/kg nitrogen doubled the crop in the brown forest soil and calcareous chernozem, while in case of marshy meadow soil abounding in organic matters the increase of crop was smaller.

The higher water supply increased the yield on the calcareous chernozem and marshy meadow soil, but on the brown forest soil the yield was higher at 50% water capacity.

The amount of extracted nitrogen depending on the soil ($P=0,1\%$). The calcareous chernozem and marshy meadow soil supplied similar (200 mg/pot) amount of nitrogen for grass, it can be explained that the higher mass of grass on calcareous chernozem and the higher nitrogen content of grass on marshy meadow soil equalise each other. From the brown forest soil only 110 mg nitrogen/pot was extracted by plants.

References

- Borchmann, W. (1963): Über die Abhängigkeit des Mineralstoffgehaltes verschiedener Futterpflanzen von der Höhe der Wasserversorgung. III. Zeitschrift für Landwirtsch. Versuchs- und Untersuchungswesen, 9. 173-198.
- Debreczeni B. (1975): A műtrágyázás és az öntözés kölcsönhatása a műtrágyák hasznosulása és hatékonysága szempontjából. Agrártud. Közl. 34. 3. 551-557.
- Eichler, B. – Köppen, D. – Grüner, A. (1997): Nutzung von Phosphorvorräten durch Zwischenfrüchte im Gefäßversuch. 41. Jahrestagung vom 24.-27. 09. 1997 in Kiel, Tagungsband S. 309
- Kincses S. (2001): Az NPK trágyázás hatása az őszi búza tápelem-felvételének dinamikájára, öntözött és nem öntözött körülmények között. Észak-alföldi Régió Mezőgazdasági és Vidékfejlesztési Regionális Tudományos Tanácskozás és Konferencia, Debrecen. Debreceni Egyetem, Agrártudományi Közlemények. Különszám. 41-46.
- Kincses S. – Filep T. – Loch J. (2002): Az NPK trágyázás hatása a kukorica tápelem-felvételének dinamikájára, öntözött és nem öntözött körülmények között. Debreceni Egyetem, Agrártudományi Közlemények. 2002/1. 23-27.
- Kiss Sz. (1978): A tápanyag- és vízellátás hatása a szálkásperje nyersfehérje- és ásványianyag-tartalmára. Doktori értekezés, Debrecen
- Liebig, J. v. (1879): Die Chemie in ihrer Anwendung auf Agricultur und Physiologie. Neunte Auflage. Druck und Verlag Friedrich Vieweg und Sohn, Braunschweig.
- Loch J. – Nosticzius Á. (1992): Agrokémia és növényvédelmi kémia. Mezőgazda Kiadó, Budapest
- Mengel, K. (1972): Ernährung und Stoffwechsel der Pflanze. VEB Gustav Fischer Verlag, Jena

The research work was financially supported by the “Hungarian Scientific Research Fund” (OTKA T 032343)

THE EFFECT OF FOLIAR FERTILIZATION WITH FUNGICIDES ON SUGAR BEET (*BETA VULGARIS L.*)

L. Ruzsányi † and L. Varga

University of Debrecen, Centre of Agricultural Sciences
Department of Crop Production and Applied Ecology

Introduction

Sugarbeet is considered to be a valuable crop and plays an important role in the crop rotation where it is grown. (*Vierling, Zeddies, 1996*)

Sucrose concentration and the ratio of sucrose to total soluble solids (sucrose plus impurities) determine the processing quality of sugarbeet. Among the more important impurity components are sodium, potassium, and amino- nitrogen. Almost any cultural practice may affect the quality of the crop.

The foliar application of amino acids, seaweeds, and biostimulants has proved to be effective in attenuating crop stress resulting from soil subsidence, a lack or excess of water, low temperatures and other weather conditions. Several years experimentation indicates a 12-15% improvement in sugar production in Northern Italy and a 15-18% in Central Italy. (*Tugnoli, Bettini, 2003*)

Barlog, Grzebisz (2001) studied the effect of foliar magnesium application on the yield and quality of sugar beet roots. The 8(th) leaf stage appeared to be the most critical stage of sugar beet growth with respect to magnesium foliar application. The application of 0.5 kg Mg ha⁻¹ increased the yield of roots by 9.9% and the yield of white sugar increased by 9.5%. Technological parameters of sugar beet roots were not significantly affected by the treatments.

The application of Epsom salt as a foliar treatment increased sucrose concentration by 0.25, 0.20 and 0.26% in growing seasons 1995, 1996 and 1997, respectively. (*Kristek et al., 2000*)

Strobilurins are one of the most important classes of agricultural fungicides. First launched in 1996, the strobilurins now include the world's biggest selling fungicide. (*Bartlett et al., 2002*)

Kresoxim-methyl or azoxystrobin induce severe physiological changes in field wheat plants. In combination, they seem to enable plants for better adaptation to the environment. In most cases, this leads to an average yield increase up to 5-10%. (*Habermeyer et al., 1998*)

Plants treated with Juwel (kresoxym-methyl and epoxiconazole) are greener, more vigorous and produce significantly more yield and better quality. (*Ruzsányi, 2001*)

Strobilurins give large yield responses in 1999, over and above those achieved by triazoles alone although responses were lower than in previous years. (Clark, Jones, 1999)

The results suggest that the fungicide-induced delay of senescence is due to an enhanced antioxidative potential protecting the plants from harmful active oxygen species. (Xuan Wu, Tiedmann, 2001)

The effects of the fungicides azoxystrobin (a strobilurin) and epoxiconazole (a sterol biosynthesis inhibitor) were studied in winter wheat. Treatments with each of the two fungicides prolonged green leaf area retention and increased yield compared with untreated control plots. Azoxystrobin maintained green leaf area for longer than epoxiconazole. (Bertelsen et al., 2001)

Using leaf discs and intact wheat plants (*Triticum aestivum* L.), the physiological effects of the strobilurin-type fungicide kresoxim-methyl were studied. Kresoxim-methyl shifted the hormonal balance, favouring cytokinins particularly of the dihydrozeatin riboside-type, as opposed to ethylene and its biosynthetic precursor 1-aminocyclopropane-1-carboxylic acid (ACC). This was closely correlated with delayed leaf senescence. (Grossmann et al., 1999)

Apart from its fungicidal effect, the strobilurin kresoxim-methyl (BAS 490 F) was found to induce physiological and developmental alterations in wheat (*Triticum aestivum* L.) which are seen in connection with improved yield. The inhibition of ethylene biosynthesis by kresoxim-methyl, together with an increase in endogenous cytokinins could explain the retardation of senescence and the intensified green leaf pigmentation in wheat exposed to this strobilurin. (Grossmann, Retzlaff, 1997)

In our experiment we examined the effect of fungicides with strobilurin active ingredients and potassium, magnesium combined with fungicides on sugar beet.

Methods

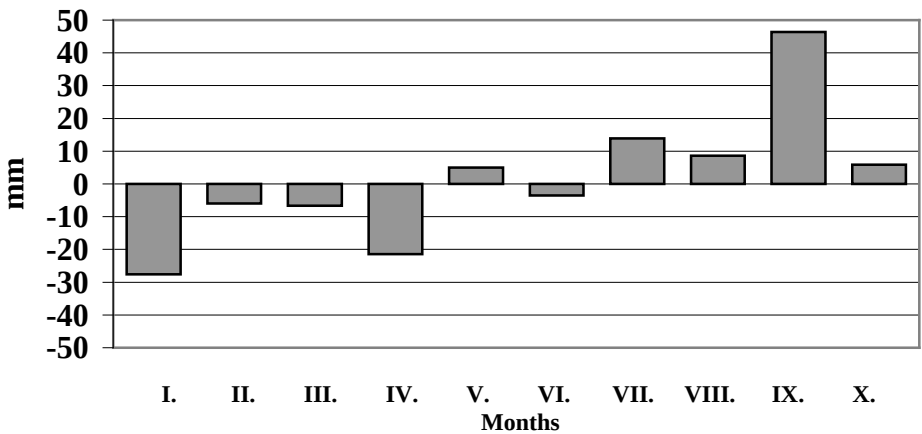
Our small-plot experiment in randomised blocks in four replications was set up in Hajdúböszörmény in 2002 on chernozem soil. Soil characteristics are shown in Table 1.

Table 1: Soil characteristics of the experiment field

pH (KCl)	pH (H2O)	Soil plasticity value (K _A)	Humus %	P ₂ O ₅ mg kg ⁻¹	K ₂ O mg kg ⁻¹
6.9	7.3	42	3.7	243	275

The precipitation of the vegetation period (March-October) was 48.2 mm higher than the average of 30 years (409.1 mm). In March, June and July the precipitation was lower than the average. In July it was only half of and in September it was two times higher than the average amount of rain. *Figure 1.*

Figure 1: Difference between precipitation in 2002 and the average of 30 years



The studied sugarbeet variety was Delphin. Depth of the fall ploughing was 0.35 m, the fore crop was winter wheat.

Ten foliar treatments were applied in four replications. Plot size was 15 m × 2.7 m.

We examined the effect of two fungicides with strobilurin active ingredients (Juwel, 1 l ha⁻¹, Sfera , 0.75 l ha⁻¹), potassium (KCl, 20 kg ha⁻¹) and magnesium (MgSO₄, 10 kg ha⁻¹) sprayed with 450 l ha⁻¹ water. The application was performed by hand. The treatments and dates are in *Table 2.*

Table 2: Treatments and application dates

Treatments	Application dates	
	5th July	1st August
1. Control	+	+
2. Tango 1 l ha ⁻¹ (<i>epoxiconazole</i> + <i>tridemorph</i>)	+	+
3. Juwel 1 l ha ⁻¹ (<i>epoxiconazole</i> + <i>kresoxim-methyl</i>)	+	+
4. Sfera 0.75 l ha ⁻¹ (<i>trifloxystrobin</i> + <i>cyproconazole</i>)	+	+
5. Juwel + magnesium sulphate 10 kg ha ⁻¹ (<i>MgSO₄ 7H₂O</i>)	+	+
6. Sfera + magnesium sulphate	+	+
7. Juwel + potassium chloride 20 kg ha ⁻¹ (<i>KCl</i>)	+	+
8. Sfera + potassium chloride	+	+
9. Juwel + potassium chloride + magnesium sulphate	+	+
10. Sfera + potassium chloride + magnesium sulphate	+	+

The manual harvest of sugar beet started on 28th October. We determined the weight of root in the field. Qualitative parameters (sugar content, Na, K and alpha-amino N) of the root samples were analysed after harvest in the laboratory of the Szerencsi Sugar Factory Inc..

In the vegetation period, we collected leaf samples four times. Element, chlorophyll, and NO₃ contents were analysed in the Department of Food Processing and Quality Testing.

Results and discussion

We measured the lowest beet yield on the control blocks. There were no significant differences between strobilurin and nutrient combinations.

The gross and net sugar yield were the lowest on the control plots. The sugar yield on the standard control was higher, but there was no significant difference compared to the control. The increase in sugar yield on the plots treated with stobilurins was significantly higher than on the control. There were no great differences between treatments by fungicides combined with nutrients. Value of LSD_{5%} of gross sugar yield was 4.8, and the value of LSD_{5%} of net sugar yield was 4.2. *Figure 2., Figure 3.*

The most efficient treatment was the application of Juwel combined with potassium (Gross sugar yield: 51.2 kg plot⁻¹, Net sugar yield: 43.1 kg plot⁻¹). Differences between treatments were significant at 0.5% significance level.

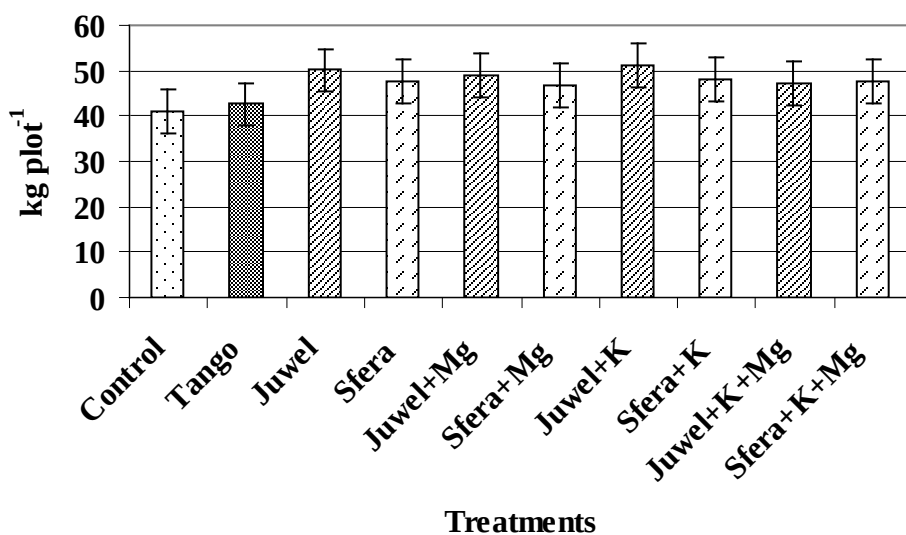


Figure 2: Gross sugar yield in different treatments

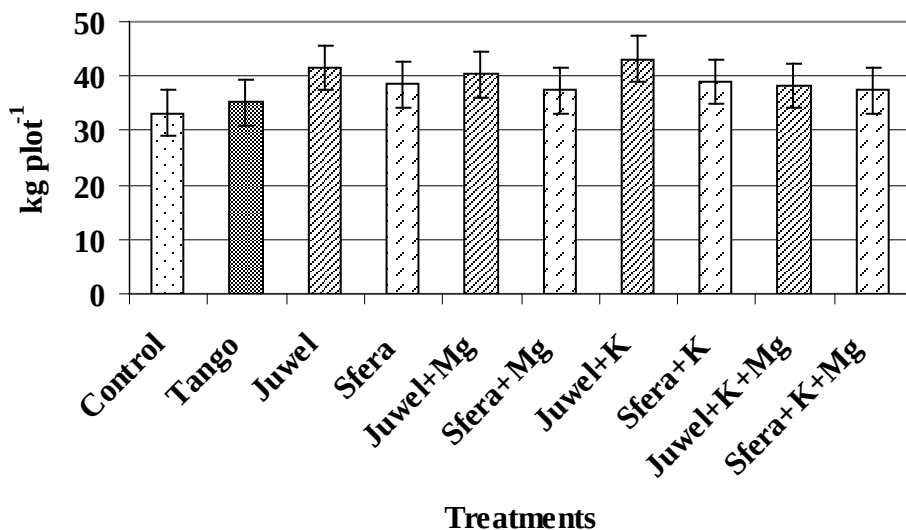


Figure 3: Net sugar yield in different treatments

We can draw the conclusion that the foliar treatments with bioactive fungicides influenced the yield and quality parameters in this field experiment. Foliar fertilization with the fungicide containing kresoxim methyl increased the sugar yield most effectively.

Treatments with kresoxym methyl decreased the NO₃ content of leaves significantly. *Figure 4.*

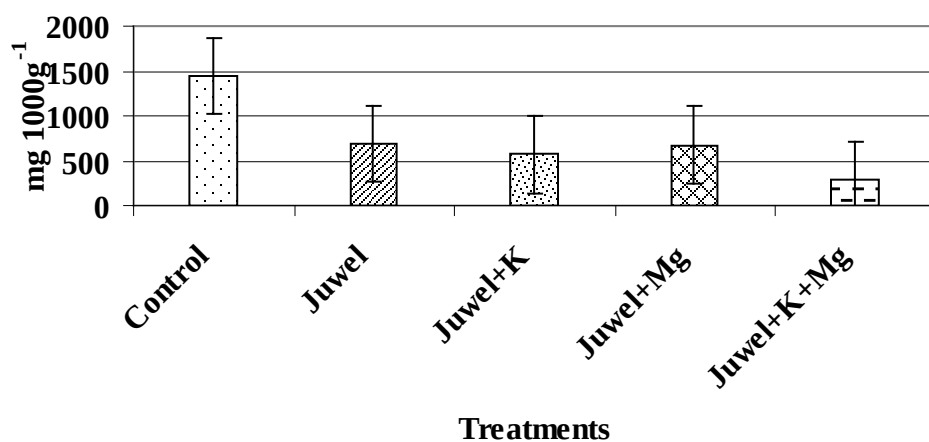


Figure 4: Nitrate content of the leaf samples at harvest time

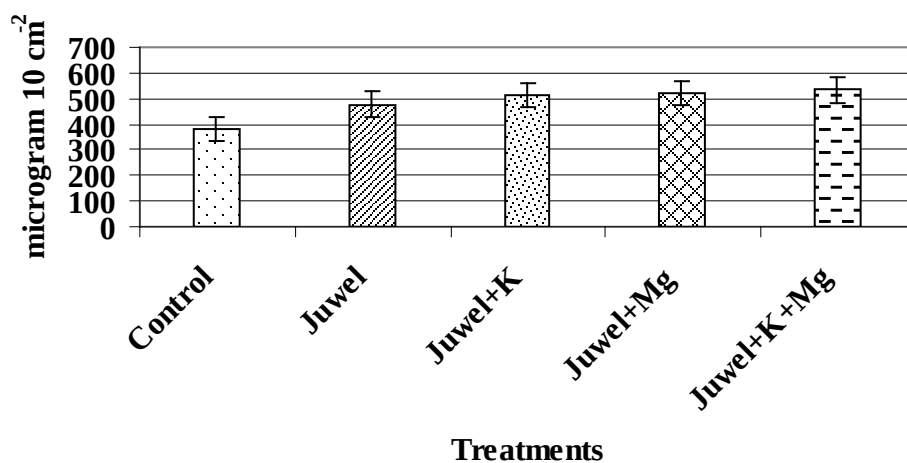


Figure 5.: Chlorophyll content of the leaf samples at harvest time

The result of the leaf analysis shows that the chlorophyll content was significantly higher on the treated blocks than on the control. The highest chlorophyll content was measured on the blocks treated with potassium, magnesium combined with Juwel (534.5 microgram 10cm⁻²). *Figure 5.*

References

- Barlog P., Grzebisz W. (2001): Effect of magnesium foliar application on the yield and quality of sugar beet roots. ROSTLINNA VYROBA 47 (9): 418-422.p.
- Bartlett D.W., Clough J.M., Godwin J.R., Hall A.A., Hamer M., Parr-Dobrzanski B. (2002): The strobilurin fungicides. PEST MANAGEMENT SCIENCE 58 (7): 647-662.p.
- Bertelsen J.R., Neergaard E., Smedegaard-Petersen V. (2001): Fungicidal effects of azoxystrobin and epoxiconazole on phyllosphere fungi, senescence and yield of winter wheat. PLANT PATHOLOGY 50 (2): 190-205.p.
- Clark B., Jones D. (1999): Strobilurin fungicides, <http://www.hgca.com/articles/documents/R99Paper03.doc>
- Grossmann K., Kwiatkowski J., Casper G. (1999): Regulation of phytohormone levels, leaf senescence and transpiration by the strobilurin kresoxim-methyl in wheat (*Triticum aestivum*). JOURNAL OF PLANT PHYSIOLOGY 154 (5-6): 805-808.p.
- Grossmann K., Retzlaff G. (1997): Bioregulatory effects of the fungicidal strobilurin kresoxim-methyl in wheat (*Triticum aestivum*). PESTICIDE SCIENCE 50 (1): 11-20.p.
- Habermeyer J., Gerhard M., Zinkernagel V. (1998): The impact of strobilurins on the plant physiology of wheat. 7th International Congress of Plant Pathology, Edinburgh, <http://www.bspp.org.uk/icpp98/5.6/3.html>
- Kristek A., Kovacevic V., Antunovic M. (2000): Response of sugar beet to foliar magnesium fertilization with epsom salt. ROSTLINNA VYROBA 46 (4): 147-152.p.
- Ruzsányi L. (2001): Effect of Juwel on improving yield and quality of sugar beet. GYAKORLATI AGROFÓRUM 12 (7): 56-57.p.
- Tugnoli V., Bettini G. (2003): The use of foliar fertilizer application in sugar beet growing. IIRB-ASSBT congress, San Antonio
<http://www.iirb.org/content/Congress%20pages/Prog%20Agronomy%20poster.pdf>
- Vierlin G., Zeddies J. (1996): Cost of sugar beet production – Comparison of selected EU – regions. ZUCKERIND 121 (8): 635-639.p.
- Wu Y.X., Tiedemann A. (2001): Physiological Effects of azoxystrobin and epoxiconazole on senescence and the oxidative status of wheat. PESTICIDE BIOCHEMISTRY AND PHYSIOLOGY 71 (1)

THE EFFECT OF POTASSIUM FERTILIZATION ON POTATO YIELD QUALITY AND QUANTITY

J. Kruppa and E. Zsom

University of Debrecen, Centre of Agricultural Sciences
Department of Crop Production and Applied Ecology, Hungary

Introduction

The level of the Hungarian potato production is low. In order to maintain at least our domestic market positions – also after the EU admission – we should improve the level of production. To achieve this, quality should be improved besides the enhancement of yield per hectare and simultaneous reduction of the production costs. To attain the above aim a more thorough knowledge on the ecological, biological and production factors influencing potato quality is needed. Growers should prepare to satisfy the demands of processing and packaging requesting higher volume and quality.

The genetically determined maximum yield can only be realized, if the necessary nutrients and water are available and the temperature is optimal during the whole vegetation period according to the plant's requirements. The amount, the ratio of the applied fertilizers, the form of the active agent, the timing and method of application greatly influence the quality and the biological value of tubers besides effecting yield quantity.

Out of the nutrients, N influences primarily the yield quantity, while potash determines quality and inner contents. Plants with good potash supply have a better tolerance to cold. Potato requires a relatively smaller amount of phosphorus compared to other nutrients (TERBE, 2000).

POCSAI (2001) considers the following important to note:

The experiments verified the excellent response of potato to fertilization, however, the effect of variety is stronger than that of fertilization. The preconditions of high yields are the shared N fertilization and the application of proper N doses during the vegetation period. The highest N dose (198 kg/ha) did not influence the yield significantly, but it increased the number of tubers and consequently, changed the distribution of tubers by size.

When choosing the potash fertilizer, it is useful to take into consideration the end use. The sulphate-type potash fertilizers are to be preferred, if the end use requires high starch content (potato for industrial purposes, chips, pommes-frites), because sulphate has a less disadvantageous effect on starch formation than chlorine. From the results of the experiments the following can be concluded:

Potash supply highly influences the quality and quantity of potato yield, potash improves the storage qualities of potato and eliminates blue-spottedness when high doses of potash are applied the decrease in starch content is smaller for sulphate type fertilizers than for chlorides (GLAS et al., 1997).

The colouration in raw state and blue-spottedness are such quality parameters which have a major role at food potato and at tubers to be stored for a longer period before use. The proper potash supply reduces the colouration in raw state. Also, the blue-spottedness is reduced, which can easily develop due to mechanical effects. Several examinations proved that the resistance to blue-spottedness increases with the increasing potash content. When the potash content of tubers is over 2.5 %, such colouration hardly appears (LOCH et al., 1993).

In experiments on acidic sandy soils deficient in Mg between 1996 and 1998 (KRUPPA 1999), the simultaneous application of Ca, K and Mg fertilizers resulted in a significant yield increase. In order to achieve a 25-30 t/ha yield, he suggests the application of a 30% dose of CaCO_3 (1.5 t/ha) directly applied under the forecrop (triticale) or a 60-90% dose of CaCO_3 (3-4.5 t/ha) applied 3-4 years prior to production besides the necessary N and P fertilizers. To obtain the optimum yield on acidic sandy soils deficient in Mg, he suggests the application of 180-200 kg/ha K_2O , 45-50 kg/ha Mg. As a result of the Ca, K and Mg treatments the proportion of food potato (45 mm <) increased while the disadvantageous colouration of the tubers decreased. The combined applications of Ca, K and Mg fertilizers gave the best results both in quality and quantity.

Potato is extremely sensitive to Mg-deficiency. With Mg fertilization (80-90 kg/ha crystal magnesium-sulphate) a 20-25 % yield increase can be achieved (BOCZ, 1996). Since potato is usually grown on loose soils deficient in Mg, it is advisable to apply 30 kg/ha Mg on these areas. If there is a lack of Mg, the dry matter and starch contents will decrease (LOCH et al., 1993).

With the application of 160-240 kg K a 10-35% yield increase could be achieved and from the application of 80-120 kg Mg a further increase of 10-20% could be expected. The form of the used potash (chloride or sulphate) did not influence the yield significantly. The K fertilization increased the tuber size. The tubers from the parcels with high applied dosage (240 kg/ha agent) were the least coloured (when raw). With the application of both elements, the yield can be increased economically and the quality will also improve (KRUPPA et al., 1997).

Material and Methods

The aim of the study was to determine the optimum amount and form of K fertilizer to be applied under the agro-ecological conditions of the Nyírség (Tornyospálca) on the basis of the experiments' results.

K fertilization experiment in 2000

In the experiment, there were 10 treatments in 4 replications on 50 m² plots. The test variety was Desirée.

The experiment was set up on brown forest soil with alternating thin layers of clay substance characteristic to the Nyírség region.

Soil characteristics:

Soil type:	brown forest soil with alternating thin layers of clay substance		
Physical type:	sand		
pH (H ₂ O)		4,1	
pH (KCl)		3,9	
K _A		29	
Humus		0,47	
P ₂ O ₅ mg/kg		145	
K ₂ O mg/kg		220	
AL-Mg mg/kg		177	
AL-Ca mg/kg		629	

In the experiment several amounts and forms of potash fertilizers were applied. The applied amounts of fertilizers are shown in Table 1 and Table 2.

Table 1: Doses of N and P fertilizers per hectare

Active ingredient	The amount of active ingredient per ha in kg	Fertilizer	The amount of fertilizer per ha in kg
N	150	Ammonium-nitrate 34%	450
P ₂ O ₅	90	Szuperfoszfát 18 %	500

Table 2: Doses of K and Mg fertilizers per plot and per hectare

treatment number	K ₂ O active ingredient		Fertilizer: Potash-sulphate (50%)		K ₂ O active ingredient		Fertilizer: Potash-chloride (60%)		K ₂ O active ingredient		Fertilizer: Patent káli (30+10%)		Mg active ingredient	
	kg/ha	kg/50m ²	kg/ha	kg/50m ²	kg/ha	kg/50m ²	kg/ha	kg/50m ²	kg/ha	kg/50m ²	kg/ha	kg/50m ²	kg/ha	kg/50m ²
1	0	0	0	0	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	80	0.4	133	0.66	-	-	-	-	-	-
3	-	-	-	-	160	0.8	266	1.32	-	-	-	-	-	-
4	-	-	-	-	240	1.2	399	1.98	-	-	-	-	-	-
5	80	0.4	160	0.8	-	-	-	-	-	-	-	-	-	-
6	160	0.8	320	1.6	-	-	-	-	-	-	-	-	-	-
7	240	1.2	480	2.4	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	80	0.4	267	1.33	26.7	0.13
9	-	-	-	-	-	-	-	-	160	0.8	534	2.66	53.4	0.26
10	-	-	-	-	-	-	-	-	240	1.2	801	3.99	80.1	0.39

Potash fertilization experiment in 2001

The experiment was set up on brown forest soil also characteristic to the Nyírség region with 10 treatments in 4 replications on 50 m² plots, applying the same K treatments as in 2000 (Table 2). The applied variety was Kondor.

Soil characteristics:

Soil type:	brown forest soil
Physical type:	sandy loam
pH (H ₂ O)	5,82
pH (KCl)	5,09
K _A	34
Humusz	1,07
P ₂ O ₅ mg/kg	160
K ₂ O mg/kg	210
Mg mg/kg	92

Table 3: Doses of N and P fertilizers per hectare

Active ingredient	The amount of active ingredient per ha in kg	Fertilizer	The amount of fertilizer per ha in kg
N	204	Ammonium nitrate 34%	600
P ₂ O ₅	108	Szuperfoszfát 18 %	600

Results and Discussion

The results of the experiment in 2000

The per hectare yields of the treatments calculated on the basis of the experimental plots' results are shown in Table 4.

The colouration of the tubers in the plots in raw state and after cooking is shown in Table 5.

The colouration of potato was the smallest in the potash-sulphate treatment of high dosage (treatment 7) and in treatments with Patentkáli, consequently, quality was better in these treatments.

The highest yields were obtained in treatment 7 (potash-sulphate, 240 kg/ha potash), treatment 10 (Patentkáli, 240 kg/ha K₂O) and treatment 4 (potash-chloride, 240 kg/ha K₂O). The best results for food potato were in the same treatments and in treatment 9 (potash-sulphate, 160 kg/ha K₂O).

Table 4: The per hectare yields of the treatments calculated on the basis of the experimental plots' results

Treatment	Yield (t/ha)
1. Control	15.3
2. KCL 80 kg/ha	16.15
3. KCL 160 kg/ha	16.95
4. KCL 240 kg/ha	18.43
5. K ₂ SO ₄ 80 kg/ha	16.25
6. K ₂ SO ₄ 160 kg/ha	17.88
7. K ₂ SO ₄ 240 kg/ha	20.20
8. Patentkáli 80 kg/ha	16.73
9. Patentkáli 160 kg/ha	18.58
10. Patentkáli 240 kg/ha	19.90
SD 5%	1.022

Table 5: The effect of K and Mg on the colouration of the tubers in the plots in raw state and after cooking

Treatment	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Colouration in raw state (%)	20	20	30	10	15	10	5	5	5	5
Colouration after cooking (%)	10	10	10	0	0	0	0	0	0	0

Results of the experiment in 2001

Yields and colouration of tubers are shown in Table 7.

Table 6: The per hectare yields of the treatments calculated on the basis of the experimental plots' results

Treatment	Yield (t/ha)
1. Control	42.4
2. KCL 80 kg/ha	44.1
3. KCL 160 kg/ha	45.4
4. KCL 240 kg/ha	47.3
5. K ₂ SO ₄ 80 kg/ha	46.3
6. K ₂ SO ₄ 160 kg/ha	49.7
7. K ₂ SO ₄ 240 kg/ha	52.4
8. Patentkáli 80 kg/ha	50.3
9. Patentkáli 160 kg/ha	51.5
10. Patentkáli 240 kg/ha	55.3
SD 5%	1.821

Table 7: The effect of K and Mg on the colouration of the tubers in the plots in raw state and after cooking

Treatment	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Colouration in raw state (%)	40	30	30	20	15	10	10	10	10	5
Colouration after cooking (%)	20	20	15	10	5	0	0	5	0	0

In 2001, the following statements can be made:

- The year was favourable for potato, irrigation was not necessary. The highest yield – significantly higher compared to the control and other treatments- was obtained in treatment 10 (240 kg/ha Patentkáli).
- Yield of treatment 10 (240 kg/ha Patentkáli) was significantly higher than the second highest yield of treatment 7 (240 kg/ha potash-sulphate) and that of treatment 4 (240 kg/ha potash-chloride)
- All the treatments significantly increased the yield of potato except for treatment 2 (80 kg/ha KCl)
- The yield of tubers over 55 mm diameter was the highest in treatments 10 and 7. The distribution of tubers by size- the ratio of small tubers- was the worst for treatments 1 and 2.
- The colouration of potato was the smallest in treatments with 240 kg/ha Patentkáli, consequently, the best quality was also obtained in these. No greying after cooking was detectable at treatments 6, 7 and 9 either.
- The dry matter content of yield reduced to a greater extent in treatments with potash-chloride (treatment 3 and 4) compared to the control than in treatments with potash-sulphate and Patentkáli.

Summary

The potash fertilization experiments of 2000 and 2001 presented in this paper were carried out on acidic sandy soils in the Nyírség (Tornyospálca). In these years, the effect of 3 types of

potash fertilizers (potash chloride, sulphate of potash and Patentkáli) were examined in three different doses (80, 160 and 240 kg/ha K₂O) on 50 m² plots in 4 replications. Nitrogen and phosphorus controls were also set up.

On the basis of the experiments and examinations carried out, it can be stated that under conditions peculiar to the Nyírség – on acidic sandy soils – the biggest and highest quality yields can be achieved by the application of 800 kg/ha Patentkáli (240 kg/ha K₂O + 80 kg/ha Mg). Yields of high amount and good quality can also be achieved by the application of sulphate of potash with 240 kg/ha active ingredient. A high dose of potassium chloride (240 kg/ha) also increases the amount of yield with a similar amount as the previous fertilizers, however, the quality of the tubers is lower (due to colouration). By increasing potash supply, tuber size will increase and a better proportion of food potato can be obtained.

References

- BOCZ, E.: 1996. Burgonya in: BOCZ et al. (szerk.): Szántóföldi növénytermesztés. Mezőgazda kiadó, Budapest 574-611.
- GLAS K. – ORLOVIUS K. – TERBE I. - FODOR Z., 1997: A termésmennyiség, a termés minőség, valamint a kálium műtrágyázás összefüggése a burgonyatermesztésben. Új Kertgazdaság. 1. 82-86.
- KRUPPA, J. – I-NÉ TÓTH, J. – SZÜCS, L. – SIPOS, T. – BORUS, J. – BAGOLY, I., 1997: A nyírségi burgonyatermesztés gyakorlati kézikönyve. Budapest. USAID ACDI/VOCA 85.
- KRUPPA, J., 1999: A burgonya K-, Ca- és Mg-trágyázása savanyú humuszos homoktalajon. Mag Kutatás, Termesztés, Kereskedelem. (12) 2. 20-23.
- LOCH, J. – PETHÓ, F. – VÁGÓ, I. – KASPAR, G. – ANDRES, E., 1993: Burgonya in ANDRES, E. (szerk.): Kálium termésbiztonság és jó minőség. International Potash Institute Research Topics 15 25-26.
- POCSAI, K., 2001: A burgonya tápanyag és vízgazdálkodása. Burgonyatermesztés. 1.. 17-22.
- TERBE, J., 2000: A hajtott burgonya trágyázása. Burgonyatermesztés. 4. 39-40.

THE EFFECT OF THE MINERAL FERTILISERS ON THE WATER USE EFFICIENCY OF MAIZE (ZEA MAYS) AT THE EXPERIMENTAL STATION OF LÁTÓKÉP

M. Piskolczi¹, A. Dobos² and J. Nagy³

University of Debrecen, Centre of Agricultural Sciences, Faculty of Agriculture

¹Agrometeorological Observatory

²Department of Land Use and Rural Development, H-4032 Debrecen Böszörményi str. 138

Abstract

We have examined the effect of different quantities of mineral fertilizers on water consumption of maize hybrids in an arable land experiment at the Experimental Station of Látókép on an unirrigated split-plot research site. Since water is primarily the most important limiting factor in the growing season, one of the main aims of plant production is to increase the extent of water utilization with appropriate fertilizer doses, thus ensuring high grain yield in years of shifting precipitation conditions. The experiment lasted two years (1998, 1999), in the course of which, we have examined two hybrids on split-plots (DK 477 –FAO 430; MV 484 – FAO 450). The water use efficiency was calculated on the basis of the correlation suggested by Szász (1998). According to this $q=Y/(\Sigma P+\delta R)$, where q is the water use efficiency (kg mm^{-1}) which expresses how much main product is formed as a result of precipitation unit, Y is the useful product of maize (kg ha^{-1}), ΣP is the sum of precipitation (mm) during growing season, δR is the decrease of accessible water in the root zone during growing season, which can be estimated around 50 mm on average.

The fertilizer doses between $0\text{--}120 \text{ kg ha}^{-1}$ have increased the water use efficiency. However, the 150 kg ha^{-1} dose had a decreasing effect. The only exception was the MV 484 hybrid, where 120 kg ha^{-1} has already decreased efficiency. In the percentage of the control it can be seen that fertilization can even increase water utilization by one and a half to twofold. Its maximum value with the DK 477 hybrid in 1998 was $26,7 \text{ kg mm}^{-1}$, $32,2 \text{ kg mm}^{-1}$ in 1999, with the MV 484 hybrid in 1998 was $20,6 \text{ kg mm}^{-1}$, and in 1999 was $29,2 \text{ kg mm}^{-1}$.

Introduction

From the ecological factors the water supply of cultivated plants strongly affects the quantitative and qualitative characteristics of yield. According to Debreczeni and Debreczeniné (1994), supposing and optimal nutrient supply, in the future water supply can primarily become a yield limiting factor. According to the results of national long-term experiments the yield levels of maize depend not only on the water supply of growing season but also on the cumulative water supply of previous years. The wheat and maize long-term experiments of the NLTE (National Long-Term Experiment) point out that the yield result of maize shows strong correlation primarily with the amount of precipitation in June and July of the growing season in a specific year. According to Berényi (1951), the yield of cultivated plants is primarily determined by precipitation, thermic effects counteract or enhance the effect of these. Antal (1981) points out, that primarily precipitation (soil moisture) and soil temperature namely the

temperature and water retaining system of the soil controls the solution, flow and consumption of nutrients of the applied fertilizers and manure. Olson (1973) has observed, that with appropriate fertilisation water utilization can be more favourable but fertilization does not increase water supply. Ruzsányi (1974) concluded a similar result, according to this, nutrient supply significantly modifies the limits of water needs. With harmonious nutrient supply or fertilization the drought tolerance of plants can be increased or the unfavourable effect of drought can be eased (Debreczeni-Debreczeniné 1983). Great deviation from optimal water supply limits the nutrient uptake of plants and other important physiological functions. Antal (1974) establishes, that the water need of maize is about 30-40% higher in the warm and dry growing season, than in the cold and rainy vegetative season. In further examinations he concluded, that a 7-10°C increase in air temperature results a 50-80% change in the water consumption of maize stocks from one day to another. The increase of fertilizer doses results in an increased water need and water consumption, but after a certain limit, neither fertilizer nor irrigation increase resulted in an economic production of yield results (Antal et al. 1975). The most frequent cause of yield decrease is that the conditions of plant nutrition deteriorate due to lack of moisture (drought) or even due to excessive moisture in the soil layers. In dry periods however, fertilization can even be harmful if the water consumption of the plant is not in accordance with the available moisture supply or the concentration of soil solutes causes damage (Debreczeni and Debreczeniné 1994). In different years, even in similar soil conditions the yield increasing or decreasing effect of fertilization can be different. This is exactly why in certain regional districts, in accordance with the weather system of years with optimal heat- and precipitation supply, the quantity of economically applied fertilizer quantity is determined (Bocz 1976). By satisfying the optimal nutrient needs of plants, the water utilization of plants can be multiplied thus producing greater grain yield (Bocz-Szász 1962; Bocz 1962).

The damaging of environment can be avoided if we apply optimal fertilizer doses on a specific area in accordance with the environment and cultivated plant. The quantity of fertilizer utilized by the plant depends on temperature, the nitrogen absorption capacity of the plant, the nitrogen content of the soil, the frequency and time of application and the type of fertilizer (Cartagena et al. 1995).

The aim of our investigation was to determine an optimum, combined fertilizer quantity in the case of the two hybrids, in accordance with the local climatic conditions – with two year; micro-plot, fertilizer treatment experiments, that maximizes the utilization of water.

Materials and Methods

The experiment was set up by the Center for Agricultural Sciences of Debrecen University (Debrecen, Hungary) in cooperation with KITE of Nádudvar in 1978 at the Experimental Station at Látókép (21°35'W, 47°35'N). The experiment was set up in split-plot with four repetitions, the main plot (120m²), the fertilizer treatment (N:P:K – 1 : 0,75 : 0,88), the subplots (15 m²) served the purposes of maize hybrid examinations (80 thousand plants ha⁻¹). Sowing was carried out with a few days of difference (April 29. 1998.; April 25.), but the collection of grain yield happened in identical times. Data regarding daily values of precipitation and temperature were recorded by an automatic weather station (Table 1.), which is about 600 m far from the experiment. No irrigation was applied on the examined split plots, so when calculating water utilization we only considered water quantity from precipitation in the experiment.

Table 1: Monthly values of meteorological elements during growing season in 1998 and 1999

	Maximum daily temperature (°C)	Minimum Daily temperature (°C)	Average temperature (°C)	Average Rainfall (mm)	Solar Radiation (MJm ⁻² per day)
1998					
April	19,1	6,8	13,0	87,7	16,1
May	20,7	10,7	15,7	85,8	20,3
June	25,4	15,2	20,3	66,5	22,5
July	25,9	15,8	20,8	100,2	22,0
August	26,6	14,7	20,7	34,0	21,6
September	19,7	17,7	16,7	95,2	13,7
October	15,7	8,3	12,0	42,6	7,9
	21,9	11,9	16,9	512,0	17,6
1999					
April	18,0	7,4	12,7	68,8	16,8
May	20,9	10,6	15,8	56,8	22,4
June	25,7	15,4	20,5	114,6	24,0
July	27,5	17,3	22,4	82,5	24,1
August	25,2	14,5	19,9	29,6	20,8
September	24,9	13,3	19,1	31,4	17,0
October	15,4	6,6	11,0	14,3	10,1
	22,5	12,2	17,3	397,2	19,3

The Experimental Station can be found at the loess soil of the Hajdúság, on lowland chernozem soil with lime deposits and deep humus layer. Its physical soil characteristic is medium bound loam. Groundwater level is at 5-8 meters deep. The most important physical and chemical characteristics of the experimental area are collected in Table 2. and 3.

The total nitrogen content of the soil is 0,15% which corresponds with medium supply level. The AL-soluble P_2O_5 content of the cultivated layer shows significant heterogeneity, on the basis of AL-soluble K_2O content (240 ppm) can be classified as well supplied.

The applied combined fertilizer (N:P:K – 1 : 0,75 : 0,88) considering the control increased by 30 kg ha⁻¹, until the sixth plot, where 150 kg ha⁻¹ was the maximum dose.

Table 2: The most important physical characteristics of soil at the experimental area

Depth	Area where silt can be drained off	Fixation coefficient by Arany	Hygroscopicity	Volume -weight	Pore-volume	Minimal water capacity	Non-available
Cm	Li%	KA	Hy	g/cm3	P%	VK mintf%	HV tf%
0-20	56,8	42	2,25	1,41	46,7	33,7	12,69
20-40	58,6	43	2,25	1,43	46	31,1	12,87
40-60	57,1	43	2,13	1,31	50,5	29,1	11,16
60-80	57,5	44	2,51	1,29	51,3	28,6	12,51
80-100	58,6	48	2,07	1,30	50,9	29,1	10,76
100-120	54,1	47	2,18	1,24	53,3	27,4	10,81
120-140	55,3	46	1,91	1,24	53,3	27,8	9,47

Table 3: The most important chemical characteristics of soil at the experimental area

Depth			CaCO ₃	Humus	Total.N	AL-soluble	
Cm	H ₂ O	KCL	%	%	%	P ₂ O ₅	K ₂ O
0-20	7,3	5,6	0	2,72	0,150	133,4	240
20-40	7,2	5,4	0	2,31	0,120	48,0	173,6
40-60	7,2	5,8	0	1,68	0,100	40,4	123,0
60-80	8,0	7,2	1,1	1,02	0,086	32,4	96,5
80-100	8,4	7,5	11,64	0,81	0,083	39,8	93,6
100-120	8,4	7,5	10,63	-	-	40,6	86,1
120-140	8,4	7,5	7,5	-	-	31,6	78,0

Estimation of water utilization

The water utilization coefficient was calculated on the basis of the correlation suggested by Szász (1998), where q is the water utilization coefficient (kg mm^{-1}) which expresses how much main product is formed as a result of precipitation unit, Y is the useful product of maize (kg ha^{-1}), ΣP is the sum of precipitation (mm) during growing season, δR is the decrease of accessible water in the root zone during growing season, which can be estimated around 50 mm on average.

Results

Relationship of grain yield and fertilization

On the basis of yield averages it can be established, that in the case of DK 477 hybrid, 1998 was a year with better yield than that of 1999. We have only experienced smaller yield in the case of 150 kg ha^{-1} . Increased fertilizer doses resulted increased yields, until the dose of 120 kg ha^{-1} , however the dose of 150 kg ha^{-1} caused yield decrease in both years. In the case of MK 484 hybrid, the year of 1999 proved to be better regarding yield. The 150 kg ha^{-1} fertilizer dose caused a yield decrease for this hybrid too, even more, in 1999 the 120 kg ha^{-1} dose also resulted in yield decrease. It has to be mentioned that the 150 kg ha^{-1} fertilizer dose still resulted a higher yield than that of the control, but on the basis of yield levels the 120 kg ha^{-1} dose can be considered as optimal. (Table 4., Figure 1.)

The values of correlation coefficients between yield and the applied fertilizer doses were only insignificant at 5% probability level in 1999, in the case of MV 484 hybrid. In the other cases the correlation was significant. (Table 5.)

During the statistical examination of the split-plot experiment (Sváb 1973) we have established the common square-deviance sums, the mean square-deviance and from the latter the values of $SD_{5\%}$ (significant difference). On the basis of calculations it can be established, that the difference in yields due to any two fertilizer doses is $1,45 \text{ t ha}^{-1}$ in the average of strains. The difference between the two strains, in the average of yield formed by fertilizer doses is $0,84 \text{ t ha}^{-1}$. The difference between the two strains, with identical fertilizer doses is $2,05 \text{ t ha}^{-1}$. While the difference between any two combinations in which, yield due to both strain and fertilizer doses differs is $2,05 \text{ t ha}^{-1}$. (Table 6., 7., 8.)

Table 4: The yield averages of the examined years in the function of fertilizer doses

	1998	1998	1999	1999
	DK 477	MV 484	DK 477	MV 484
	(t ha ⁻¹)	(t ha ⁻¹)	(t ha ⁻¹)	(t ha ⁻¹)
1. (0 kg ha ⁻¹)	8,1±0,4	6,0±0,6	6,2±1,2	5,4±1,1
2. (30 kg ha ⁻¹)	10,5±0,5	8,1±2,9	9,7±0,4	9,6±1,0
3. (60 kg ha ⁻¹)	11,9±0,7	8,1±2,2	10,2±0,8	11,0±2,4
4. (90 kg ha ⁻¹)	12,5±0,3	9,1±2,2	11,3±0,7	12,7±0,4
5. (120 kg ha ⁻¹)	13,9±0,9	10,7±2,2	13,9±0,9	12,0±0,9
6. (150 kg ha ⁻¹)	12,4±1,3	10,1±3,4	13,7±1,6	10,2±2,7

Table 5: Values of correlation coefficients

	1998	1998	1999	1999
	DK 477	MV 484	DK 477	MV 484
Fertilizer doses				
–				
Grain Yield	0,857	0,934	0,955	0,685

Table 6: Bifactorial variance chart

Factor	SQ	FG	MQ
Total	352,0	47	
Repetition	61,4	3	
Fertilizer dose (A-factor)	133,5	5	26,7
Error (a)	18,0	15	1,2
Strain (B-factor)	100,0	1	100,0
Fertilizer x Strain (AxB)	4,8	5	1,0
Error (b)	34,3	18	1,9

SQ: common difference-sum; FG: degree of independence; MQ: mean squared deviance

Table 7: Difference between fertilizer doses and value of significant difference P=5%

Fertilizer doses	Average yield (t ha ⁻¹)
a ₁ – control	7,01
a ₂ – 30 kg ha ⁻¹	9,28
a ₃ – 60 kg ha ⁻¹	10,01
a ₄ – 90 kg ha ⁻¹	10,76
a ₅ – 120 kg ha ⁻¹	12,26
a ₆ – 150 kg ha ⁻¹	11,26
SZD 5%	1,45

Table 8: Difference between strains and value of significant difference P=5%

Strains	Average yield (t ha ⁻¹)
b ₁ – DK 477	11,53
b ₂ – MV 484	8,67
SZD 5%	0,84

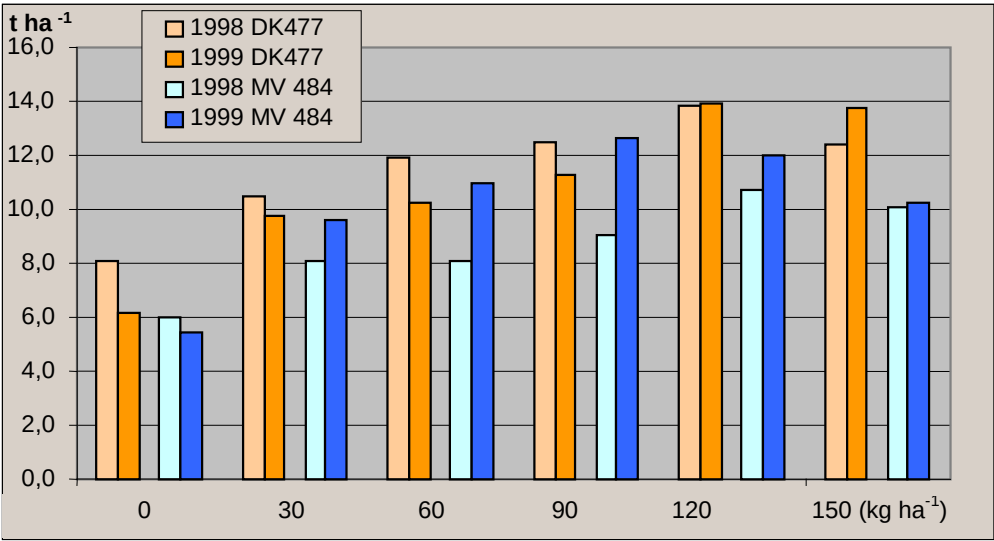


Figure 1: Relationship of yield and fertilization

Weather evaluation of the examined years

Significant difference could be experienced in the quantity and distribution of precipitation during growing season (IV.-IX.) in the examined two years. Since no irrigation have been applied on the experimental area, it was important to determine the distribution of precipitation according to time and regarding quantity. The quantity of precipitation was 469,4 mm in 1998, while in 1999 it was 382,9 mm during the growing season. This means a 86,5 mm difference in precipitation between the two years. Since winter precipitation significantly influences the water supply of the growing season, we have compared the total amount of precipitation from the november of the previous year until march of the examined year.. In 1998 this was 155,7 mm, while in 1999 it was 174,9 mm. This meant 19,2 mm of surplus precipitation in 1999, which can be regarded as insignificant (12% surplus). The effect of winter precipitation thus, is of less importance in the separation of meteorological characteristics regarding the two years than the quantity that fell directly during the growing season. It can also be established, that in 1998 precipitation distributed relatively evenly in the period between April and July (IV: 18,7%; V: 18,3%; VI: 14,2; VII: 21,3%). The same can be said about the year of 1999. The difference in the precipitation distribution during the growing season of the two years meant, that in June of 1998, 66,5 mm while in 1999 114,6 mm precipitation fell. (Table 9., 10., Figure 2., 3.)

The monthly average temperatures did not show great difference in the growing season, in the month of July only 1,6 °C difference occurred.

The value of hydrothermic indexes in 1998 was the highest in April (2,3 mm°C⁻¹), the lowest in August (0,5 mm°C⁻¹). In 1999, the hydrothermic index was the highest in June (1,9 mm°C⁻¹), the lowest was in August (0,5 mm°C⁻¹). (Table 9., 10.)

Table 9: The meteorological characteristics of the growing season in 1998, complemented with the results of November and December in 1997.

		Total monthly precipitation	Average monthly temperature	Hydrothermic index
		(mm)	(°C)	(mm/°C)
1997	XI.	66,4	3,8	
	XII.	62,0	0,7	
1998	I.	17,9	4,7	
	II.	1,2	5,1	
	III.	8,2	5,3	
	IV.	87,7	13,0	2,3
	V.	85,8	15,7	1,8
	VI.	66,5	20,3	1,1
	VII.	100,2	20,8	1,6
	VIII.	34,0	20,7	0,5
	IX.	95,2	15,7	2,0
	X.	42,6	12,0	

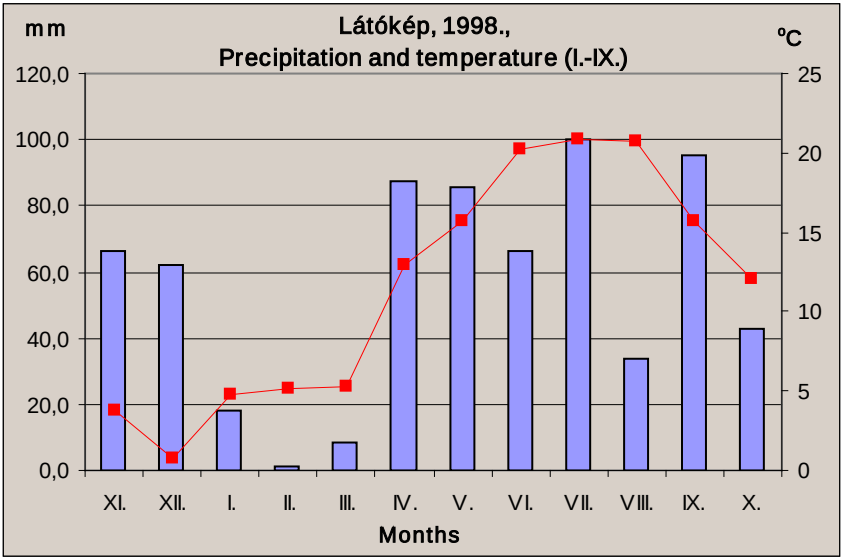


Figure 2: Average monthly precipitation and temperature values, between November 1997. – October 1998

Table 10: The meteorological characteristics of the growing season in 1999, complemented with the results of November and December of 1998.

		Total monthly precipitation	Average monthly temperature	Hydrothermic index
		(mm)	(°C)	(mm/°C)
1998	XI.	62,3	3,8	
	XII.	24,9	-4,6	
1999	I.	9,0	-0,6	
	II.	60,1	-0,5	
	III.	18,6	7,3	
	IV.	68,0	12,7	1,8
	V.	56,8	15,8	1,2
	VI.	114,6	20,5	1,9
	VII.	82,5	22,4	1,2
	VIII.	29,6	19,9	0,5
	IX.	31,4	19,1	0,5
	X.	14,3	11,0	

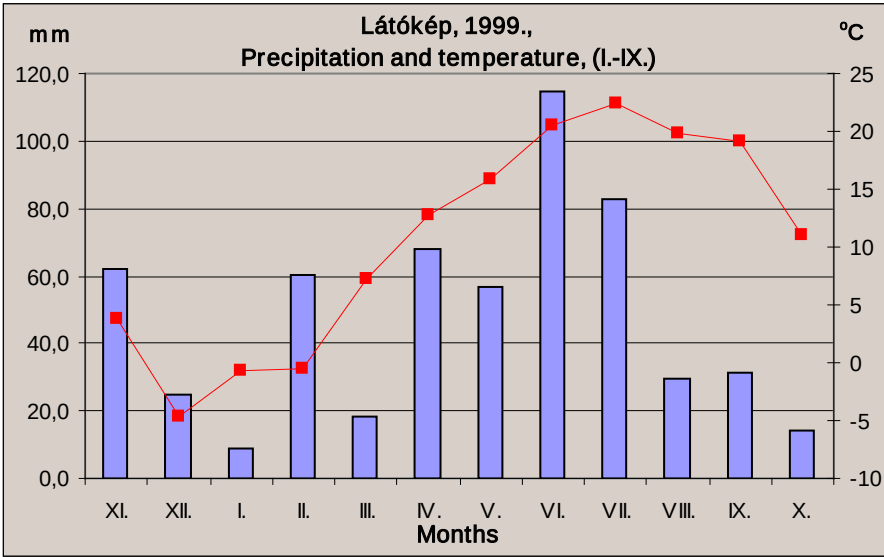


Figure 3: Monthly average values of precipitation and temperature between November 1998. – October 1999.

Water utilization efficiency

The fertilizer doses increased the efficiency of water utilization between 0-120 kg ha⁻¹. The 150 kg ha⁻¹ dosage however, had a decreasing effect. The only exemption was the MV 484 hybrid, in the case of which 120 kg ha⁻¹ has already decreased efficiency. In the percentage of the control it can be seen, that fertilization increased water utilization by even one and a half to two times. Its maximum value was 26,7 kg mm⁻¹ in the case of the DK 477 hybrid in 1998, 32,2 kg mm⁻¹ in 1999, while in the case of the MV 484 hybrid it was 20,6 kg mm⁻¹ in 1998 and 29,2 kg mm⁻¹ in 1999. (Table 11., 12.)

Table 11: The water utilization coefficient of DK 477 and MV 484 hybrids, during the examined two years

WUE (q)	1998	1999	1998	1999
(kg mm ⁻¹)	DK477	DK477	MV 484	MV 484
1. (0 kg ha ⁻¹)	15,5	14,3	11,5	12,5
2. (30 kg ha ⁻¹)	20,2	22,5	15,5	22,3
3. (60 kg ha ⁻¹)	22,9	23,7	15,6	25,3
4. (90 kg ha ⁻¹)	24,0	26,1	17,5	29,2
5. (120 kg ha ⁻¹)	26,7	32,2	20,6	27,7
6. (150 kg ha ⁻¹)	23,8	31,8	19,5	23,7

Table 12: The water utilization coefficient of DK 477 and MV 484 hybrids expressed in the percentage of the control, during the two examined years

WUE (q)	1998	1999	1998	1999
Control %	DK477	DK477	MV 484	MV 484
1. (0 kg ha ⁻¹)	100	100	100	100
2. (30 kg ha ⁻¹)	129,8	157,7	135,0	178,4
3. (60 kg ha ⁻¹)	147,6	166,0	135,9	203,0
4. (90 kg ha ⁻¹)	154,4	183,0	151,8	234,3
5. (120 kg ha ⁻¹)	171,8	225,5	179,2	222,4
6. (150 kg ha ⁻¹)	153,5	122,6	169,4	189,8

Conclusion

- - The 150 kg ha⁻¹ fertilizer dose made it possible to achieve greater yields compared to the control, but the optimal amount, on the basis of yield levels is 120 kg ha⁻¹.
- - The results of bifactorial variance analysis have shown, that the yields of the two maize strains were significantly different with identical fertilizer amounts. This also proves, that the beside years, strains also play an important role in nutrient utilization.
- - Fertilizer doses between 0-120 kg ha⁻¹ increased the efficiency of water utilization. The 150 kg ha⁻¹ dose however, had a decreasing effect.
- - In the percentage of the control it can be seen, that fertilization could increase water utilization by even one and a half to two times.

References

- Antal E. 1981: The effect of weather and climate on the emergence of fertilizer. és az éghajlat Kutatási zárójelentés. OMI
- Antal E. 1998: The relationship of weather and climate with the water cycle of plant stocks. In: Az időjárás és az éghajlat hatása a növény-víz kapcsolatrendszerre. Országos Meteorológiai Szolgálat, Budapest, pp. 15-28.
- Bocz E. 1962: Blueprint on the general conditions of achieving the objectives of 20 years of plant cultivation. Országos Tudományos Tervkészítő Bizottság keretében. DATE, Debrecen.
- Bocz E. 1976: Fertilization guide. Mezőgazdasági Kiadó, Budapest, pp. 257.
- Bocz E., Szász G. 1962: Surveying the significance of high dose fertilization on the soils Hungary. Debreceni Agrártudományi Főiskola, Növénytermesztési Tanszék pp. 17.
- Cartagena, M.C., Vallejo, A., Díez, J.A., Bustos, A., Caballero, R., Roman, R. 1995.: Effect of the type of fertilizer and source of irrigation water on N use in a maize crop. Field Crops Research 44. Elsevier, pp. 33-39.
- Debreczeni B., Bocz E. 1994: Ecological effects and relationship with fertilization. hatások és In: Debreczeni B., Debreczeni Bné (Szerk.) 1994: Trágyázási kutatások 1960-1990. Akadémiai Kiadó, Budapest, pp. 366-399.
- Debreczeni B., Debreczeni Bné 1983: Relationship of nutrients and water supply. és vízellátás Mezőgazdasági Kiadó, Budapest, pp. 265.
- Olson, R.A., Thompson, C., Grabouski, P.H., Stukenholtz, D.D., Frank, K.D., Dreier, A.F., 1964: Water requirement of grain crops as modified by fertiliser use. Agron. J. pp. 56, 427-432.
- Ruzsányi L. 1974: The effect of fertilization on the water consumption and water utilization of specific arable land plant stocks. Növénytermelés 23. pp. 249-259.
- Sváb J. 1973: Biometrical methods in research. Mezőgazdasági Kiadó, Budapest, pp. 167-176.
- Szász G. 1998: The role of natural water supply in the growth of main plants and quantity and quality formation of yield. In: Az időjárás és az éghajlat hatása a növény-víz kapcsolatrendszerre. Országos Meteorológiai Szolgálat, Budapest, pp. 29-45.

FERTILIZING CAPACITY OF FRESH AND COMPOSTED SOLID FRACTION OF SWINE MANURE ON BRASSICA OLERACEA VAR. CAPITATA

R. Moral, J. Moreno-Caselles, M. D. Perez-Murcia, A. Perez-Espinosa, C. Paredes and M. A. Bustamante*

Department of Agrochemistry and Environment, Miguel Hernandez University,
EPS-Orihuela, Ctra Beniel Km 3.2, 03312-Orihuela (Alicante), Spain
Tel: 966749652, Fax: 966749655, E-mail: marian.bustamante@umh.es

Abstract

In this experiment, the effect of fresh and composted solid fraction of swine manure fertilization (FSF and CSF, respectively) on the yield and NPK vegetal extraction of the Milan cabbage plant (*Brassica Oleracea* var. capitata) was compared with the results obtained using a mineral fertilization (MF, equivalent to 300 kg N ha⁻¹). The experiment was conducted in the Segura river valley in the South East of Spain, in a calcareous and clayey-loam soil. The organic wastes used in this study were the fresh and composted solid fraction of swine manure (FSF and CSF, respectively). The organic fertilization was applied to soil in two different rates: I and II, supplying equal amount of N and 50% more of N than in MF, respectively. The fresh mass and dry mass of the marketable part (head) and leaves were determined. NPK extraction from soil to plant was also estimated. The fresh and composted solid fraction of swine manure slurry amendment showed statistically a similar or higher effect on the yield of different parts of the Milan cabbage plant than the mineral fertilizer. Increasing rates of organic fertilizer application only resulted in greater total biomass yield in plots with fresh solid fraction. Organic amendments favored the nutrient extraction by Milan cabbage, especially for K and P.

Introduction

Intensive livestock production generates large amounts of manure that are applied to a limited land area in the proximity to the manure source. The use of swine manure slurry as organic fertilizer represents an economical and widespread method, which can improve the soil properties (Mbagwu et al. 1994) and recycle nutrients in agricultural soils and thus reduce the need of mineral fertilizers (Vasconcelos et al. 1999). The influence of the swine manure slurry on the crop production has been studied in several works. Bernal and Roig (1993) observed substantial increases of plant and fruit production in pepper, tomato and lettuce crops in soils fertilized with 50 m³ ha⁻¹ of slurry. However, slurries could induce high nitrogen losses as nitrate, anoxic conditions in heavy soils, etc. Martinez and Peu (2000) observed in an eight-year experiment of pig slurry application that at least a 25% of applied N remained in soil and another 12,5% was leached as nitrate. The use of the solid phase of the swine manure could be an interesting way to minimize the loss of this nutrient. Maeda et al. (2003) reported that livestock compost could be applied not only to pastures but also to vegetable fields, where fertilization is usually more intensive, due to their consideration of slow-release fertilizer. Nitrogen source, dose and method of application are difficult to optimize. Everaats and De

Moel (1998) observed varying effects for band placement of N fertilizer and no effect for split application on yield and quality of white cabbage. Several researchers (Vasconcelos et al, 1999; Lai and Cheung, 1999) reported increased yield in wheat, radish grown on soils amended with the solid phase of swine slurry. The aim of this experiment was to study the effect of fresh and composted solid fraction of swine manure slurry on the yield of Milan cabbage using different application rates of each waste compared with a mineral fertilization. In addition, concentration of NPK in different vegetal parts was monitored and discussed.

Materials and Methods

The experiment was conducted in the Segura river valley in the South East of Spain at the Research Station of the Miguel Hernandez University. The soil of this area is a Xerofluvent (Soil Survey Staff, 1998) and clayey-loam soil. The organic wastes used in this study were the fresh and composted solid fraction of swine manure slurry (FSF and CSF, respectively) from an experimental swine farm in Lorca (Murcia). In this experiment, the solid fraction of swine manure slurry was separated by screened solid separators. This solid fraction (SF) was composted with straw (S), garden refuse (GR) and swine manure slurry (SMS) (78%SF + 20%S + 2%GR + 0.8 lkg⁻¹ SMS, on a fresh weight basis) by the turned composting system. The characteristics of the soil and organic wastes are given in table 1.

Four treatments, in a completely randomized design with three replicates per treatment, were set up in experimental plots of 16 m² each one, with 0.5 m distance between plots. Fertilizer treatments were: MF, mineral fertilizer (with a complex 16 N-16 P₂O₅-16 K₂O) equivalent to 300 kg N ha⁻¹; FSF and CSF, organic fertilization with fresh and composted solid fraction of swine manure slurry, respectively, and C a control treatment without fertilization. The organic fertilization was applied to soil 14 days prior to plant and in two different rates: supplying equal amount of N and 50% more of N than MF (1 and 2 respectively), while the MF was added the first day. Milan cabbage seedlings of uniform size were selected and thirty-six seedlings were planted in each plot. In order to monitor the plant NPK content, four plants per plot were taken at 40 (1M) and 102 days (2M). The fresh mass and dry mass of different parts of the plants, edible part (head) and leaves were determined. N was determined by a macro-Kjeldahl method. Dried samples were mineralized by microwave acid digestion, using HNO₃/H₂O₂ en ratio 4:1 (v/v) (Moral et al. 1996). P was by measuring the absorbance of the phospho-molybdovanadate complex at 460 nm (Kitson and Mellon, 1944) and K was determined using atomic emission spectrophotometry. Data were analyzed for treatment effects using one-way analysis of variance (ANOVA) and comparison of treatment means was performed by the Tukey test at $P < 0.05$.

Results and Discussion

Yield

The marketable yield (head) and the non-commercial aerial part (leaves) of Milan cabbage affected by the different fertilizing scenarios are shown in figure 1. In general terms, soils amended with organic materials produced a higher biomass production than control soils. In our experiment, the mineral fertilization applied at the beginning of the experiment did not induce a higher yield in head or leaves compared to control. This fact reflected the low efficiency of the mineral application, with a high lixiviation of nitrates (data not shown) and probably other processes that induced losses of added N. Composted material (CSF) seemed to produce a higher biomass yield than the fresh one (FSF). This could be due to the nature of the crop, with a low vegetal development that could be more favored by the low liberation of nutrients, especially nitrogen and phosphorus, of the composted in front of the fresh one. Considering the whole aerial part, increasing the rate of FSF application increased the yield, whereas the use of the high dose of CSF produced a lower biomass production than the low dose. This fact also was observed by Smith et al. (2001) in an experiment with *Phaseolus vulgaris* grown on soil-compost mixtures, obtaining a lower yield when the high dose of compost was employed (50 % (m/m) soil-compost mixture).

Nutrient content

Nitrogen content in cabbage plants is shown in table 2. There were no big differences between treatments. Nitrogen presence in leaves was affected by sampling, with lower levels in second sampling compared to the first one. This fact is probably due to the dilution effect of the higher biomass production in time. According to this, control plants increased its nitrogen concentration along the experiment. No statistical differences were observed between composted (CSF) and fresh (FSF) organic materials. In general terms, increasing application doses did not affect the nitrogen content in leaves. The inorganic fertilization induced similar nitrogen contents in the cabbage non-commercial parts (leaves) than the organic treatments. In the commercial part (head), nitrogen content was not affected by the fertilization scenarios compared to control.

Phosphorus content in cabbage leaves was increased by the inorganic fertilization and the highest dose of fresh material (FSF-2). This effect was very significant in the first sampling, but not in the second one. In cabbage head, significant increases of P for the fertilized treatments, especially in MF and FSF-2, were observed compared to control. The application dose of FSF

increased the P concentration in leaves (1M) and in head, with no influence for the soils amended with the composted solid fraction of pig slurries.

The inorganic fertilization increased the potassium content in all vegetal parts and samplings. CSF treatments did not induce any differences compared to control plants and only FSF treatments in some cases induced few variations on P concentration. This evolution could be associated with the low presence of K in organic materials, especially in composted ones, due to the high mobility of this element.

Nutrient extraction

The nutrient extraction by crops is an interesting testing for fertilizing treatments (figure 2). Considering the whole aerial part of Milan cabbage, it was observed that nitrogen extraction was higher in soils organically fertilized than inorganic ones, except for the low application dose of FSF. The application rate increased the nitrogen extraction for FSF but the opposite was true for CSF. Hernandez et al. (2002) reported that higher application doses of sewage sludge did not result in greater inorganic nitrogen in soils. In our experiment, the composted material resulted the most efficient fertilizer according to the N extraction and biomass production. The fertilizing scenarios increased the P extraction compared to control soils. However, no differences were observed between mineral and organically fertilized soils. In addition, fresh or composted solid phase of pig slurries did not affect the P extraction, except for the FSF-2. The K extraction by plants was positively affected by fertilization. The highest extraction was found for FSF-2 and CSF-1. The mineral fertilization also favored the K accumulation in aerial parts of Milan cabbage, with similar results to FSF-1 and CSF-2.

Conclusions

The use of fresh and composted solid fraction of swine manure slurry as organic fertilizers showed a statistically similar or higher effect on the yield of different parts of the Milan cabbage plant than the mineral fertilizer. Increasing rates of organic fertilizer application only resulted in greater total biomass yield in plots with fresh solid fraction, which should be considered for establishing composted solid fraction application rates. Organic amendments favored the nutrient extraction by Milan cabbage, especially for K and P.

Acknowledgements

This work was supported by Science and Technology Office of the Valencia Government (Project GV 00-007-16).

References

- Bernal, M.P.; Roig, A. 1993. The Influence of Pig Slurry Fertilisation on the Mineral Content of Horticultural Crops Grown in Calcareous Soils. *J. Sci. Food Agric.* 62: 129-135.
- Everaats A.P.; De Moel, C.P. 1998. The effect of nitrogen and the method of application on yield and quality of white cabbage. *Eur. J. Agron.* 9: 203-211.
- Kitson, R.E.; Melon, M.G. 1944. Colorimetric determination of P as molybdovanado phosphoric acid. *Ind. Eng. Chem. Anal. Ed.* 16: 379-383.
- Lai, C.M.L.; Cheung, R.Y.H. 1999. Utilization of Pig-on-litter Compost and Anaerobically Digested Sewage Sludge for the Growth of Edible Crops: Rate of Application and Effects of Heavy Metals. In *Remediation and Management of Degraded Lands*. Wong, M.H.; Wong, J.W.C.; Baker, A.J.M. Eds.; Lewis Publishers (CRC Press). Boca Raton (Florida). 349-363.
- Maeda M.; Zhao B.; Ozaki Y.; Yoneyama T. 2003. Nitrate leaching in an Andisol treated with different types of fertilizers. *Environ. Pollut.* 121: 477-487.
- Martinez, J.; Peu, P. 2000. Nutrient fluxes from a soil treatment process for pig slurry. *Soil Use Manag.* 16: 100-107.
- Mbagwu, J.S.C.; Unamba-Oparah, I.; Nevoh, G.O. 1994. Physicochemical Properties and Productivity of Two Tropical Soils Amended with Dehydrated Swine Waste. *Biores. Technol.* 49: 163-171.
- Moral, R.; Navarro-Pedreño, J.; Gomez, I.; Mataix, J. 1996. Quantitative analysis of organic residues: effects of sample preparation in the determination of metals. *Commun. Soil Sci. Plant Anal.* 27: 753-761.
- Smith, D.C.; Beharee, V.; Hughes, J.C. 2001. The Effects of Composts Produced by a Simple Composting Procedure on the Yields of Swiss Chard and Common Bean. *Sci. Hort.* 91: 393-406.
- Soil Survey Staff. 1998. *Keys to Soil Taxonomy*, Eighth Edition, USDA. Washington.
- Hernandez, T.; Moral, R.; Perez-Espinosa, A.; Moreno-Caselles, J.; Perez-Murcia, M.D.; Garcia, C. 2002. Nitrogen mineralization potential in calcareous soils amended with sewage sludge. *Biores. Technol.* 83: 213-219.
- Vasconcelos, E.; Cabral, F.; Cordovil, C. 1999. Wheat Yield and Leachability of Phosphorus and Mineral Nitrogen in Pig Slurry Amended Soils. *Commun. Soil Sci. Plant Anal.* 30: 2245-2257.

Table 1: Selected characteristics of the soil and organic wastes used (dry weight basis).

	<i>Soil</i>	<i>Organic wastes</i>	
		FSF	CSF
pH	8,6	6.6	6.4
EC (S m ⁻¹)	0.07	0.23	0.29
C _{org} (g kg ⁻¹)	9.2	416.0	427.7
N _t (g kg ⁻¹)	1.0	19.4	15.7
C/N	9.2	21.4	27.2
P (g kg ⁻¹)	0.04	15.8	10.1
K (g kg ⁻¹)	3.8	6.3	7.9

EC: Electrical conductivity; C_{org}: total organic carbon; N_t: total nitrogen; -: Not determined.

Table 2: NPK concentration (g/kg d.w.) in the marketable part (head) and leaves of Milan cabbage

Treatment	N (g/kg)		P (g/kg)		K (g/kg)	
	1M	2M	1M	2M	1M	2M
Leaves						
C	30 a	29 c	1,9 a	2,0 a	13,3 a	15,0 a
MF	31 a	25 b	3,4 b	2,4 ab	24,7 b	18,3 cd
FSF-1	37 ab	25 bc	1,9 a	2,5 b	14,2 a	19,5 d
FSF-2	40 b	21 a	3,6 b	2,6 b	24,6 b	16,2 ab
CSF-1	35 ab	27 bc	1,8 a	2,1 ab	12,8 a	17,2 bc
CSF- 2	36 ab	24 ab	1,7 a	2,4 ab	13,6 a	16,4 ab
<i>F-anova</i>	*	***	***	*	***	***
Head						
C		25 ab		2,9 a		21,5 a
MF		24 a		3,9 c		25,4 b
FSF-1		26 ab		3,4 b		22,2 a
FSF-2		28 b		4,1 c		23,2 ab
CSF-1		27 ab		3,2 b		22,1 a
CSF- 2		25 ab		3,2 b		22,6 ab
<i>F-anova</i>		*		***		*

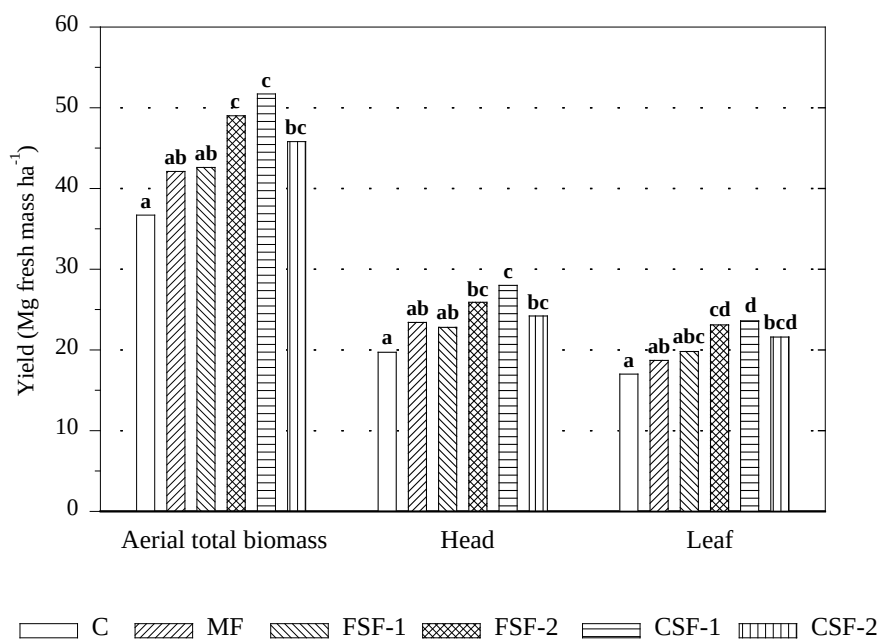


Figure 1: Yield (Aerial total biomass, head and leaf biomass), Mg m.f. ha⁻¹, of Milan cabbage depending on the fertilizing treatments.

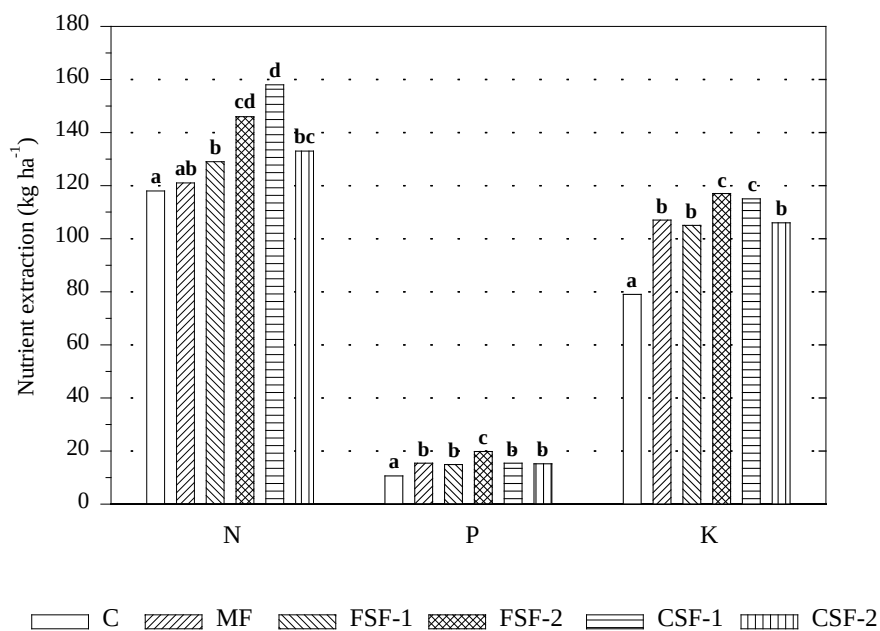


Figure 2: Nutrient extraction (kg/ha) of Milan cabbage aerial parts depending on the fertilizing treatments.

INFLUENCE OF STABILISATION TREATMENT OF SEWAGE SLUDGE ON THE RELEASE OF PLANT AVAILABLE NITROGEN

R. Moral, C. Paredes*, M. A. Pérez-Murcia, A. Pérez-Espinosa, J. Moreno-Caselles, B. Rufete and E. Agulló

Department of Agrochemistry and Environment, Miguel Hernandez University
EPS-Orihuela, Ctra Beniel Km 3.2, 03312-Orihuela (Alicante), Spain
Tel: 966749651, Fax: 966749619, E-mail: c.paredes@umh.es

Abstract

A laboratory incubation study was conducted to determine the influence of stabilisation treatment of sewage sludge, sludge application rate and soil type on the release of plant available nitrogen. For this study surface layer (0-25 cm) samples of three calcareous soils were collected at Orihuela (S₁), Ribera de Molina de Segura (S₂) and Guardamar (S₃) (SE Spain), being clayey-loam, loam and sandy textured, respectively. Anaerobically and aerobically digested and composted sludges from water treatment plant in Torrevieja, Benidorm and Aspe, respectively, were mixed with each soil type at the rates of 0 (C), 20 (I) and 40 (II) g compost kg⁻¹ soil (d.w.). Amended and control soils were placed in a controlled incubation chamber under an aerobical non-leached procedure for 13 weeks at 20°C. The soil moisture content was maintained at 60% of field capacity. Total N and N released (NH₄⁺ and NO₃⁻) were measured at the beginning of the experiment and at the end of the incubation. The results obtained indicated that the inorganic N increase in sludge-treated soils was dependent on the type of stabilisation treatment of the sludge and the characteristics of the receiver soil of the sludge, being this increase higher for aerobically treated sludge and fine textured soils. In general terms, the increment of sludge application did not result in greater inorganic N increase but in higher N losses.

Introduction

Application to the soil of organic waste such as sewage sludge represents an economical and widespread method, which can improve soil properties and recycle nutrients in agricultural soils and thus reduce the need of mineral fertilisers. However, the inadequate management of sludge application can produce several problems on agronomic and environmental terms, especially focused on nitrogen losses to atmosphere and ground water (European Environment Agency, 2000). Due to a 50-90% of the N in sludge is organic (Sommers, 1977), it is necessary to know N mineralisation in order to predict N availability during crop season. Mineralisation of the organic N in sludge depends on several factors such as soil type, soil pH, temperature, moisture and rate and type of sludge. Different authors have indicated that the mineralised organic N content varies according to the type of sewage sludge stabilisation process, composting, anaerobic and aerobic (Epstein et al., 1978, Hernández et al., 2002). In several incubation experiments of sewage sludge-amended soils, no differences due to the application rate were observed with regard to the inorganic N content of the amended soils (Lindeman and Cardenas, 1984; Hernández et al., 2002). However, Hébert et al. (1991), in an experiment of N

mineralisation in composted manure-amended soil, found that the highest value for mineralised-N corresponded to waste-amended soil with the highest total N content. Also, Hernández et al. (2002) observed that organic N mineralisation in sludge-treated soils was dependent on the characteristics of soil, being N mineralisation greater for soil of light texture.

Therefore, the aim of the present work was to study the influence of the stabilisation treatment of sewage sludge, application rate and the characteristics of the receiver soil of the sludge on the release of plant available nitrogen.

Materials and Methods

Incubation experiment

The soils used in this study, sampled at the surface layer (0-25 cm), were collected at Orihuela (S₁), Ribera de Molina de Segura (S₂) and Guardamar (S₃) (SE Spain), being clayey-loam, loam and sandy textured, respectively. Anaerobically and aerobically digested sewage sludges (ANASS and AERSS, respectively) and a composted sewage sludge (CSS) from water treatment plant in Torre Vieja, Benidorm and Aspe, respectively, were employed as amendments. Some properties of the soils and sludges are given in Table 1.

Sludges were mixed with each soil type at the rates of 0 (C), 20 (I) and 40 (II) g sludge kg⁻¹ soil (d.w.). Amended and control soils were aerobically incubated in controlled conditions (non-leached procedure, 13 weeks at 20°C, soil moisture: 60% of field capacity). Total N and N mineralised (NH₄⁺ and NO₃⁻) were measured at the beginning of the experiment and at the end of the incubation.

Analytical methods

The soil and sewage sludge samples were analysed for pH and electrical conductivity in water suspensions (1:5 and 1:10 w/v in soil and sewage sludge samples, respectively). Total organic carbon was determined by oxidizing with K₂Cr₂O₇ in H₂SO₄ according to Yeomans and Bremner (1989) and total nitrogen by Kjeldahl method. NH₄⁺-N was extracted with 2 M KCl (1:10 and 1:30 w/v in soil and sewage sludge samples, respectively) and determined colourimetrically (Honeycutt et al., 1991). NO₃⁻-N was determined in the CaSO₄ extract (1:3 and 1:30 w/v in soil and sewage sludge samples, respectively) by second-derivative spectroscopy method (Simal et al. 1985; Sempere et al., 1993). To evaluate the release of N during the mineralisation of sewage sludges, the following equations were used:

$$\text{Mineralised organic N (mg kg}^{-1}\text{)} = (\text{Organic N}_{\text{soil}} + \text{Organic N}_{\text{sludge}}) - \text{Organic N}_{\text{end}}$$

$$\text{Inorganic N increase (mg kg}^{-1}\text{)} = (\text{NH}_4^+ - \text{N} + \text{NO}_3^- - \text{N})_{\text{end}} - [(\text{NH}_4^+ - \text{N} + \text{NO}_3^- - \text{N})_{\text{soil}} + (\text{NH}_4^+ - \text{N} + \text{NO}_3^- - \text{N})_{\text{sludge}}]$$

$$\text{Lost N (mg kg}^{-1}\text{)} = \text{Mineralised organic N} - \text{Inorganic N increase}$$

$$\text{Nitrification index (\%)} = \frac{(\text{NO}_3^- - \text{N})_{\text{end}} - [(\text{NO}_3^- - \text{N})_{\text{soil}} + (\text{NO}_3^- - \text{N})_{\text{sludge}}]}{(\text{NH}_4^+ - \text{N} + \text{NO}_3^- - \text{N})_{\text{end}} - [(\text{NO}_3^- - \text{N})_{\text{soil}} + (\text{NO}_3^- - \text{N})_{\text{sludge}}]}$$

Data were analysed for treatment and soil type effects using one-way analysis of variance (ANOVA); comparison of treatment means was performed by the Tukey test ($P < 0.05$).

Results and Discussion

In most cases, the addition of sewage sludge increased significantly the mineralised organic N content, being the increment higher in the soils amended with the greatest application rates of sludge (Figure 1a). The soils with ANASS and AERSS treatments showed higher organic N mineralisation, probably due to anaerobically and aerobically digested sewage sludges had greater total N content than the composted one (Table 1). These results agreed with the findings of others authors (Hérbert et al., 1991; Moral et al., 2002), who reported a positive relationship between total N content and N mineralisation processes. The influence of soil type on sludge organic N mineralisation was different for each sludge (Table 2).

The incorporation of sewage sludge in the soils increased their inorganic N content, except in the case of ANASS-II, CSS-I and CSS-II, where the inorganic N increase was negative or non-appreciable (Figure 1b). This fact could be attributed to gaseous losses of the mineralised organic N due to ammonia volatilisation (Nelson, 1982) or denitrification processes (Williams et al. 1992) and/or immobilisation processes, because the incubation was carried out under a non-leached procedure. In an incubation study of soil amended with composted sludge, Tester et al. (1977) observed immobilisation of inorganic N produced during the organic N mineralisation of composted sludge. Increasing rates of anaerobic and aerobic digested sewage sludge application did not produce in all cases greater inorganic N release. This was in agreement with the findings of Lindeman and Cardenas (1984) and Hernández et al. (2002) in incubation experiments of amended soils with different rates of sludge. The inorganic N increase of soils was significantly higher in S₁, because of N losses in this soil were lower (Table 2).

In all soils, the N losses were statistically greater in the treatments with high application rate of sludge, being these losses higher in the AERSS amended soils (Figure 1c). The increase of N losses with increasing sludge application rates has been observed by others investigators in

sludge-amended soil incubation experiments (Ryan et al., 1973; Lindeman and Cardenas, 1984; Hernández et al., 2002).

The nitrate percentage formed from mineralised organic N of the sludge in each soil was determined by the nitrification index (Figure 1d). In all soils, the addition of sewage sludge increased significantly the nitrification process in soil, being the increment higher in the ANASS and AERSS amended soils. The influence of soil type on nitrification index was different for each sludge (Table 2).

Conclusions

According to the results obtained, it can be concluded that the inorganic N increase in sludge-treated soils was dependent on the type of stabilisation process undergone by the sludge, and the characteristics of the receiver soil of the sludge, being this increase higher for aerobically treated sludge and fine textured soil. At least in the half of the cases, an increasing sludge application did not result in greater inorganic N increase but in higher N losses, which should be taken into account for establishing sludge application rates.

References

- European Environment Agency, 2000. Calculation of nutrient surpluses from agricultural sources. Technical report, No 51.
- Epstein, E., Keane, D.B., Meisinger, J.J., 1978. Mineralization of nitrogen from sewage sludge and sludge compost. *J. Environ. Qual.* 7, 217-221.
- Hérbert, M., Karama, A., Parent, L.E., 1991. Mineralization of nitrogen and carbon in soils amended with composted manure. *Biol. Agric. Hortic.* 7, 349-361.
- Hernandez, T., Moral, R., Perez-Espinosa, A., Moreno-Caselles, J., Perez-Murcia, M.D., García, C., 2002. Nitrogen mineralisation potential in calcareous soils amended with sewage sludge. *Biores. Technol.* 83, 213-219.
- Honeycult, C.W.; Potar, L.J., Halteman, W.A., 1991. Predicting nitrate formation from solis, fertilizers, crop residue, and sludge with thermal units. *J. Environ. Qual.* 20(4), 850-856.
- Lindeman, W.C., Cardenas, M., 1984. Nitrogen mineralization potential and nitrogen transformations of sludge-amended soil. *Soil Sci. Soc. Am. J.* 48, 1072-1077.
- Moral, R., Paredes, C., Pérez-Murcia, M.D., Pérez-Espinosa, A. y Moreno-Caselles, J., 2002. Nitrogen dynamics in a semi-arid soil remedied with anaerobic sewage sludge compost. In: *Sustainable Use and Management of Soils in Arid and Semiarid Regions (Volume II)*. (Eds.) Faz Cano, A., Ortiz Silla, R., Mermut, A.R. Quaderna Editorial. Murcia, Spain.
- Nelson, D.W., 1982. Gaseous losses of nitrogen other than through denitrification. In: *Nitrogen in agricultural soils*. (Ed.) Stevenson, F.J. *Agronomy* 22, 327-364.
- Ryan, J.A., Keeney, D.R., Walsh, L.M., 1973. Nitrogen transformations and availability of an anaerobically digested sewage sludge in soil. *J. Environ. Qual.* 2, 489-492.
- Sempere, A., Oliver, J., Ramos, C., 1993. Simple determination of nitrate in soils by second-derivative spectroscopy. *J. Soil Sci.* 44, 633-639.
- Simal, J., Lage, M.A., Iglesias, I., 1985. Second derivate ultraviolet spectroscopy and sulfamic acid method of determination of nitrates in water. *J. Assoc. Of. Anal. Chem.* 68, 962-964.
- Sommers, L.E., 1977. Chemical composition of sewage sludge and analysis of their potential use as fertilisers. *J. Environ. Qual.* 6, 225-232.
- Tester, C.F., Sikora, L.J., Taylor, J.M., Parr, J.F., 1977. Decomposition of sewage sludge compost in soil. I. Carbon and nitrogen transformations. *J. Environ. Qual.* 6, 459-463.
- Williams, E.J., Hutchinson, G.I., Fehsenfeld, F.C., 1992. NO_x and N₂O emissions from soil. *Global Biogeochemistry Cycles* 6, 351-388.

Yeomans, J.C., Bremner, J.M., 1989. A rapid and precise method for routine determination of organic carbon in soil. Commun. Soil Sci. Plant Anal. 19, 1467-1475.

Table 1: Characteristics of the soils (S₁, S₂ and S₃), and composted and anaerobically and aerobically digested sewage sludges (CSS, ANASS and AERSS, respectively) used (dry weight basis).

	S ₁	S ₂	S ₃	CSS	ANASS	AERSS
pH	8.2	7.9	8.0	6.8	6.5	6.9
EC (S m ⁻¹)	0.03	0.04	0.02	0.33	0.42	0.19
C _{org} (g kg ⁻¹)	8.1	3.9	5.6	301.0	228.2	232.1
Kjeldahl N (g kg ⁻¹)	1.22	0.65	0.71	28.7	52.5	68.9
C/N	6.4	5.7	7.4	10.2	4.1	3.3
NH ₄ ⁺ -N (mg kg ⁻¹)	4	6	4	1290	1350	2660
NO ₃ ⁻ -N (mg kg ⁻¹)	52	34	42	900	2700	900
Sand (%)	23.6	35.6	88.1	-	-	-
Silt (%)	38.0	38.2	5.7	-	-	-
Clay (%)	38.4	26.2	6.2	-	-	-
Texture	Clayey-loam	Loam	Sandy	-	-	-

EC: Electrical conductivity; C_{org}: total organic carbon; -: Not determined.

Table 2: Mineralised organic N, inorganic N increase, lost N and nitrification index in the soils S₁, S₂ and S₃ for each treatment (unamended soil, composted and anaerobically and aerobically digested sewage sludge, C, CSS, ANASS and AERSS, respectively) and doses (I and II). Doses I and II, 20 and 40 g sludge kg⁻¹ soil (d.w.), respectively. S₁, S₂ and S₃, clayey-loam, loam and sandy textured, respectively. Columns with the same letter are not significantly different at *P*<0.05 (Tukey test).

Soil	Treatment						
	C	CSS-I	CSS-II	ANASS-I	ANASS-II	AERSS-I	AERSS-II
Mineralised organic N (mg kg ⁻¹)							
S ₁	87 y	167 z	104	173	293 x	603 y	1143
S ₂	24 xy	-83 x	83	150	716 y	415 x	1258
S ₃	-68 x	37 y	102	239	610 y	546 y	1283
<i>F-anova</i>	*	***	NS	NS	**	**	NS
Inorganic N increase (mg kg ⁻¹)							
S ₁	-	-	-	451 z	382 z	413 z	510 z
S ₂	-	-	-	142 x	347 y	170 x	446 y
S ₃	-	-	-	247 y	-63 x	256 y	38 x
<i>F-anova</i>				***	***	***	***
Lost N (mg kg ⁻¹)							
S ₁	88 y	171 z	106	-277 x	-89 x	190	634 x
S ₂	24 xy	-81 x	79	8 y	369 y	246	812 y
S ₃	-68 x	44 y	93	-8 y	674 z	290	1246 z
<i>F-anova</i>	*	***	NS	***	***	NS	***
Nitrification index (%)							
S ₁	-	88.4 x	93.4 z	99.3 y	99.3	99.4 y	99.4 y
S ₂	-	93.3 y	90.7 x	98.7 x	99.0	99.1 x	99.1 y
S ₃	-	88.8 xy	92.1 y	99.3 y	630.1	99.4 y	96.7 x
<i>F-anova</i>		*	***	***		**	***

***, **, *: Significantly different at *P*<0.001, 0.01 and 0.05, respectively.

NS: Not significant. -: Values near to zero.

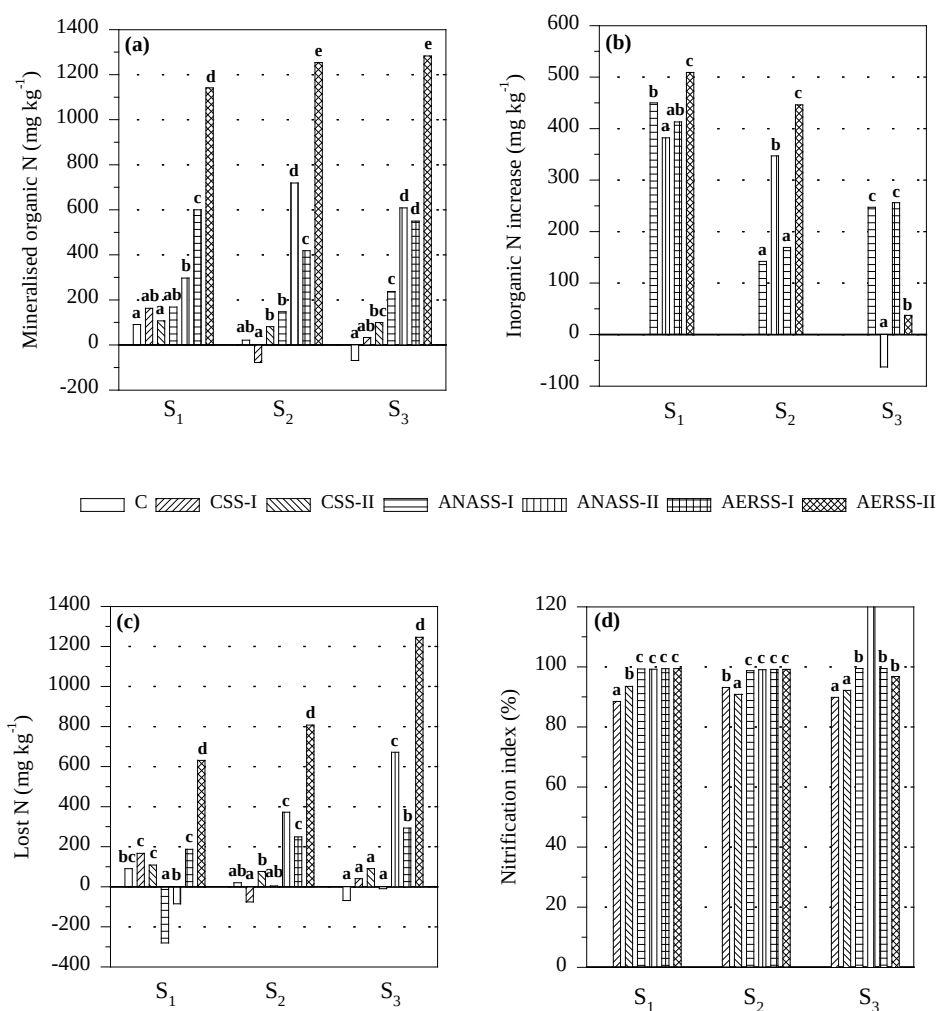


Figure 1: Effects of different treatments (unamended soil, composted and anaerobically and aerobically digested sewage sludge, C, CSS, ANASS and AERSS, respectively) and doses (I and II) on mineralised organic N (a), inorganic N increase (b), lost N (c) and nitrification index (d) in the soils S₁, S₂ and S₃. Doses I and II, 20 and 40 g sludge kg⁻¹ soil (d.w.), respectively. S₁, S₂ and S₃, clayey-loam, loam and sandy textured, respectively. Columns with the same letter are not significantly different at $P < 0.05$ (Tukey test).

