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The Conference arranged Czech Branch of ISTRO by Research Institute for Fodder Crops Ltd., Troubsko with Mendel University of Agriculture and Forestry in Brno and Research Institute for Crop Production, Praha.

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<u>Conference topics:</u>

1. New methods of soil tillage systems (mechanization of agriculture, energy inputs, economy)
2. Changes of soil fertility (physical, chemical and biological aspects)
3. Development of deleterious factors (plants conditions, pests)
4. Ecological aspects (risk elements in soils, remediation and revitalization of soils)
5. Information systems (informatics, biometrics, GIS)

PROGRAMME

28 June – Tuesday - arrival

12^{00} – 21^{00} Registration desk opened - location in Hotel Myslivna at Brno

29 June – Wednesday

7^{30} – 8^{30} Breakfast
8^{00} – 9^{30} Registration desk opened in Hotel Myslivna

9^{30} – 10^{00} Official Opening of the Conference:
Ing. Jaromir Prochazka, CSc. - President of Czech Branch of ISTRO

Prof. Ing. Jan Kren, CSc. - Sub-Dean of the Faculty of Agronomy of the Mendel University Brno

<u>Section I:</u> **New methods of soil tillage systems (mechanization of agriculture, energy inputs, economy)**

<u>Chairman: Ing. Jaromir Prochazka, CSc. (CZ)</u>

10^{00} – 10^{25} **Hula, J.,** Kovaricek, P., Mayer, V., Vlaskova, M.: Energy consumption and work quality of machines for soil-conservation tillage (CZ)
10^{25} – 10^{50} **Kren J.:** How to use information soil charakteristic (CZ)
11^{15} – 11^{40} **Jandak J.,** Filipek J.: The Effect of Particle Size Distribution of Skeletal Plough Layers of Cambisols on Wear of Tilling Mechanisms (CZ)
11^{40} – 12^{05} **Javurek M.,** Vach M., Strasil Z.: Assessing conventional and soil protection cropping from production, economic and energetic standpoint in the Czech conditions (CZ)

12^{15}- 13^{15} lunch

<u>Chairman: Dr. DSc. univ. Prof. Marta Birkas (HUN)</u>

13^{15} – 13^{40} **Prochazka J.,** Malek J., Procházková B., Hartman I.: Effect of selected species of catch crops on soil environment (CZ)
14^{05} – 14^{30} Kovac K., Macak M., Zak S..: Assessment of sustainability of conventional and conservation soil tillage systems by use of productivity, energy and economic indicators (SK)

<u>Section II</u>: **Changes of soil fertility (physical, chemical and biological aspects)**

14^{30} – 14^{55} **Birkas M.,** Jolankai M., Gyuricza C., Percze A., Schmidt A.: Soil quality management for decreasing the production loss under extreme climatic conditions (HUN)
14^{55}– 15^{20} **Kutilek M.**, Jendele L., Panayiotopoulos K.P.: Pore size distribution due to soil compression (CZ)

15^{20} – 15^{45} **Javadi A.**: Investigation possibility to break plow pan during plowing by a combined plow (Iran)

15^{45} – 16^{10} Dumitru E., Enache R., Suraianu V., Simionescu V., Negrila M., Marinca C., **Canarache A.:** Recent research in Romania on direct drilling and reduced tillage (ROM)

16^{10}– 16^{35} **Maiksteniene S.,** Arlauskiene A.: Effect of different cropping systems on the quality of heavy cambisol (LT)

16^{45} Poster disskusion

18^{30} Welcome dinner

30 June (Thursday)

8^{00} – 9^{00} Breakfast

9^{30} **Plenary Introduction and Scientific Papers and Poster discussion**

Section II **- continuation:**

Chairman: Prof.Dr. Zdenek Landa (CZ)

9^{30} – 9^{55} **Rosner J.,** Zwatz, E., Klik, A., Gyuricza, C. : Conservation tillage systems – Soil – Nutrient – and Pesticide Loss (AUT)

9^{55} – 10^{20} **Vaclavik F**.: Use of system EKOTECH to ensure "good agronomical practices" (CZ)

10^{20} – 10^{45} **Sayre K.,** Limon-Ortega A., Govaerts B., Martinez A., Cruz M.: Effects following twelve years of irrigated permanent raised bed planting systems in Northwest Mexico (MEX)

10^{45} – 11^{10} **Vavera R**., Ruzek P., Kusa H.: Yield and quality of winter wheat corn after perennial different soil treatment (CZ)

11^{10} – 11^{35} **Velykis A**., Satkus A.: Effect of sustainable tillage and extension of winter crop part in rotations on soil physical properties (LT)

11^{35} – 12^{00} **Firm Eijkelkamp b.v.** (NL): Equipment for soil sampling and soil research

12^{00}- 13^{00} lunch

***Section III*:** **Development of deleterious factors (plants conditions, pests)**

Chairman: Prof. Ing. Jan Kren, CSc. (CZ)

13^{00}- 13^{25} **Tyr S**., Lacko-Bartosova M.: Weeds infestation and weed management in integrated and ecological farming systems (SK)

13^{25}- 13^{50} **Landa Z.,** Kubicek J., Hornak P., Bohata A., Osborne L.S.: Entomopathogenic fungi in soil - natural components of biointensive IPM. (CZ, USA)

13^{50}- 14^{15} **Tesarova M**., Sidibe Abdoulaye, Poschl M.: Effect of soil biota on soil and crop health (CZ)

14^{15}- 14^{40} **Pokorny R.,** Moravcova H.: The effect of some agronomical practices on incidence of some pathohens of winter wheat in the year 2004 (CZ)

14^{40}- 15^{05} Hamouz K., **Lachman J.** , Orsak M., Dvorak P.**:** Effect of different soil-climatic conditions on the quality of table potatoes

Section IV: **Ecological aspects (risk elements in soils, remediation and revitalization of soils)**

15^{05}- 15^{30} **Gyuricza, Cs.,** Rosner, J., Bencsik, K., Ujj, A., Stingli, A.: Conservation soil tillage effects on selected environmental parameters (HUN)

15^{30}- 15^{55} **Varallyay G.,** Farkas C.,Tóth E., László P.: Soil tillage practice for the prevention or reduction of the risk of extreme soil moisture regime (HUN)

Section V: **Information systems (informatics, biometrics, GIS)**

15^{55}- 16^{20} **Castrignano' A.,** Cherubini C., Giasi C.I.,. Castore M., Di Mucci G., Molinari M.: Using Multivariate Geostatistics for Describing Spatial Relationships Among Some Soil Properties (IT)

16^{20}- 16^{50} **Final disskusion and close**

1 July – Friday

8^{00} – 21^{00} Field trip - Conference tour in Moravia - demonstration of equipment for soil sampling by fy Eijkelkamp b.v. – Zuran, National monument of the battle by Slavkov, Castle in Slavkov – a guided conducted tour, cropping farm in South Moravia Visnove, visit of wine cellar with degustation of south Moravian wines - Satov

2 July – Saturday - departure

POSTER PRESENTATION

Section I:

1. **Asadi H., Mehrvar M. R.:** Economical Assessment of Planting Systems on Irrigated Wheat Yield in Iran (Iran)
2. **Bucur D., Jitareanu G., Ailincai C**.: The study of economical and ecological implications of the capitalization of irrigated sloping lands in Moldova plain (N-E Romania) (ROM)
3. **Musil J., Cervinka J.**: The measuring device for the determination of traction forces by cultivate (CZ)
4. **Ratonyi T., Megyes A., Huzsvai L., Sulyok D., Nagy J.**: Evaluation of mulch tillage equipment on soil physical status in the Hungarian Great Plain (HUN)
5. **Rucknagel J., Hofmann B., Christen O.:** A new approach to assess the risk of soil compaction in arable soils (DE)

Section II:

6. **Badalikova B., Hruby J.**: Effect of different soil tillage on the change of soil physical properties (CZ)
7. **Badalikova B., Hruby J., Hartman I.:** Effect of humus content in soil on the uptake of heavy metals by plants

14^{40}- 15^{05} Hamouz K., **Lachman J.** , Orsak M., Dvorak P**.:** Effect of different soil-climatic conditions on the quality of table potatoes

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8. **Bielinska E.J. , Stankowski Sł., Maciorowski R., Meller E., Tomaszewicz T., Honzik R., Ustiak S.:** Biological activity and certain physico-chemical properties of reclamation layers and brown coal blanket claystones of “Strymicka vysypka” object (Chomutov, Czech Republic) (POL)
9. **De Giorgio D., Castrignano’ A., Fornaro F.:** Effect of tillage and nitrogen on durum wheat in a mediterranean climate (IT)
10. **De Giorgio D., Ferri, D., Convertini, G.**: Comparison among different agronomic technical in a long time trial on almond trees carried out on a mediterranean area (IT)
11. **De Giorgio D., Lamascese N., Fornaro F**.: Soil tillage and root distribution of broad bean (*Vicia faba L. major*) on a silty clay soil in southern Italy (IT)
12. **Dryslova, T., Prochazkova, B., Hartman, I**.: Effect of different soil tillage and straw management on nitrate nitrogen dynamics in soil profile under winter wheat in years 1998-2004 (CZ)
13. **Govaerts B., Sayre K.D., Martinez A., Deckers J.**: The NDVI handheld sensor to characterize maize/wheat crop growth under different tillage and residue management (MEX)
14. **Hartman, I., Prochazkova, B. Dryslova, T.**: Soil structure in relation to different straw management (CZ)
15. **Jitareanu G., Bucur D.:** Study on the possibilities of water and soil conservation on arable lands in the hilly area of the Moldavian plain (North-Eastern of Romania) (RO)
16. **Jug, D., Stipesevic, B., Zugec, I.:** Effects of conventional and reduced tillage systems in winter wheat – soybean crop rotation on crops biomass development (HR)
17. **Kovac L., Kotorova D., Balla P., Danielovic M.:** Effect of conservation soil tillage technologies on cereal crops yield
18. **Kristaponyte I.**: Efficacy of fertilization systems diffeering in intensity on a heavy soil (LT)
19. **Megyes A., Huzsvai L., Ratonyi T., Sulyok, D.:** A method for characterizing the quality of tillage in a long-term field experiment (HUN)
20. **Neudert L.:** Different soil tillage practices and their influence on changes of soil physical properties (CZ)
21. **Owczarzak W., Dubas A., Mocek A.:** Comparative analysis of selected parameters of the topsoil structure in a long-term conventional tillage and direct drilling
22. **Pokorny E., Stralkova R, Pospisilova L.:** Actual Aberration of Topsoil Basal Respiration in Central Moravia (CZ)
23. **Prochazkova, B., Hartman, I., Dryslova, T.**: Effect of Different soil tillage systems and crop residue management on grain yield and quality in spring barley (CZ)
24. **Remesová I., Hartman I., Prochazková B.:** Impact of different soil tillage and straw management on weed species spectrum (CZ)
25. **Santrucek J., Svobodova M., L. Boruvka:** Changes of set-aside arable soil properties (CZ)
26. **Svoboda J., Zemanek P.:** Monitoring soil compression in enduring growth (CZ)
27. **Svoboda P., Haberle J.:** The effect of soil properties on depth and root density in selected crops (CZ)
28. **Ulrich S., Hofmann, B., Tischer, S., Christen, O.**: Biological and physical soil properties in a long – term tillage trial in Germany (GE)
29. **Vucans R., Lipenite I.**: Effect of fertilizer on nutrient balance in crop rotation (LT)

Section III:

30. **Bielinska E. J., Pranagal J.:** The effect of long-term agricultural using of silty soils on phosphatases activity   (POL)
31. **Lachman J., Hamouz K., Dvorak P., Pivec V.:** Effect of ecological way of potato cultivation on the yield and quality of potato tubers
32. **Smutny V., Dvorak, J., Winkler, J.**: The influence of short term fallow on the change of weed seedbank (CZ)
33. **Stroblova M., Prochazkova B., Hartman I.:** The effect of selected biopreparation on the development of arbuscular mycorrhiza in winter wheat (CZ)
34. **Toth Š, Porvaz P.:** The influence of selected growing factors on the Alfalfa (M*edicago sativa l.)* hay yield
35. **Tyr S., Lacko-Bartosova M.**: Farming systems and integrated weed infestation control (SK)
36. **Vach M., Hysek J., Javurek M.,**: The impact of biopreparations applied in conditions of different stand establishment of winter wheat and spring barley (CZ)

Section IV:

37. **Djordjevic A.**: Mobile   nickel   content in serpentine rankers of Serbia (YU)
38. **Gyuricza Cs., Földesi P., Mikó, P.**: Soil tillage and greenhouse effect (HUN)
39. **Hruby J., Badalikova B., Hartman I.**: Economic and ecological utilization of pellets on the basis of fluid ashes and fly-ashes for agricultural and landscaping   (CZ)
40. **Svoboda M., Suchardova M. et all:** Stability verification of combustion products for utilization in agriculture and for recultivation of landscape (CZ)

CONTENTS

Section III

Oral presentation

Poster presentation

Section IV

Oral presentation

Poster presentation

Section V

Oral presentation

Section I - addendum

Oral presentation

Section II - addendum

Poster presentation

ENERGY CONSUMPTION AND WORK QUALITY OF MACHINES FOR SOIL-CONSERVATION TILLAGE

Hůla J., Kovaříček P., Mayer V., Vlášková M.

Research Institute of Agricultural Engineering, Praha, Czech Republic

Abstract

Within the repeated loosening by the blade tiller Horsch Phantom FG 7,5 to the depth of 80-100 mm was found the diesel fuel consumption lower by 18,6 % compared with the first loosening to the same depth after the wheat harvest. At the skimming by the disc tiller Dowlands DH 4500 in set with a tractor John Deere 7800 was found a slight decrease of diesel fuel consumption ($l.ha^{-1}$) with growing working speed of the set (in range from 7 to 11 $km.h^{-1}$). Similar trend was recorded also for the pre-seeding soil tillage by the combinatory Saturn 6000 in set with tractor John Deere 7800 (working speed from 6 to 10,5 $km.h^{-1}$). During the shallow loosening by the disc tiller after the maize harvest for silage was proved that the change of the discs working angle adjustment did not affect significantly of the crop residua placement into the soil.

Key words: conservation soil tillage; diesel fuel consumption; after harvest crop remainders

Introduction

For successful application of the minimal and soil-conservation technologies of soil tillage and crop stands establishing is important to meet the requirements for machines regarding the acceptable energy consumption at high performance and work quality. The high performance of machines is a condition of early realization of individual working operations, favourable machines energy consumption is important to reach good costs for working operations. The high requirements for machines work quality are necessary for a expected benefit of non-traditional technologies for soil cultivation focused to its protection against erosion and other unfavourable impacts and to the conditions provision for crop quality stand establishing with aim to read the demanded yield.
At the agricultural enterprises was measured the diesel fuel consumption and work quality of selected machines. The machine sets were evaluated for the soil shallow loosening and pre-seeding soil preparation. In all the cases were evaluated machines with passive working organs with assumed good work quality at higher working speed. For the machines for shallow loosening is required the work quality, mainly the soil mixing and crumbling, conditioned by the set speed. At the higher set speed the tractive force and loosening specific resistance are increasing. The increasing of these values must not be evaluated negatively because the machines with passive working organs have proved the mentioned higher crumbling and mixing effect, i.e. the higher work quality at higher set speed. Too intensive effect of the working organs on soil but could be a failure during the sandy and clay-sandy soils tillage at low soil moisture.

Methods

For the diesel fuel consumption measuring for soil tillage was used the motor diesel flow-meter Mannesmann Kienzle EDM 1403 and the evaluating unit IMP1A. The route length, time of measuring and working speed of machines set were scanned by means of the 12-channel receiver GPS Garmin 35.

The machines sets used for diesel fuel measuring:

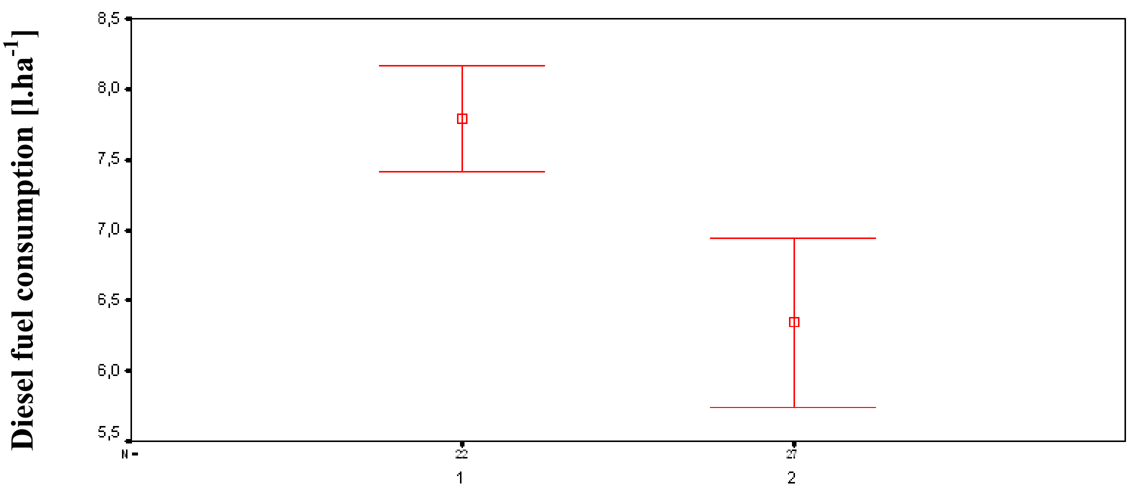
- Blade tiller Horsch Phantom (working width 7 m) in set with tractor CASE 7320.
- The soil tillage was realized after the winter barley harvest on the clay soil with favourable moisture for its tillage.
- The disc tiller Dowlands DH 4500 (working width 4,5 m) in set with tractor John Deere 7800. Total plots acreage was 507,9 ha (with recorded motor diesel fuel consumption at sharing).
- Combinator Saturn 6000 (working width 6 m) in set with tractor John Deere 7800, total plots acreage at measuring: 325 ha.

The machines set used for evaluation of the tiller effect on the crop remainders:

- The disc tiller Preciser 6000 (working width 6 m) in set with tractor John Deere 8200. Evaluation of the tiller working organs adjustment effect on the after-harvest remainders placement in the soil.

Results

The graph in Fig. 1 expressed the mean values of confidential intervals for the diesel fuel consumption at skimming and repeated loosening into the depth 80-100 mm, performed by the blade tiller Horsch Phantom FG 7,5 in set with tractor CASE 7320. The average consumption of the motor diesel fuel at skimming was 7,79 $l.ha^{-1}$ at repeated loosening 6,34 $l.ha^{-1}$. After the repeated loosening was found a high coverage of the soil surface by the crushed straw of the winter wheat (68 %). From this results a suitability of the verified type of the blade tiller for utilization in the technologies of the soil-conservation tillage (minimum value of coverage at the soil-protection technology is 30 %).



1. Skimming (Horsch Phantom) 2. Repeated loosening (Horsch Phantom)

Fig. 1. Average values of diesel fuel consumption and confidential intervals for skimming and repeated loosening into the identical depth

In the graph in Fig. 2 is expressed the dependence of the diesel fuel consumption ($l.ha^{-1}$) on the working speed ($km.h^{-1}$) at skimming by the disc tiller Dowlands DH 4500 in set with tractor John Deere 7800. For expression of the dependence was used the linear model of the function. The correlation coefficient shows the mean dependence between ***x*** and ***y*** (r = 0,57).
The anticipated reason of the presented dependence is a difference between the motor diesel consumption increase per 1 hour (diesel fuel consumption per 1 hour with growing working speed is increasing) and the growth of the acreage set performance with increasing working speed. At the percentage expression of the increase the set acreage performance is growing faster than the motor diesel fuel consumption. A favourable effect of the higher working speed on the diesel fuel consumption per hectare may be expected only in the certain range of the working speed (graph in Fig. 2). Our precious measuring has confirmed the results presented in literature (Linke 1993; Gebresenbet et Jönsson 1992): for the tiller with passive working organs the specific resistance is growing with the speed increasing linearly till the speed 12-15 $km.h^{-1}$.
The effect on the diesel fuel consumption has also variability of the soil conditions and instant soil moisture. Other factor is the plot shape and working travel length.
In the graph in Fig. 3 is expressed dependence of the motor diesel fuel on the set working speed of tractor John Deere 7800 and combinatory Saturn with working width of 6 m of the pre-seeding soil preparation for spring crops in the technology of the soil cultivation without ploughing. Also in this operational measuring was recorded tendency of the diesel fuel consumption ($l.ha^{-1}$) decreasing with increased set speed in presented range of the working speed. For the dependence expression was used the function linear model. The correlation coefficient shows a strong dependence between ***x*** and ***y*** (r = 0,77).

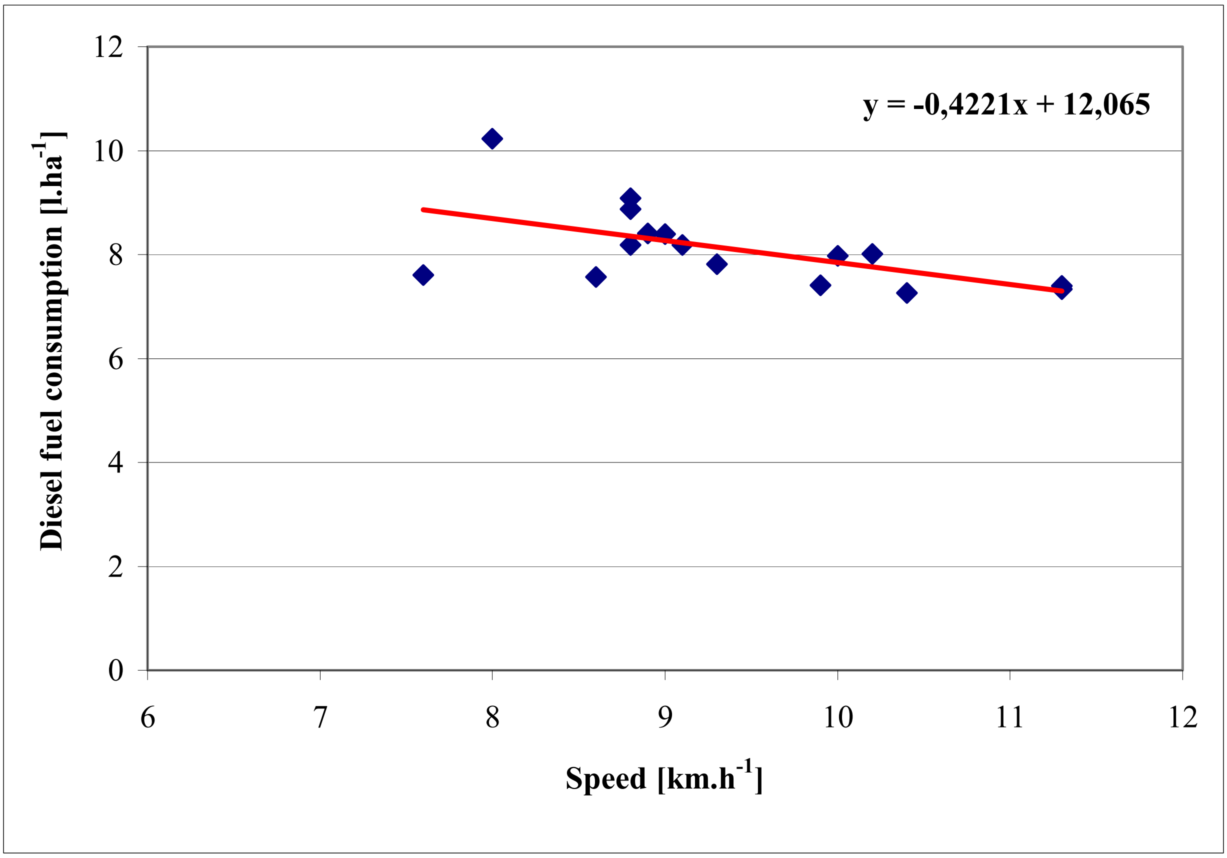


Fig. 2 Dependence of diesel fuel consumption (l.ha^{-1}) on working speed (km.h^{-1}) of skimming by the disc tiller Dowlands DH 4500 in set with tractor John Deere 7800

The modern sets for soil tillage enable to read a favourable indicators of the motor diesel fuel consumption with requirements for work quality maintenance and high acreage performance. The lowest specific consumption read the tractors at maximum traction output corresponding with the optimum traction force for given gear stage.

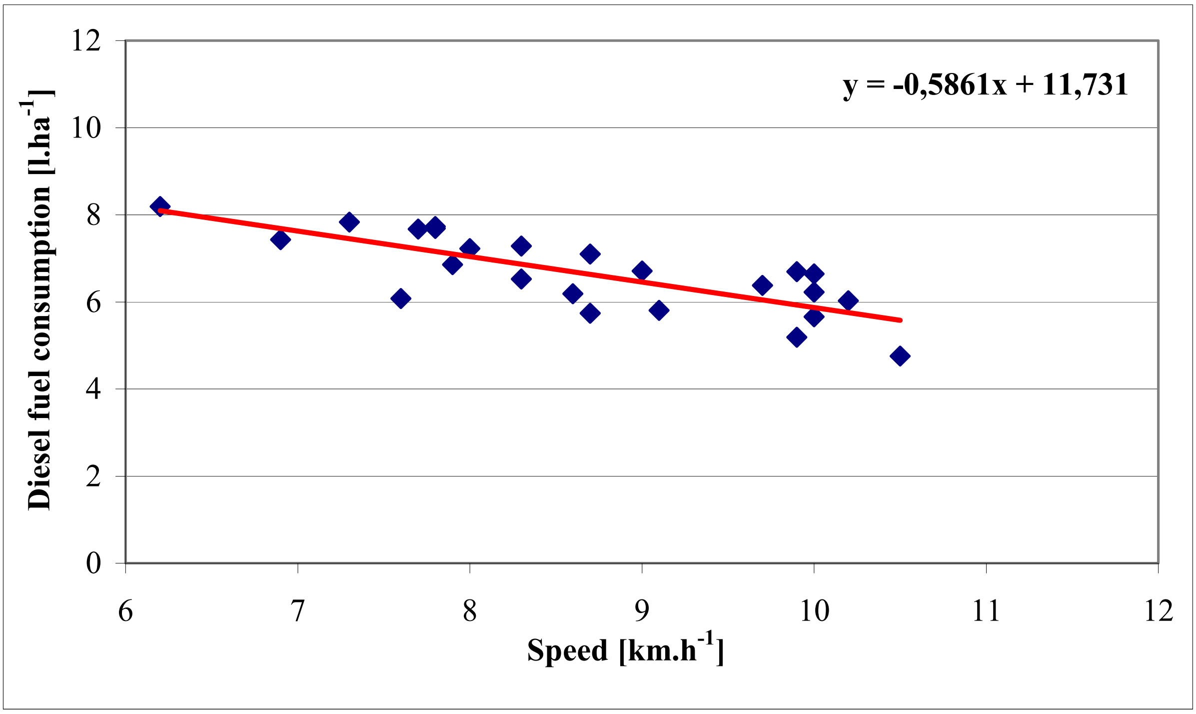


Fig. 3 Dependence of diesel fuel consumption (l.ha^{-1}) on working speed (km.h^{-1}) at the pre-seeding soil tillage by combinator Saturn 6000 in set with tractor John Deere 7800

The modern tractors with engine with high torque exceeding and gearbox with loaded shift gears enable to operate in regime of traction force utilization corresponding with the maximum traction output (Bauer 1997). At the soil tillage in the systems without ploughing is read to join the requirement for high acreage performance with economical operation with utilization of engine in regime of low specific fuel consumption. The presented results of the operational monitoring of the machine sets confirm this conclusion.
In table 1 are presented results of the silage maize after-harvest residua evaluation, which have remained on the soil surface after its tillage by the disc tiller at various adjustment of the discs working angle, loosening depth and working speed. It was proved that by the regulation of the working bodies of the mentioned disc tiller it was not possible to increase considerable the share of the after-harvest residua remaining on the soil surface at the soil tillage. From this resulted a limited usability of this group of the disc tillers for technologies where the anti-erosion protection is priority.

Table 1 Weight of the after-harvest remainders of the silage maize remaining on the soil surface after its cultivation by the disc tiller

Discs working angle (^{o})	Loosening depth (mm)	Working speed ($km.h^{-1}$)	Weight of crop remainders on the soil surface ($g.m^{-2}$)
13,7	70	12	128
13,7	70	9	217
13,7	70	6	310
13,7	100	12	298
17,1	100	12	146
17,1	70	12	181
10,3	70	12	183
10,3	100	12	81
Before soil tillage			601

Results presented in this paper were obtained during solution of the research project QD 1213 (Ministry of Agriculture – Czech Republic).

Bibliography

LINKE, CH., 1993: Zugkraftbedarf von einfachen Bodenbearbeitungswerkzeugen bei hohen Arbeitsgeschwindigkeit, 8/9: 486-487.

GEBRESENBET, G. – JÖNSSON, H., 1992: Performances of seed drill coulters in relation to speed, depth and rake angles. Journal of Agricultural. Engineering Research. *52*, 2: 121-145.

BAUER, F., 1997: Volba traktorových souprav pro zpracování půdy. In: Hůla, J. et. al. Zpracování půdy. Praha, Brázda, p. 116-138.

KÖLLER, K., 2003: Techniques of soil tillage. In: Titi, A.: Soil tillage in agroecosystems. CRS Press, p. 1-25.

THE EFFECT OF PARTICLE SIZE DISTRIBUTION OF SKELETAL PLOUGH LAYERS OF CAMBISOLS ON WEAR OF TILLING MECHANISMS

Jandák J., Filípek J.

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Abstract

The effect of particle size distribution of skeletal plough layers on wear of tilling mechanisms was simulated in a drum apparatus designed by Bond in which steel prisms made of high-grade, low-alloy steel 14 260 (ČSN 420002) rotated together with experimental soil samples. Skeletal ploughing layers of cambisols cause a much stronger wearing effect than those of chernozem, which has no skeleton. The clay fraction (particles < 0.001 mm) showed the strongest wearing effect (R^2 = 0.9257). Strong dependences of steel wear were recorded for fractions 2.00 – 0.25 mm, 0.05 – 0.01 mm and < 0.01 mm, viz. R^2 = R^2 = 0.8186; 0.7752 and 0.7620, respectively. The relationship between the wear and the skeleton was of medium strength (R^2 = 0.6284).

Keywords: soil; wear; steel; particle size distribution;

Introduction

There are only very few literary data about the wear of steel in soil. The majority of papers (e.g. Salokhe et al., 1991; Bhole et al., 1992; Owsiak, 1998; Bhakat et al., 2004; Gupta et al., 2004 etc.) deal with testing of steel quality. Fielke et al., (2003) conducted tests using a range of soil types and moisture contents and observed a large effect of soil type and condition on the wear rates. However, there is no study available, which would deal in detail with effects of particle size distribution of skeletal plough layers on the wear of tilling mechanisms.

Material and methods

The wear of tilling mechanisms in skeletal plough layers was conducted in a drum apparatus designed by Bond. Testing bodies were fixed in a rotor. Peripheral speed of testing bodies was 438 $m.min^{-1}$. The testing drum contained 1300 cm^3 of tested soil sample.

Testing bodies were made of high-grade, low-alloy steel 14 260 (ČSN 420002) showing the following chemical composition: C - 0.55 %, Mn - 0.6 %, Si - 1,4 % and Cr - 0.6 %. Steel was normalized for 2 hours at the temperature of 850 ^{o}C and thereafter cooled on air. The testing body was manufactured by milling and grinding and it had the shape of a prism with the following dimensions: 76 x 25.4 x 6.3 mm. The roughness of its surface was R_a = 0.4 µm and the hardness was expressed as 250 HV.

Testing bodies were tested in seven ploughing layers different soil types:

1. Ap - an eutric cambisol, developped from diorite (lokality Brno), 28.17 % rock fragments, texture in the fine-earth fraction sandy loam.

2. Ap - an eutric cambisol, developped from granulite (lokality Bory), 29.87 % rock fragments, texture in the fine-earth fraction sandy loam.

3. Ap - an eutric cambisol, developped from paragneiss, (locality Krahulov), 30.15 % rock fragments, texture in the fine-earth fraction sandy loam.

4. Ap - an eutric cambisol, developped from orthogneiss, (locality Laštovičky), 6,79 % rock fragments, texture in the fine-earth fraction loam.

5. Ap - an eutric cambisol, developped from syenite (locality Nové Město), 37.99 % rock fragments, texture in the fine-earth fraction sandy loam.

6. Ap - an eutric cambisol, developped from phyllite (locality Javůrek), 49.04 % rock fragments, texture in the fine-earth fraction silt loam.

7. Ap - a typical chernozem developing from loess (lokality Bratčice), without rock fragments, texture in the fine-earth fraction silt loam.

Regarding the design of the drum testing apparatus it was necessary to remove the skeleton with the diameter above 10 mm. The following periods of rotation were used:

15 min., 30 min., 60 min., 120 min. and 240 min. The soil texture was analyzed using the pipette method. Wear of steel prisms was estimated by means of gravimetry.

Results

Changes in texture of ploughing layers of soils under study, as affected by various time intervals of rotary movement of steel prisms are presented in Tab. 1. Particle size of ploughing layer of a typical chernozem on loess remained unchanged even after 240 min. of rotation with steel prisms.

The most marked increase in the content of fine-earth fraction due to the skeleton crushing could be observed in the ploughing layer from the locality Javůrek (with the parent rock phyllite). The observed proportion results were as follows: after 15 and 240 minutes 20.39 % and 32.92 %, respectively. At the same time, contents of all fractions of fine soil particles increased in the course of experiments: for instance, that of coarse silt (fraction with the size of particles ranging from 0.05 to 0.01 mm) increased during the experiment by 11.24 % and of clay (fraction < 0.001 mm) by 5.58 %. This means that weathered phyllite could be easily crushed by rotating steel prisms.

Marked changes in soil texture were observed also in the ploughing layer from the localities Bory (parent rock granulite), Nové Město (parent rock syenite) and Krahulov (parent rock paragneiss). After 240 minutes, the increase in the contents of fine-earth fractions was 28.73 %, 26.59 % and 26.18 %, respectively.

In other localities, changes in soil particle size were less obvious. In the locality Brno-Jundrov (parent rock diorite), the increase in the contents of fine-earth particles after 240 minutes was 14.17 % and in the locality Laštovičky (parent rock orthogneiss), the content of fine soil particles increased only slightly, i. e. only by 4.81 % after 240 min. of rotation.

The wear of prisms during the course of experiments is presented in Tab. 2. In all intervals of measuring, the highest wear of steel prisms was found out in ploughing layers of localities Javůrek, Krahulov and Nové Město. After 15 minutes, the highest wear was recorded in the locality Javůrek (parent rock phylite). In the following time intervals the wear of prisms was markedly slower in this locality than in localities Krahulov (parent rock paragneiss) and Nové Město (parent rock syenite). After 30 minutes, the highest wear was recorded in the locality Krahulov and after 60, 120, and 240 minutes in the locality Nové Město. As far as cambisols were concerned, the lowest wear was recorded in the locality Laštovičky. This was obviously associated with a low proportion of skeleton (Tab. 1). In the locality Bratčice, the plouging layer of which was without skeleton, the wear was much lower than in elsewhere.

Basic characteristics of the dependence of steel wear on percentages of individual particle fractions are presented in Tab. 3. The dependence of wear on the content of particles of the size 10.00-2.00 mm can be expressed by the polynomic function

$$y = -0.3076x^2 + 8.8329x - 0.7597.$$

The value of the coefficient of determination (0.6284) indicates a medium-strength dependence.
The dependence of wear on the content of particles of the size of 2.00 – 0.25 mm can be

Table 1. Changes in texture ploughing layers as dependent on period of rotation

Lokality	Time of rotation [min]	Contents of particle size fractions						
		Diameter [mm]						
		10,00 - 4,00	4,00 - 2,00	2,00 - 0,25	0,25 - 0,05	0,05-0,01	< 0,01	< 0,001
Brno - Jundrov	0	12,47	15,70	29,31	13,82	15,40	13,30	7,24
	15	8,73	16,58	35,10	8,80	16,59	14,20	8,07
	30	5,26	14,92	32,46	14,12	18,10	15,14	8,69
	60	4,90	14,61	35,13	15,39	14,40	15,57	9,18
	120	4,77	12,43	37,51	15,67	13,35	16,27	10,10
	240	3,50	10,50	36,89	16,30	16,30	16,51	11,99
Bory	0	14,20	15,67	13,54	31,19	13,27	12,13	7,07
	15	3,20	3,80	25,71	38,62	15,75	12,92	8,45
	30	3,20	2,78	25,90	37,73	17,44	12,95	9,22
	60	3,20	1,68	24,08	38,39	19,51	13,14	9,25
	120	1,05	1,52	27,31	40,29	16,58	13,25	10,01
	240	0,83	1,31	29,99	38,17	16,42	13,28	10,02
Krahulov	0	12,74	17,41	28,84	15,45	11,93	13,63	6,54
	15	3,85	8,31	37,99	19,81	14,70	15,34	6,93
	30	3,75	6,49	40,68	20,01	12,86	16,21	7,92
	60	2,21	5,56	37,27	22,96	14,71	17,29	8,40
	120	2,16	4,42	37,39	23,59	14,75	17,69	8,53
	240	0,99	2,98	39,77	24,19	14,25	17,82	8,92
Laštovičky	0	3,12	3,67	14,02	21,03	30,76	27,40	10,69
	15	1,91	3,66	15,05	19,95	30,77	28,66	11,26
	30	1,63	3,49	16,25	18,13	31,38	29,12	11,72
	60	0,90	3,00	16,26	19,41	31,24	29,19	12,92
	120	0,36	1,92	15,40	20,02	32,98	29,32	13,15
	240	0,28	1,70	14,67	20,49	33,14	29,72	13,42
Nové Město	0	16,40	21,59	25,27	12,49	12,84	11,41	5,83
	15	3,93	12,75	37,37	13,58	17,63	14,74	7,02
	30	3,46	11,82	38,26	13,96	17,43	15,07	7,54
	60	2,98	11,33	37,42	16,31	16,59	15,37	7,65
	120	2,10	10,47	38,92	14,51	17,74	16,26	7,81
	240	1,16	10,24	37,60	16,93	16,63	17,44	8,19
Javůrek	0	18,06	30,98	9,48	10,84	15,80	14,84	6,50
	15	7,90	20,75	16,26	15,13	21,42	18,54	9,49
	30	6,68	20,17	16,55	13,69	23,49	19,42	9,61
	60	4,44	18,76	14,88	13,71	26,97	21,24	10,88
	120	4,40	17,41	17,80	13,90	25,01	21,48	10,88
	240	2,69	13,43	16,34	16,91	27,04	23,59	12,08
Bratčice	0	0,00	0,00	1,35	12,31	42,56	43,78	23,76
	15	0,00	0,00	1,66	11,24	43,28	43,82	24,36
	30	0,00	0,00	1,57	8,50	45,86	44,07	24,64
	60	0,00	0,00	1,57	11,91	42,61	43,91	25,36

	120	0,00	0,00	1,40	11,75	42,72	44,13	25,48
	240	0,00	0,00	1,22	11,90	42,74	44,14	25,68

Table 2. Wear of steel prisms and speed of wear as dependent on period of rotation

Lokality	Time of rotation [min]				
	15	30	60	120	240
	Wear Speed of w.	Wear Speed of w.	Wear Speed of w.	Wear Speed of w.	Wear Speed of w.
Brno - Jundrov	6,88	11,38	14,75	21,25	28,50
	0,459	0,379	0,246	0,177	0,119
Bory	6,50	11,38	15,63	19,13	27,88
	0,433	0,379	0,261	0,159	0,116
Krahulov	13,75	**29,50**	42,00	54,38	74,38
	0,917	**0,983**	0,700	0,453	0,310
Laštovičky	7,00	8,88	11,00	12,75	16,50
	0,467	0,296	0,183	0,106	0,069
Nové Město	11,50	28,50	**52,00**	**65,50**	**76,00**
	0,767	0,950	**0,867**	**0,546**	**0,317**
Javůrek	**14,50**	20,00	28,00	34,50	37,50
	0,967	0,667	0,467	0,288	0,156
Bratčice	1,00	1,00	2,50	2,50	4,50
	0,067	0,033	0,042	0,021	0,019

Table 3. Basic parameters of dependence of wear of steel on particle size fractions

Particle size fraction [mm]	Regression equation	Coefficient of determination
10.00 - 2.00	$y = -0{,}3076x^2 + 8{,}8329x - 0{,}7597$	0.6284
2.00 - 0.25	$y = 3{,}1351x^{0{,}7615}$	0.8186
0.25 - 0.05	$y = -0{,}1793x^2 + 9{,}3761x - 62{,}427$	0.2208
0.05 - 0.01	$y = 174{,}1e^{-0{,}0787x}$	0.7752
< 0.01	$y = 152{,}78e^{-0{,}0772x}$	0.7620
< 0,001	$y = 6860{,}2x^{-2{,}3088}$	0.9257

expressed by the exponential function

$$y = 3.1351x^{0.7615}$$

and the value of the coefficient of determination (0.8186) indicates a strong dependence.
The dependence of the steel wear on the content of particles of the size of 0.25-0.05 mm is illustrated by a plynomic function

$$y = -0.1793x^2 + 9.3761x - 62.427$$

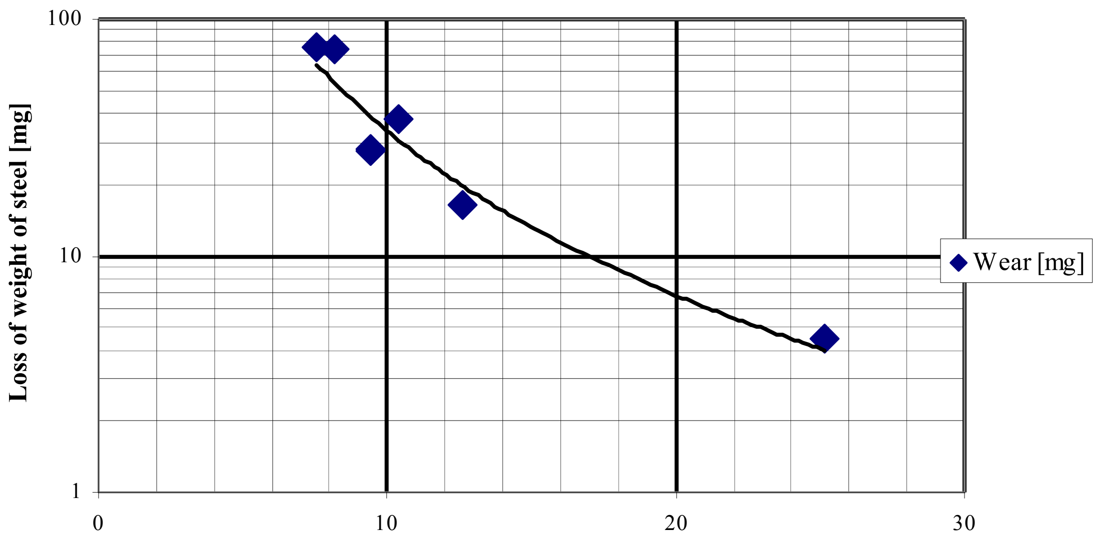
and the value of the coefficient of determination (0.2208) indicates a weak dependence.

The dependence of wear on the content of particles of the size of 0.05-0.01 mm can be expressed by the exponential function

$$y = 174.1e^{-0.0787x}$$

and the value of the coefficient of determination (0.7752) indicates a strong dependence.

Figure 1: Effect of Contents of Paricles < 0,001 mm on Wear of Steel



The dependence of wear on the content of particles of the size of < 0.01 mm can be expressed by the exponential function

$$y =152.78e^{-0.0772x},$$

and the value of the coefficient of determination (0.7620) indicates a strong dependence.

The relationsip between the steel wear and the content of particles of the size of < 0.001 mm is illustrated in Fig. 1. The dependence of wear on the percentage of this fraction can be expressed by the exponential function

$$y = 6860.2x^{-2.3088},$$

and the value of the coefficient of determination (0.9257) indicates a very strong dependence.

Conclusions

Skeletal ploughing layers of cambisols cause a much stronger wearing effect than those of chernozem, which has no skeleton. The clay fraction (particles < 0.001 mm) showed the strongest wearing effect (R^2 = 0.9257). Strong dependences of steel wear were recorded for fractions 2.00 – 0.25 mm, 0.05 – 0.01 mm and < 0.01 mm, viz. R^2 = R^2 = 0.8186; 0.7752 and 0.7620, respectively. The relationship between the wear and the skeleton was of medium strength (R^2 = 0.6284).

References

BHAKAT, A.K, MISHRA, A.K., MISHRA, N.S., JHA, S. (2004): Metallurgical life cycle assessment through prediction of wear for agrocultural grade steel. Wear 257 (3-4): p. 338-346.

BHOLE, S.D., JU, H.J. (1992): Abrazive wear evaluation of tillage tool materials. Lubrication engineering 48 (12): p. 925-934.

FILKE, J.M., Riley, T.W, Slattery, M.G., Fitzpatrick, R.W. (2003): Comparison of tillage forces and wear rates of pressed and cast cultivator shares. Soil & Tillage Research 25 (4): p. 317-328.

GUPTA,A.K., JESUDAS, D.M., DAS, P.K., BASU, K. (2004): Performance evaluation of different types of steel for duck foot sweep application. Biosystems engineering 88 (1): p. 63-74.

OWSIAK, Z. (1997): Wear of symmetrical wedge-shaped tillage tools. Soil & Tillage Research 43 (3-4): p. 295-308

ASSESSING CONVENTIONAL AND SOIL PROTECTION CROPPING FROM PRODUCTION, ECONOMIC AND ENERGETIC STANDPOINT IN THE CZECH CONDITIONS

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Abstract

Production, economy and energetic consumption from results of last four years of long term experiment with winter wheat, spring barley and pea in crop rotation was evaluated. In this experiment 3 tillage technologies were used.: 1.*Conventional tillage,* 2. *Minimum tillage,* 3. *No-tillage*. Provided, that the basic conditions at a site are ensured then by using of protection soil tillage technologies it is possible to achieve the comparable or higher production than in conventional tillage. Minimum soil tillage with possible straw and post harvest residues incorporation shows to be the cheapest way comparing with other two tested soil tillage variants. Catch crop use MT technology come to be the most expensive from tested ways and in case of comparable yields the cost effectiveness is the lowest. No-till technology is anticipated to be the cheapest but the costs often increase by necessity of use of more expensive pesticides. The highest demand of total supplementary power inputs was calculated for winter wheat under CT technology the lowest one for pea in CT too. The best utilization of supplementary energy inputs was calculated for winter wheat.

Key words: winter wheat, spring barley, pea, different soil tillage, production, economic and energetic balances

Introduction

In the Czech Republic there are grown about 1.6 million ha of cereals and on the half of this area winter wheat is grown on. Agronomical practices and stand establishment methods of field crops, especially cereals, have passed through run of changes during last decade. The thing is that the growing system of cereals allows utilizing minimization and soil protection technologies of stand establishment very well. An increasing interest in utilization of soil protection technologies of cropping both all over the world and in our country confirms their justified position in the systems of soil management. According to expert estimate the total area, where soil protection technologies of crop stand establishment and various kinds of minimization ways of soil tillage including direct drilling into no tilled soil are used, is minimally 800 thousand ha. In farming practice it is concerned in simple minimization i.e. decrease of depth and intensity of tillage during establishment of field crops. Subsequently ways of protection soil tillage with use of organic matter from post harvest residues of pre-crops or from catch crops are applied more and more. Experimental results and experience from farming show favourable influence of minimization technologies on economy of plant production as a result of reduction of operation number and consequently lower direct costs, fuel and working time consumption per production unit.

Besides improvement of economic parameters of crop production protection technologies have favourable effect on soil fertility so that there is more supply of organic matter into the

soil than it is usual. It causes more intensive development of soil microorganisms and some parameters of soil quality are enhanced as a result of their higher activity. Some physical soil properties are improved as well.
For verification reasons of some above-mentioned data and information we assess production, economy and energetic consumption from results of three-year cycle of long term field experiment with 3 crops in crop rotation where those crops are grown under 3 tillage technologies: conventional with plough, minimum and no-tillage. Minimum and no-tillage technologies were conceived as soil protection ones, it means that especially in minimum tillage there were done the working operations for incorporation of chopped straw and other post harvest residues by shallow tillage into the soil and to establish of stands of catch crops before follow up spring crops.

Material and methods

Since 1995 field experiments have been conducted at the experimental site Praha - Ruzyne. This experimental site is located in sugar beet production type on orthic luvisol, loam soil. The experiment is running as a rotation of three crops: winter wheat, spring barley and pea. A split-plot design with four replications was used. Grain yield was determined on a 16 m^2 test area at harvest.
From the year 2000 the experiment design and tillage methods were used as follows:

1. Conventional tillage (CT): mouldboard ploughing to a depth of 0.20 m, current seed-bed preparation and sowing
2. Minimum tillage (MT):
   a) for winter wheat: chopping of pea straw and incorporating into the soil by disc tiller, sowing with John Deere 750 drill machine
   b) for spring crops (barley, pea): after pre-crop harvest shallow tillage, seed-bed preparation, catch crop sowing, in spring direct drilling into no tilled soil covered by frost killed biomass of catch crop (mustard)
3. **No-tillage (NT): straw taking away, before sowing application of non-selective herbicide (glyphosat), direct sowing into no tilled soil with drill machine John Deere 750 A**

Nitrogen fertilization was as follows: for winter wheat 100 kg per ha; spring barley 80 kg per ha, pea 40 kg per ha. The P and K fertilizers were applied before drilling of catch crops in all variants in universal dose 54 kg P_2O_5 and 100 kg K_2O per ha. Standard herbicides were applied depending on the intensity of weed infestation at each site.
There was evaluated production (yields of main and secondary products) in individual tillage variants, counted costs of individual operations, determined market price of total product in particular crops and counted cost effectiveness. It was also calculated some parameters of supplementary energy intensiveness and determined energetic coefficient (energy output/energy input) for main product of individual crops and for total production.

Results and discussion

a) production
The yield results, which have been average from period 2001 – 2004, are shown in Fig.1. It is quite clearly apparent that in mentioned years under given site conditions the reduction and change of soil tillage cause no significant yield differences of both cereals. As for winter wheat the yields from CT and NT are quite the same, the yield in MT is insignificantly lower. As for spring barley the yields from MT and NT are just the same and yield in CT is by 2 % lower but the difference is statistically insignificant. The only significant yield difference was

found in pea results where in NT the yield is in average of years lower by 10 respectively 11 % than in MT and CT variant.
After American authors (CANNELL a HAWES, 1994) plough-less technologies guarantee higher yields of field crops than classic plough ways of soil tillage. According to results from Canada (ARSHAD, 1999) reduced soil tillage is preferred because brings better yield results, while direct drilling into no-tilled soil is practised by way of exception only because it fail of yield either in experiment or in farming. REINHARD et al. (2001) and similarly DZENIA et al. (1999) present the results from Switzerland and Poland where they found minimum and statistically insignificant yield differences among soil tillage methods of different intensity.
ŠIMON, JAVŮREK (1999) present the results from exact field experiments on fertile chernozems where the yields of cereals were significantly higher in conventional variants than after drilling into no-tilled soil.
From this short review it is evident that the results of study of soil tillage impact on crop yields are different and their dissimilarity logically proceed from different soil and climatic conditions of site which are drawn from.

b) economics

In experimental crop rotation there were compared direct and total costs of concrete growing technologies of three crops with different intensity and depth of tillage and with various organic matter utilization (CT, MT, NT) that are used in farming practice. On the base of attained yields in the field experiments and given market price of assessed crops in particular years in the Czech Republic it was calculated market price of the main product and total production of biomass. By comparing of market price of total product and total costs the cost effectiveness was calculated. The results are put in table 1 and in Fig. 2.
The highest cost effectiveness in average of all three ways of soil tillage there were achieved in winter wheat (food variety) growing in spite of that total costs were relatively high because it was gained high production which was sold for a good price. As for particular ways of stand establishment the highest cost effectiveness was reckoned in MT technology (29,9 %), in NT it was by about 11 % lower and in CT by 17,5 % lower comparing with MT.
Cost effectiveness of brewing barley growing under the same cost level for given technologies as in wheat was by about a half lower than in food wheat was calculated. Lower price of total production in consequence of significantly lower grain yield was the reason of the decrease in spite of that the market price was slightly higher than in wheat.
As for particular tillage variants, the highest cost effectiveness was achieved in NT (16 %) then in conventional tillage and finally in MT the cost effectiveness was the lowest. It was caused by catch crop stand establishment which increased the total costs of MT technology in spite of that price of total production was higher.
Pea growing technology shows minus values of cost effectiveness because on the base of achieved grain yields it is not possible to realize production for such a price, the price of total production to be higher than the total costs. In frame of these minus values the highest cost effectiveness was reached in CT variant (-8,6 %), the lowest in MT technology (-21,9 %) where, similarly as in MT technology of barley growing, the cost increase was caused by catch crop sowing.
In agricultural practice the above mentioned economy parameters range in a little another values because the average yields (winter wheat 4,82 $t.ha^{-1}$, spring barley 3,85 $t.ha^{-1}$ and pea 2,50 $t.ha^{-1}$) do not achieve the level of yields in exact field experiments. It means that the price of total production per ha is lower. There is assumed that total costs per area unit for individual tillage technologies and crops are also in average lower. Consequently it means that the average level of cost effectiveness for food wheat and brewing barley growing in the Czech Republic is in plus values in most of cases.

Under actual market price and level of costs for growing technologies the pea growing is economically inefficient. Nevertheless in the Czech Republic there are grown about 3000 ha of pea for its excellent attributes as a pre-crop especially for cereals and as a crop improving soil properties.
Generally, to particular technologies of soil tillage for cereal growing it is possible to say that with decreasing soil tillage intensity the costs for growing technology decrease too. But in no-till technology the costs can go up owing to necessity of application non-selective and more effective (more expensive) herbicides and higher nitrogen doses to reach comparable yield with conventional technology. Use of catch crops in minimum tillage technologies for spring crops increases costs furthermore and at the same yield the profitability is considerably lower than in conventional way of soil tillage. But shallow tillage with chopped straw incorporated proves to be cheaper (see table 1:winter wheat). BRUNOTTE et al. (1996) came to the similar results when compared costs for stand establishment of sugar beet by conventional way, by sowing in mulch from frost-killed catch crop and in mulch from wheat straw.

c/ energetics

From viewpoint of energetic balances three crops grown under three different soil tillage technologies (CT, MT, NT) were compared. Results of assessing are put in table 2. Energetic inputs including different ways of soil tillage, seeds, fertilizers, pesticides and all operation from sowing to harvest are calculated according to standardized fuel consumption and kWh used in practice (PREININGER, 1987) and according to amount of chemicals and seeds consumed in given technology. The calculation comprises both direct and indirect component of supplementary energy. Energetic outputs are determined from actual measures of energetic content of main and secondary products of given crops determined as dry matter combustion heat. As a criterion for determination of energetic balances there was used energetic coefficient (energy produced and total energy inputs rate).
The highest demand of total supplementary power inputs was found in conventional tillage technology - CT (15.71 $GJ.ha^{-1}.year^{-1}$) then in minimum tillage – MT (15.49 $GJ.ha^{-1}.year^{-1}$) and finally in no-tillage – NT (14.74 $GJ.ha^{-1}.year^{-1}$) see table 2. As for crops the highest demand of total supplementary power inputs was calculated for winter wheat under CT technology the lowest inputs for pea in CT too. The best rate of energy produced and total energy inputs (i.e. the best utilization of supplementary energy inputs) for the main, respectively total product was calculated for winter wheat in MT technology. On the contrary the worst coefficient was found at pea growing in MT. The high values of total energy inputs for barley and pea in MT variant comparing with other inputs were caused by catch crop used. Positioning of catch crops in crop rotation before spring crops in MT technology does not lead to significant increase of the main and total production (energy output) both barley and pea in comparison with other soil tillage technologies.

Conclusions

- Minimization or protection soil tillage are not precarious reason for production decrease. Provided, that the basic conditions at a site are ensured it is possible to achieve the comparable or higher production than in conventional tillage.
- Minimum soil tillage with possible straw and post harvest residues incorporation shows to be as the cheapest way comparing with other two tested soil tillage variants. If the certain level of yield is provided and production is sold for a good price it can be reached high profitability of given crop growing by this tillage technology.

- In case of catch crop use MT technology come to be the most expensive from tested ways and at comparable production the cost effectiveness is the lowest.
- In no-till technology there is assumption for the cheapest soil tillage way but the costs often increase as a result of necessity to use more effective and expensive pesticides, higher dose of nitrogen and profitability is often reduced by lower production.
- In tested soil tillage technologies regardless of crops there was calculated energy demand as follows: CT (15.71 $GJ.ha^{-1}.year^{-1}$) then in minimum tillage – MT (15.49 $GJ.ha^{-1}.year^{-1}$) and finally in no-tillage – NT (14.74 $GJ.ha^{-1}.year^{-1}$).
- The highest demand of total supplementary power inputs was calculated for winter wheat under CT technology the lowest inputs for pea in CT too.
- The best utilization of supplementary energy inputs was calculated for winter wheat in MT technology.

References

Arshad, M.A., 1999: Tillage practices for sustainable agriculture and environmental quality in different agroecosystems. Soil Tillage Res., 34: 99-108.

Brunotte, J., Hollmann, P., Sommer, C., Roth, Ch., 1996: Nutzen-Kosten Vergleich zum Erosionsschutz mit Mulchsaatverfahren. Landtechnik. 51: 12-13.

Cannel, R.Q., Hawes J.D., 1994: Trend in tillage practices in relation to sustainable crop production with special reference to temperate climates. Soil Tillage Res., 30:245-282.

Dzenia, S., Szarek, P., Wereszczaka, J., Bien, E., 1999: Effectiveness of different tillage systems in rotation on very good barley complex soils. In:Proc.Conf. Ekologiczne aspekty mechanizacji nawozenia, ochrony roslin, uprawy gleby i zbioru roslin uprawnych. Warszawa: 163-168.

Javůrek, M., Vach, M., Strašil, Z., 2002: The evaluation of conventional and soil protection cropping from production, economic and energetic standpoint in Czech conditions. In: Proc. of VII Congr. ESA, Córdoba, Spain: 501-502.

Preininger, M, 1987: Energy evaluation of production processes in plant production. UVTIZ Methodology, No. 7, 29 pp.

Reinhard H., Chervet A., Sturny W.G., 2001: Effect of no-tillage on yields (1995-1999). Agrarforschung, 8: 6-11.

Strašil, Z., 1990: Energy balance of crop rotations of different crop structure. Rostlinná výroba, *36*, (LXIII), No 1: 1-7.

Šimon, J., Javůrek, M., 1999: Impact of conservation soil tillage on crop production and some soil properties. In: ISTRO Conf. Proc. „Contemporary state and perspectives of the agronomical practices after year 1999. Brno: 194-196.

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Table 1: Economic evaluation of different ways of cropping

Crop	Technology	Average yield		Direct costs / €.ha^{-1} /	Total costs / €.ha^{-1} /	Main product price / €.ha^{-1}/	Total production price / €.ha^{-1}/	Cost-effectiveness /%/
		Grain /t.ha^{-1}/	Straw /t.ha^{-1}/					
Winter wheat	CT	6,45	4,71	499	744	733	836	12,4
	MT	6,42	4,60	450	639	730	831	29,9
	NT	6,45	4,56	490	701	733	833	18,8
Spring barley	CT	5,05	3,38	451	683	691	767	12,3
	MT	5,15	3,56	491	736	704	785	6,7
	NT	5,16	3,35	441	669	706	782	16,8
Pea	CT	3,16	2,15	372	558	453	510	- 8,6
	MT	3,12	2,10	430	644	447	503	-21,9
	NT	2,81	1,83	374	561	403	452	-19,6

Notes: CT= conventional tillage; MT= minimum tillage; NT= no-tillage

Table 2: Energetic balances of different tillage technologies of choice crops (GJ.ha^{-1}. year^{-1})

Crop	Soil tillage	Energetic outputs			Total energy input	Energetic coefficient	
		Energy of main product	Energy of secondary product	Total energy output		Main product	Total production
Winter wheat	**CT**	117.74	84.28	202.02	19.66	5.99	10.28
	MT	117.20	82.31	199.51	17.60	6.66	11.34
	NT	117.74	81.60	199.34	17.99	6.54	11.08
Spring barley	**CT**	92.10	59.90	152.00	17.43	5.28	8.72
	MT	93.92	63.09	157.01	17,03	5.51	9.22
	NT	94.10	59.37	153.47	15.93	5.91	9.63
Pea	**CT**	56.66	38.63	95.29	10.05	5.64	9.48
	MT	55.94	37.73	93.67	12.25	4.57	7.65
	NT	50.38	32.88	83.26	10.29	4.90	8.09
Crop average	**CT**	**88.83**	**60.94**	**149.77**	**15.71**	**5.65**	**9.53**
	MT	**89.02**	**61.04**	**150.06**	**15.49**	**5.75**	**9.69**
	NT	**87.41**	**57.96**	**145.36**	**14.74**	**5.93**	**9.86**

Notes: CT = conventional tillage, MT = minimum tillage, NT = no tillage

Fig. 1: Grain yields of winter wheat, spring barley and pea grown under different soil tillage intensity (average of years 2001 - 2004)

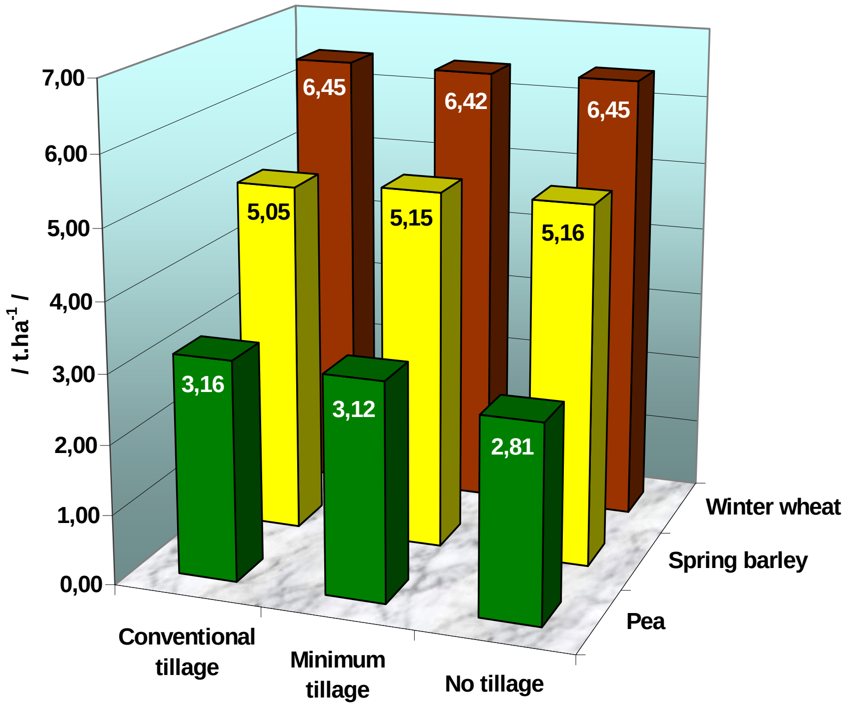
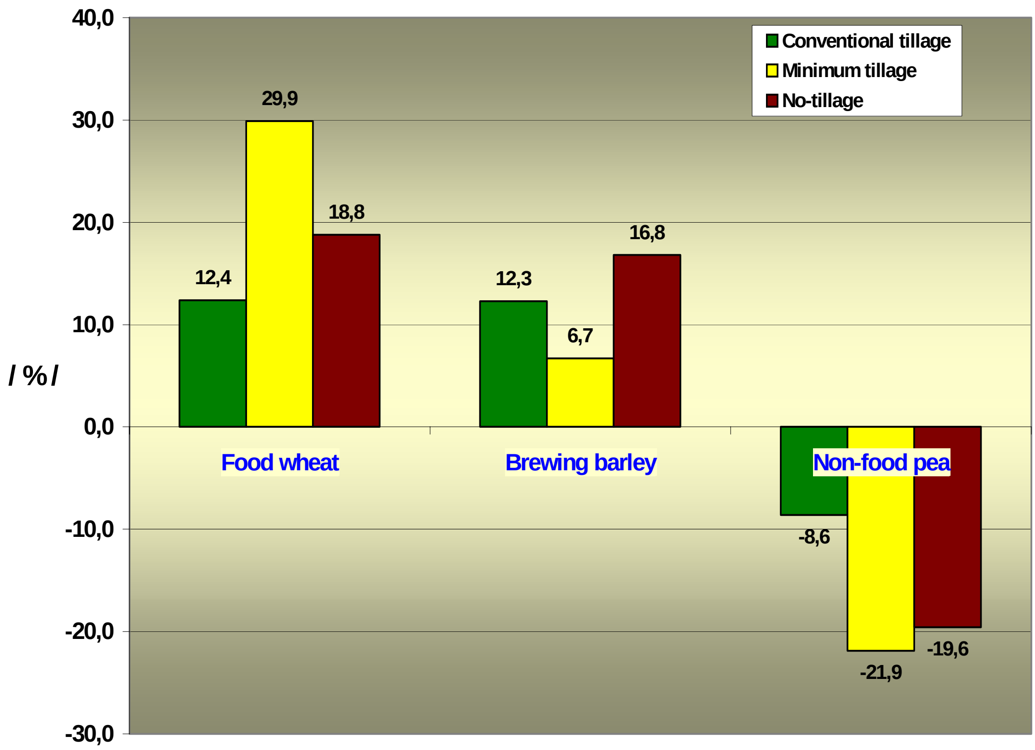


Fig. 2: Cost effectiveness of different tillage technologies for winter wheat, spring barley and pea



ASSESSMENT OF SUSTAINABILITY OF CONVENTIONAL AND CONSERVATION SOIL TILLAGE SYSTEMS BY USE OF PRODUCTIVITY, ENERGY AND ECONOMIC INDICATORS

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Introduction

Long - term experiments are leading indicators of sustainability and serve as an early warning system to detect problems that threaten future agricultural productivity. A non-decreasing trend in yield is necessary to call a system sustainable. The stability of yield is also an important characteristic to be considered when judging the value of a cropping system relative to others. Berzsenyi et al. (2000) have observed, that the yields of maize and wheat in a monoculture than in a crop rotation.

Most dry land farming system depend an tillage to grow crops. There is overwhelming evidence that repeated tillage destroying the soil resource base and causing adverse environmental impacts. Tillage degrades the fertility of soils, causes air and water pollution, intensifies drought stress, destroy wildlife habitat, wastes fuel energy and contributes to global warming. It is becoming well documented scientifically that continuous no-till is the most effective and practical approach for restoring and improving soil quality which is vital for sustained food production and a healthy environment.

With continuous no-till soil organic matter increases, soil structure improves, soil erosion is controlled and in time crop yields increase substantially from what they were under tillage management, due to improved water relations and nutrient availability. These changes help to promote a cleaner and healthier environment and a more sustainability agriculture (Papendick and Parr, 1997, Chen et al., 2004).

Numbers of field stationary experiments with various soil tillage (Hrubý et al. 1989, Miština 1992, Prochazkova, Dovrtel 2000 and others) brought much new knowledge of positive influence of minimum and no – tillage on field crops production. Using these technologies save working time, direct cost, improve farmers economy and offers wider environmental benefices. In conservation methods of crop growing the conventional crops technology with ploughing and classic bed preparation gave way to new constructions of farm machinery (Javůrek, Šimon, 2001). It does not concern a separated cultivation measures but a new integral technology of soil tillage, fertilisation especially nitrogen and suitable crop rotation. In connection with conservation tillage gets of by foreground of growing of cover crops. Appropriate conservation tillage practices for each region may make judicious use of cultivation to address soil and climatic constraints and use tillage for straw incorporation to avoid the adverse effects crop residues on the growth of the following crop (Hakansson, 1994)).

The subject of project is growing of cash crop under dry climate condition, using conservation technology with lower rate of nitrogen fertilisation and different structure of crop rotation. The aim of the study is the productivity evaluation of different crop rotation (cash crops), soil tillage system (conventional, reduced, minimum and no-till) and lower rate of nitrogen fertilisation. Some indicators such as cereal unit, soil organic matter, energy balance and economic result have been studied.

Materials and methods

The influence of the different agricultural practices on indicator of productivity and sustainability was studied in four crop rotation and tillage systems using two low rate of nitrogen fertilisation.
Field trial was located at the Research Institution of Plant Production Piešťany, Experimental Station Borovce. Research activity of station focused on study of progressive farming systems (limited inputs in water protected areas – soils in corn belt, on Luvi-Haplic Chernozems). The particle-size distribution of the surface horizon (0-0.2m) at the site is 59% sand, 25% silt and 16% clay.
The depth of the humus horizon is 0.4 till 0.5 m and it is slightly differentiated to the alluvial and illuvial horizon. The content of humus in the tilt top soil profile is medium and low in the sub tilth top soil horizon two. The tilt top soil and the sub tilth top soil horizon have the medium compaction. The soil has a high retention of water, wilting point results in the high usability of soil moisture.
At the beginning of the experiment, the average organic C content was 14g C kg^{-1} and pH varied from 5.6 to 6.1 across the experimental area.
Since 1992 to 1997 field experiments have been conducted at 32 treatments (4 crop rotation x 2 rate of nitrogen x 4 tillage systems) with four replicates with all phases of each rotation present each year which represents 128 small plots (3 x 6 m for each). The split-plot design has been used. The experiment was established in the autumn 1991 with following treatments:
Soil tillage treatments
CT - conventional soil tillage - after forecrop the soil was ploughed to the depth of 0.2 m (0,30 for sugar beet). For seedbed cultivation a cultivator was used. Seeding was done by conventional drill Amazone D8-30 together with a tine harrows. For the maize, sugar beet and sun flower drilling, the standard planter was used.
RT - reduced soil tillage - shallow soil loosening to the depth 100 – 120 mm**,** for primary tillage the stubble tiller L-S 90/380 equipped with press wheels was used. Seeding was done by conventional drill Amazone D8-30 Special joined with rotary harrows Amazone KG. For the maize, sugar beet and sunflower drilling the standard planter was used.
MT - **minimum soil tillage** – during field experiment the different equipment for soil cultivation was used During 1992 – 1993 soil was cultivated by RAU-Rototiller joined with RAU-Rotosem drill equipped with an air seeding mechanism, in the year 1994- 1995 Horsch EXACTOR was used and in the years 1996 – 1997 drilling with Tye planter following shallow loosening to the depth 010 – 0.12 m (for the sugar beet deep loosening) was used.
NT **- no-till production -** planters for no - till system following application of system herbicide was used. Crop residues were chopped by combine harvester chopper and spread over the surfaces of the field, followed by no-till drilling (1992 – 1995 Moore, 1996 – 1997 Tye planter was used). For the sowing of maize for grain and sunflower KINZE 2000 was used.
Crop rotations systems (cash cropping system)
CR1 - sugar beet, spring barley, peas, winter wheat, sunflower, winter wheat
CR2 - winter wheat, maize, spring barley, spring oil rape, spring barley, peas
CR3 - peas, winter wheat, maize, spring barley, oil winter rape, spring barley
CR 4- spring barley, peas, winter wheat, sunflower, maize, spring burley
Treatments of NPK fertilisation as follows in order N1 and N2. Winter wheat and spring barley 50 / 25, maize, oil rape 80 /40, sunflower 60/30, sugar beet 40 both treatment and pea 20/ 10 kg $N.ha^{-1}$ annually. Rate of P K 40 $kg.ha^{-1}$ were used for the each treatment.

The productivity system calculated by cereal units, pesticide and fuel costs, brutto energy, content of soil organic matter and total nitrogen, potassium and phosphorus after six year rotation have been assessed. Labour consumption was calculated by growing winter wheat, spring barley and maize only.

Results and discussion

The average productivity of trials represent by cereals units (CU) was ranged from 4.94 CU t ha $^{-1}$ (1997) to 7.78 CU t ha^{-1} (1992). The highest production of CU was reached in crop rotation CR1 (7.01 _t ha^{-1}) which include sugar beet. The lowest average production of CU was reached in crop rotation CR 2 (5.58 t ha^{-1}) which included spring oil rape. The production of CU was significantly influenced by soil tillage treatments. The best productivity has been noted in conventional (CT) and reduced system (RT) of soil tillage. The significant differences between conventional tillage (CT) and minimum (MT) and no-till (NT) have been noted **(Fig. 1)**.

The higher level of nitrogen fertilization with comparison to half dose of nitrogen, support higher productivity of CU up to 5.39%. Average production of all crop rotations and treatments was 6.22 CU. The highest one was at conventional tillage (CU 6.4 t h^{-1}) and in crop rotation CR I (7.01 CU t h^{-1}).

Productivity of evaluated treatments **(Tab. 1)** was influenced by weather conditions, crop rotations, nutrient fertilization (highly significant) and soil tillage (significantly). The weather predominantly modifies the influence of crop rotation and than soil tillage (highly significant).

Table 1. Analysis of variance

Source of variation	Sum of squares	d.f.	Mean square	F-ratio
Crop rotation A	52.24	3	17.41	60.17++
Soil tillage B	3.12	3	1.04	3.59+
Fertilisation C	6.33	1	6.33	21.88++
Years D	156.01	5	31.20	107.81++
Interactions				
AxD	315.04	15	21.00	72.57++
BxD	10.17	15	0.67	2.34++
Residual	37.33	129	0.28	
Total	586.29	191		

The assessment of pesticides and fuels costs, labour consumption by growing winter wheat, spring barley and maize for grain reveal the higher cost for pesticide consumption by using no till and minimum tillage technology. On the other hand, the fuel cost and labour consumption was higher by using conventional technology of soil tillage **(Fig. 2)**. The highest brutto energy output was by CT (216 GJ h^{-1}) and in crop rotation CR 4 (224 GJ ha^{-1}) with spring barley, peas, winter wheat, sunflower, maize, spring burley sequences and the lowest one by NT (202 GJ h^{-1}) and in CR 2 (193 GJ h^{-1}) with winter wheat, maize, spring barley, spring oil rape, spring barley, peas sequences (**Fig. 3**).

The earthworms are consider as bio indicator that can be used as quantitative indicator in soil health assessments (Mitchell et al. 2000). The biomass of *lumbricidae*, as documented Marko

et al., (1995) at the same trials gave evidence of positive influence of reduced, minimum and predominantly no tillage of soil **(Fig. 4**).
The basic agrochemical soil properties after first complete crop rotation period expose the data in **Table 2**. The agrochemical soil properties were not affected by crop rotation nor by soil tillage treatment.

Table 2 The basic agrochemical soil properties after finish of experiment, in the year 1997

Variant	C_{ox}	Nt	pH	K	P	Mg	Ca
CT	1.49	0.1459	6.47	408	141	381	3250
RT	1.62	0.1539	6.42	434	153	357	3460
MT	1.66	0.1602	6.24	489	168	388	2817
NT	1.56	0.1509	6.25	409	145	366	2958
CR 1.	1.62	0.1582	6.46	392	140	432	2826
CR 2.	1.55	0.1525	6.65	434	129	343	3787
CR 3.	1.55	0.1484	5.84	462	171	346	2568
CR 4.	1.62	0.1517	6.43	454	167	382	3304

The highest content of C_{ox} and Nt was measured by shallow soil loosening to the depth 100 – 120 mm RT (1.62% $C_{ox,}$ 0,1539% Nt) and by minimum tillage MT (1.66%C_{ox}, 0,1602% Nt). Between C_{ox} and Nt content was significant relation expressed by polynomial trends **(Fig. 5)**. The using of conventional tillage in our special trial decrease soil organic matter substantially. The using and dissemination of appropriate tillage technologies is one of the measure for C sequestration in agricultural soil which is serious problem solve by present research projects. The objective of this research is to provide a quantified assessment of likely carbon sequestration in soils from practical management options and management effects in cropland (Liebig, 2005)
Our results reveal considerable qualitative differences between the varying crop rotation and soil tillage treatment. Crop rotation is a key factor regarding market crops. In discussing cropping sequence for a balance rotation we are recommending a minimum of four or five different crops in a rotation. From the point of utilizing of soil fertility we can recommend winter wheat and maize for grain, which offer good productivity expressed by cereals unit. When reduced contact intensity (minimum and no-till treatment) the comparative trials with different soil tillage system provide evidence of positive effect on content of soil organic matter and on the biological mass and the abundance of earthworm which are more then two times as many as in ploughed soil. The same results was published by Tebruge (1995). The cost for pesticide, oil and labour reveal quite clearly that the ploughing procedure involves the higher cost for oil and labour work.
The most stability of crop production in the years 1992 – 1997 was ensured by the suitable crop rotation with higher evaluated level of nitrogen from mineral fertilizers. The results of field stationary experiment show the different possibilities for using soil conservation tillage (especially No - till) with interaction of weather and crop rotation. Nitrogen fertilisation and suitable crops such as winter wheat and maize for grain offer yield production which is comparable with conventional crop production system.
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References

Berzsenyi, Z., Gyorffy, B.,Lap, D. (2000): Effect of crop rotation and fertilisation on maize and wheat yields and yield stability in a long-term experiment. European Journal of Agronomy 13, (2-3): 225-244

Hakansson, I. (1994): Tillage for crop production and fpr protection of soil and environmnetal –wuality – a Scandinavian viewpoint. Soil and Tillage Research. 30, (2-4): 109-124

Hrubý, J. (1989): The effect of different cultivation of soil on the yield-forming components of winter-wheat varieties. Rostl. výroba, 36, 3, 249-258

Javůrek, M., Šimon, J. (2001): The influence of stand establishment and site conditions on grain yield of winter wheat. Rostl. výroba, 47, 11, 513-519

Liebig M.A, Gollany, H.T. (2005): Sequestering Carbon in Cropland, Effects of Management in Semiarid Regions of NW USA and Western Canada. USDA, 105 p.

Marko, F. et al. (1995): Rozširovanie pestovania kukurice bezorbovou technológiou. (Správa za riešenie účelovej činnosti MP SR v roku 1995), 42 p.

Marshall, E.J.P. (1993): Soil biota as bioindicators of sustainability and biodiversity of agroecosytems. In: Agriculture, Scientifics basis for codex of good agricultural practice. Report. EUR 14957 En. L-2920 Luxemburg, 95-100.

Miština, T. (1992): Aspects of the further development of grain production under the new social and economic-conditions. Rostl. výroba, 38, 8, 624-626

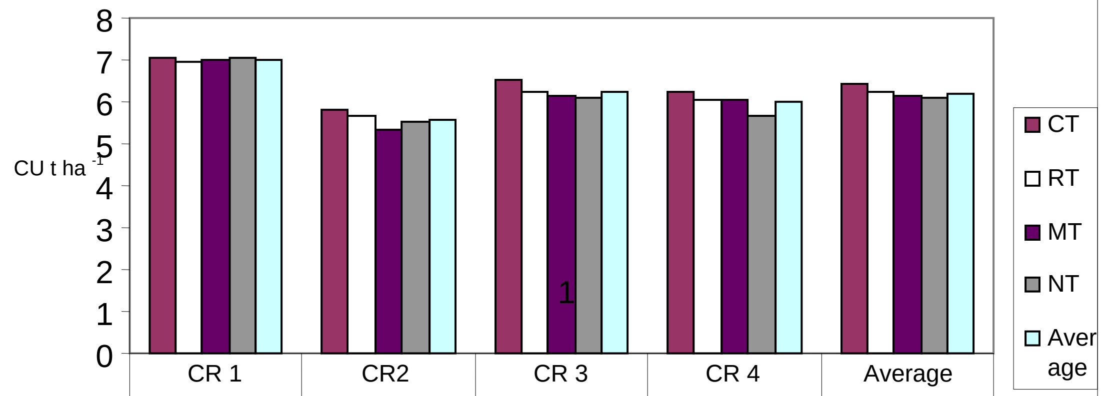
Mitchell, J. et al. (2000): Soil management and soil quality for organic crops. University of California: Division of Agriculture and Natural Resources. Publ. No. 7248

Papendick, R.I, Parr, J.F. (1997): No-till farming: The way of the future for a sustainable dry land agriculture. In: Annals of arid zone 36 (3): 193-208

Prochazková, B., Dovrtěl, J. (2000): The effect of different soil tillage on the yields of winter wheat. Rostl. Výroba, 46, 10, 437-442

Tebrugge, F. (1995): Workshop summary. In: Experience with applicability of no-tillage crop production in the West-European countries. C.A. No AIR 3-CT93-1464. Proceedings of the EC-Workshop-II-Silsoe,15-17 May,1995.

Fig. 1. Production of average cereals units at crop rotation and soil tillage treatments, in the years 1992 - 1997 (t ha $^{-1}$)



	CR 1	CR2	CR 3	CR 4	Average
CT	7.03	5,82	6,52	6,25	6,43
RT	6,95	5,68	6,25	6,05	6,23
MT	7	5,32	6,15	6,06	6,13
NT	7,06	5,51	6,11	5,67	6,08
Average	7,01	5,58	6,25	6.00	6,21

Fig. 2. Pesticides (P),fuel (F) and labour consumption (LC) at soil tillage treatments (CT,RT,MT,NT) by growing winter wheat (WW), spring barley (SB) and maize for grain (M)

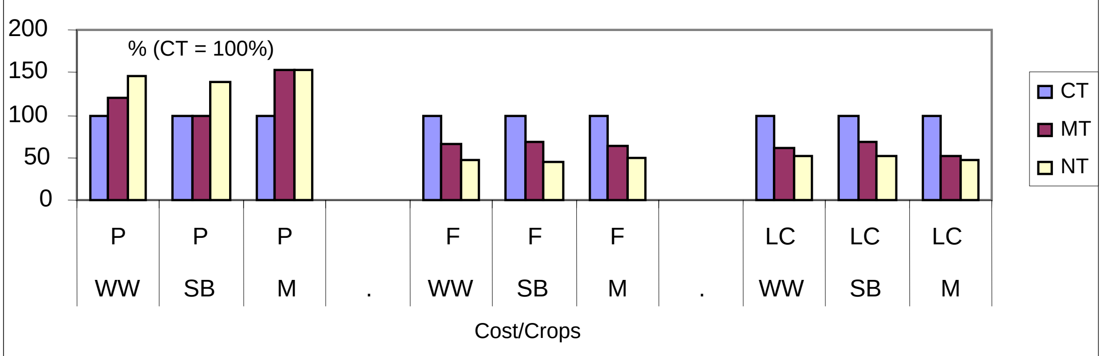


Fig. 3. Average brutto - energy output at treatment crop rotation and soil tillage in the years 1992 - 1997 (GJ/ha)

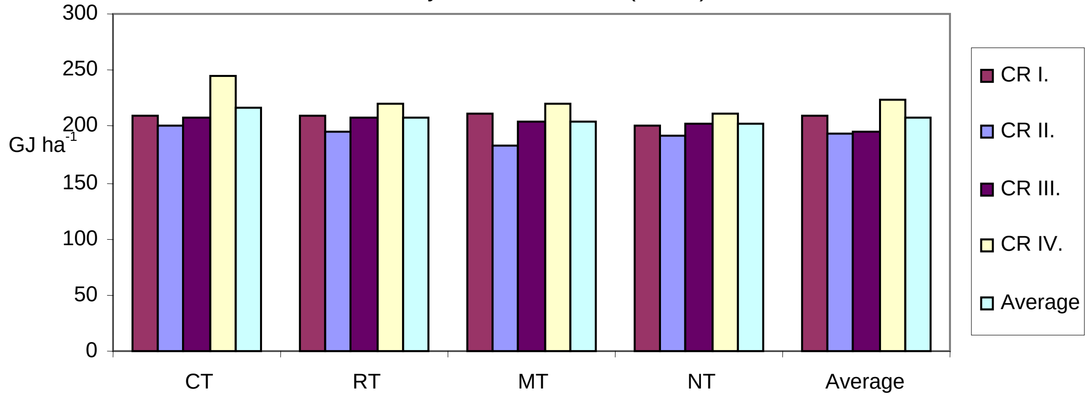


Fig. 4. Biomass lumbricidae weight at CT, RT, MT and NT soil tillage in the years 1995 - 1996 kg ha^{-1} (Marko et al.,1995)

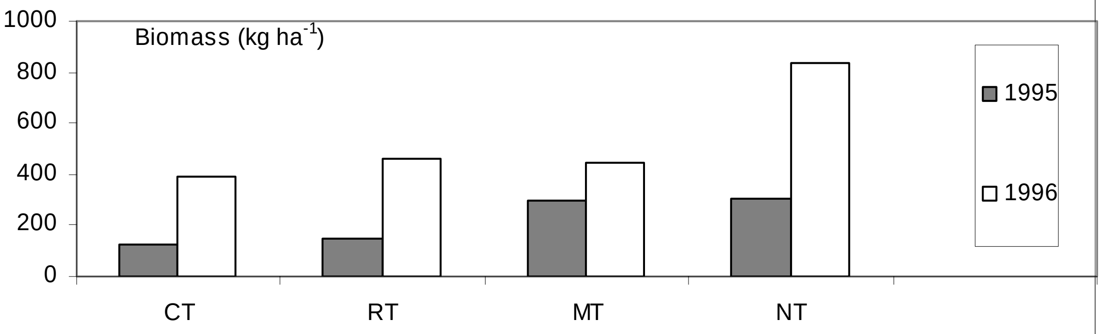
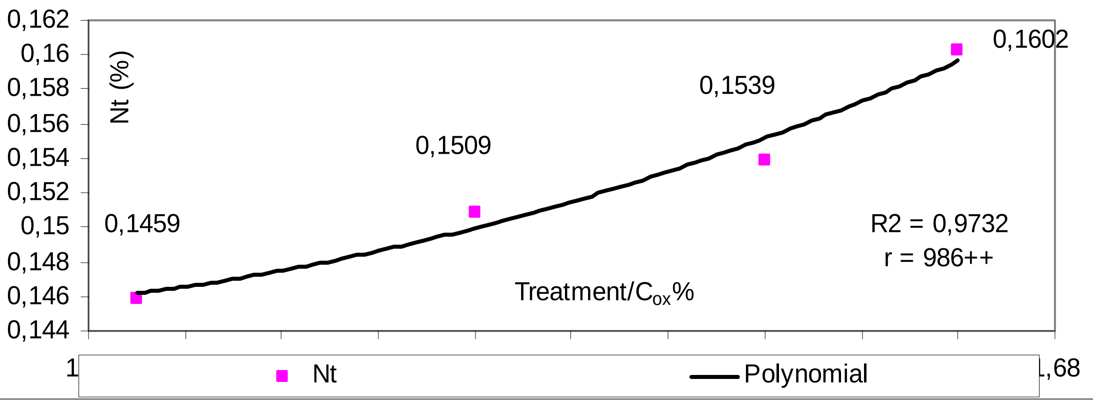


Fig.5. Relation between C_{ox} and Nt at soil tillage treatments (CT,RT,MT,NT)



CATCH CROPS AND THE SOIL ENVIRONMENT

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Abstract

The impact of selected green manure catch crops on the soil structure was analyzed in field trials (1999-2005) at different periods since they were ploughed. For evaluation the soil structure coefficients were applied. The structural stages of soils were found to be strongly dependent on the soil kind at the experimental site, as well as on the weather conditions before sampling.
A positive impact of catch crops ploughed down as compared with a variant without catch crops use, remained present in soils from the day, when catch crops were ploughed down, till the time of the following crop (spring barley) harvest; it however have no influence upon the grain yield and quality, presumably at the arid climatic conditions.
At the 35 years long lasting field experiments the impact of catch crops use (like white mustard, phacelia) was evaluated in the combination with the straw ploughed down in the cereals monocultures from the point of view of the soil humus content and quality.
Long lasting use of catch crops aimed at the increase of both the amount and quality of humus in soils. Contents of all humus- and humic acids, as well as relation between humic- and fulvic acids were increasing, namely if the straw was ploughed down simultaneously.
Using catch crops decreases the content of nitrates in soil both in autumn and spring, but after autumn ploughing term the nitrate content in spring was increased.

Key words: Catch crops, soil structure coefficient, humus, nitrate content

Introduction

In Czech agricultural enterprices on middle or less fertile soils, especially without animal husbandry, is missing the enriching effect of farmyard manure and lucerne or clovers. The support of organic matter into soil is decreasing. This status may be one of the reasons of decreasing soil fertility and soil physical properties.
Using of suitable catch crops for green manure is one of the measurements leading to enrich soil organic matter and stimulate the biological activities in the soil. Organic matter from tops and roots of plants improves the soil physical status and before catch crops ploughing down protects soils against erosion.
Organic matter in the soil increases other soil properties. Some soil humus fractions create calciumhumates, that are important for realizing soil aggregates. The improved state of soil aggregation is due to an increase in organic carbon. The positive influence on the soil aggregation depends also on the kind of plant, i.e. catch crops species or variety, plough down terms etc. Soil aggregates under 0,1 mm have lower soil organic carbon value. The relations among structural state of soil, C_{ox} and humic acids are positive.

The aim of this contribution is to solve some questions connected by using catch crops in farming systems and relations of their growing to soil structure state and nitrate content in the year of establishment the stands and by the following crop, and in the long term experiments to analyze the impact of catch crops using on the organic matter or humus content in the soil and its quality.

Materials and methods

In the first field experiment was studied the impact of catch crops on the soil structure. The experiments were established in the years 1999 and 2001 in sugar beet growing region at Troubsko on degradeted chernozem in split-plot design in four replications. The altitude of the experimental site is 280m above sea level, average annual temperature 8,6^{o}C, average rainfalls 547 mm. Content of phosphorus and potassium good, pH 7,2. The various catch crops were sown after the winter wheat harvest and plough down before winter. In the spring was sown the spring barley. The soil samples were extracted inthe time of catch crops ploughing down, before spring barley sowing and after harvesting. Soil samples were evaluated by soil structure coefficient (agronomic valuable and less valuable soil aggregates ratio).
The impact of catch crops on the organic matter content in soil and humus quality was evaluated from the long term field trials with monocultures of cereals in Ivanovice established in 1965. The experimental site is in the sugar beet region, the altitude is 225 m, average annual temperature 8,6^{o}C, average rainfalls 542 mm. Content of phosphorus and potassium good, pH 7,0. Samplings was done 35 years after establishment in the year 2000 from the variants with long term using of catch crops (white mustard, tancy phacelia). The soil samples were from the horizon 0 – 200 mm in 6 repetitions in each variant. On the variants with long term straw ploughing down was additional fertilization 20 kg N.ha^{-1}. The content of organic matter (C_{ox}), content of humus acids, humic- and fulvic acids were identified.
The content of nitrates in soil was studied in the years 2004-2005 in Troubsko in the terms in autumn, when the catch crops were ploughed down and then in the spring (variants with catch crops ploughed in autumn and in the spring.

Results and discussion

Five catch crops species sown in summer after the winter wheat harvest (white mustard – Sinapis alba, oil radish – Raphanus sativus var. oleifera, tancy phacelia – Phacelia tanacetifolia, fodder mallow – Malva vericillata, safflower – Carthamus tinctorius and winter rye – Secale cereale, var. multicaule) were used in the field experiments. The highest yields of dry matter of tops and roots were by white mustard (about 6,5 t.ha^{-1}), the lowest by safflower (about 1,5 t.ha^{-1}). There were also considerable differences among crops in the water content, in the relation of top and root mass, and in the speed of resolution of their mass in the soil. The soil structure coefficients are in the following table.
The results show, that the structural state in the term of catch crops harvest or plough down before winter and in the spring months is similar. The variants without catch crops had the structural coefficient 1,10 – 1,13, with catch crops 1,16 – 1,28. Next year after the spring barley harvest was the structural state better (better weather conditions in the term of sampling), but first of all it was influenced by support of catch crops organic matter into soil (variants without catch crops 2,7, with catch crops 3,22 – 5,19).

Table 1
The impact of catch crops on the soil structure

	Structure coefficient		
	catch crop harvest	spring barley sowing	spring barley harvest
Without catch crop	1,10	1,13	2,70
White mustard	1,42	1,16	4,24
Oil radish	1,21	1,22	5,24
Tancy phacelia	1,25	1,26	5,19
Fodder mallow	1,28	1,22	3,22
Safflower	1,28	1,18	4,89

The structural state of soils depends on C_{ox} and humic acids content (Ridky 1977, Bajracharya et al. 1998, Rimovsky 1966, Castro-Filho et al 1998). In accordance with our results Mushtag (1973) described also, that positive influence on the soil aggregates stability and soil structural state depends on the kind of catch crop.

Table 2
The impact of catch crops on the humus content and quality

	Variant			
	Straw harvesting	Green manuring	Straw ploughing down	Straw ploughing down and green manuring
C_{ox} content in %	1,57	1,61	1,61	1,68
Humus content in %	2,71	2,77	2,78	2,90
Relative comparison	100,00	102,20	102,60	107,00
Humus acids content in %	0,70	0,74	0,70	0,73
Relative comparison	100,00	105,70	100,00	104,30
Humic acids content in %	0,40	0,41	0,42	0,45
Relative comparison	100,00	102,50	105,00	112,50
Fulvic acids content in %	0,30	0,33	0,28	0,28
Relative comparison	100,00	110,00	93,30	93,30
HA:FA ratio	1,33	1,24	1,50	1,61

The results in table 2 from the 35 years long lasting field experiment show, that using catch crops for green manure increases C_{ox} content in the soil by 0,04% and plough down straw by 0,07% absolutely, i.e. 2,2 and 4,4% relatively. Content of humic acids carbon was also increased with using catch crops from 0,40 to 0,41% and in combination with straw from 0,42 to 0,45%, i.e. relative increasing 2,5 and 7,5%. The similar results were given by e.g. Perfilev (1995). Ploughing down only the catch crops increasa the content of fulvic acids carbon, by using straw or in combination straw with green manure the fulvic acids carbon content decreases. The best effect was achived by long using of green manure (easily resoluble organic matter) and straw (slowly resoluble organic matter) simultaneously.

Table 3
Content of nitrates in mg.kg^{-1}

Catch crop	Nitrate content		
	Ploughed in autumn Content in autumn	Ploughed in autumn Content in spring	Ploughed in spring Content in spring
Without catch crop	4,3	8,0	2,8
White mustard	2,4	10,3	1,8
Tancy phacelia	3,6	9,5	2,3
Fodder mallow	4,2	8,5	2,5
Safflower	4,1	8,3	2,6
Winter rye	2,3	10,2	1,5

The level of nitrate content in the soil after the catch crops ploughed down was quite small, especially in spring. The highest content was achieved on the variants without catch crop and on the variants with smaller yields of green matter. On the opposite, the smallest nitrate content in the soil was on variants with better yields (white mustard, winter rye). Similar results were also shown by Gustafson et al. (1998) and Stenberg et al. (1999).

Conclusions

In the field trials established in 1999 - 2002 on degradeted chernozem in the sugar beet growing region in the Czech Republic was observed the impact of catch crops species on the soil structure state. Catch crops for green manuring sown after the winter wheat harvest showed similar positive effect on the soil structure coefficient (relation between agronomical valuable and less valuable soil aggregates) in the time of catch crops ploughing down before winter and in the spring before sowing barley, practically on the same level. The positive effect was increased after the spring barley harvest.
In long lasting field experiment established in 1965 on typical chernozem in similar agroecological conditions was observed the impact of long lasting catch crops and straw plough down on the C_{ox}, humus and humic acids content. Trends to increase C_{ox} content in the soil, humus acids and humic acids carbon were found out consequently to catch crops and straw plough down during the 35 years. The only ploughing down of catch crops leads to decreasing of HA : FA ratio, on the other hand combination of catch crops and straw leads to increasing ratio value.
Using catch crops decreases the content of nitrates in soil both in autumn and spring, but after autumn ploughing term the nitrate content in spring was increased.

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References

Bajracharya, R M.- Lal, R,- Kimble, J.M.: Long term effect on soil organic carbon distribution in aggregates and primary particle fractions of two Ohio soils. Management of carbon sequestration in soil, Boca Raton, 1998, 113 – 123

Castro-Filho, C.- Muzilli, O.- Podanoschi, A.: Estabilidade dos agregados e sua relacao com a teor de carbono organico num latossolo roxo distrofico, em funcao de sistemas de plantio, rotacoes de culturas e metodos de preparo das amostras. Revista Brasiliera de Ciencia do Solo, 1998, 22,3, 527 – 538

Mushtag, M. A.: Der Einfluss von Pflugfurche, Fraesdrill- und Direktsaat in Verbindung mit Zwischenfruchtanbau auf Gefuegekennworte einer Filderlehm-Parabraunerde und den Ertrag von Winterweizen. Diss., Univ. Hohenheim, 1973

Perfilev, N. V.: Basic soil cultivation and the humus status of dark grey forest soils of the Northern Trans-Urals. Zemledelie, 1995, 5, 8 – 9

Ridky, K.: Pudni organicka hmota jako regulator dynamiky rostlinnych zivin v pude. Proc. Conf. Recycling of organic matter into soil, Ostrava, 1977

Rimovsky, K.: Funkce, premeny a zdroje organicke hmoty v pude. Uroda, 1996, 10

STUDY ON ECOLOGICAL AND ECONOMIC IMPLICATIONS OF THE CAPITALIZATION OF SLOPING IRRIGATED LANDS IN THE MOLDAVIAN PLAIN (NORTH-EASTERN ROMANIA)

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Abstract

The paper presents the results of investigations conducted on the North-Eastern area of Romania for establishing the modalities of efficient watering application, both as concerns the maximum capitalization of irrigation water and the conservation of soil fertility and environment quality.
For a sustainable capitalization of cultivated sloping lands by irrigation, it is necessary that environment requirements prevail to the detriment of economic reasons.
The establishment of an optimum ratio between: water consumption - crop - antierozional protection under conditions of natural frame in the area requires the application in wheat and maize of irrigation rates until 800 m³/ha.

Key words: sustainable capitalization of sloping land, irrigation management, soil fertility conservation, humus and nutrients losses, environment protection

Introduction

The dry character of the climate in the Moldavian Plain, expressed by an average deficit of rainfall varying between 73 mm in the Northern side and 168 mm in the Southern side is stressed by the rainfall torrential character (70-75 % of the total), resulting in a weak rainfall capitalization, when more than 60 % (approximately 365,000 ha) of the cultivated area is found on higher than 5 % slopes. Within this natural frame, the superior capitalization of soil agro-productive potential is conditioned by irrigation. Hydro ameliorative interference is made easier by the presence in this area of 320 ponds and accumulation lakes, which store about 185 mil m³ water, qualitatively corresponding to this purpose.
As concerns the modalities of efficient watering application, both as the maximum capitalization of irrigation water and maintaining or even improving soil fertility and environment quality, the investigations conducted had as an aim to contribute to the study of the mechanism of the erosion process and to the improvement in management techniques for irrigated sloping lands.

Material and Methods

At the Agricultural Research and Development Station of Podu-Iloaiei, Iasi county, experiments were conducted in order to estimate the effect of irrigation by sprinkling in main crops on water, soil and fertilizer losses, on a cambic chernozem having a loamy-clayey structure, poorly eroded, with a good mineral fertility, characterized by the following physical and hydro-physical indices, mean values on a depth H=0.8 m; bulk density BD=1.39 g/cm³, wilting coefficient WC=13.3% g/g, field capacity FC=25.0% g/g and the final intake rate F_{ir} =13.7 mm/h. Research was carried out according to the experiment technique regulations, on plots of leakage monitoring (4 x 25=100 m²) located on terraces having a slope of 11%. The elements of irrigation regime were established on the balance calculation of water in soil and namely according to the dynamics of soil moisture, the climate conditions and plants requirements. In order to save water and to decrease the erosion risk especially for torrential rainfall, irrigation rates have been limited to 400 and 600 m³/ha.

Results and discussion

In the autumn of 2003, the climate ensured good conditions for field preparation, sowing and sprouting of winter crops. September and October rainfall ensured the water necessary for these crops and the temperature registered during November and December has favored wheat tillering. Until the second decade of May, wheat developed almost normally but, after this period, it suffered because of the drought, the water deficit from soil reaching the equivalent of a watering norm of 500 m³ /ha (Table 1).

Table 1

Soil moisture under un-irrigated in winter wheat and grain maize crops in 2004

Winter wheat				Grain maize			
Humidity		Deficit FC - W (m³/ha)	Stock easily allowable W-MMC (m³/ha)	Humidity		Deficit FC - W (m³/ha)	Stock easily allowable W-MMC (m³/ha)
% g/g	m³/ha			% g/g	m³/ha		
12. IV - beginning of straw formation				26. IV - sowing			
20,59	2254	456	248	25,06	2745	- 35	739
26. IV - straw elongation				5. V - sprouting			
19,01	2083	627	77	20,37	2233	477	227
5. V - flag leaf appearance				1. VI - flowering-grain formation			
16,08	1761	949	- 245	19,64	2153	557	147
1. VI - flowering-grain formation				16. VII - milking			
13,72	1504	1206	- 502	22,16	2429	281	423

The rainfall regime in 2004 showed a characteristic of the climate in the Moldavian Plain, there is, although quantitatively sufficient for ensuring water to plant demands, by spreading it in time, rainfall did not result in optimum conditions for crop development. Because of the sloping land, the torrential rainfalls were weakly capitalized, which was reflected by the dynamics of soil water stock (Table l), and evolved during the vegetation period under the minimum moisture content (MMC).

Determinations carried out on leakage control plots showed, by the results obtained during the testing period, that under irrigation, water, soil and nutrients losses (Table 3) were higher to those registered under un-irrigated (Table 2), as a result of maintaining soil moisture at higher values, which required to subordinate irrigation to the erosion risk. We also confirmed the important role of vegetation among erosion factors, water and soil losses depending on the crop covering degree. As a result, the degree of crop covering differentiated much the values of losses which varied, according to the rainfall regime, between 108.4 m³ / ha in black field variant, 83.4 m³/ha in maize, 87.0 m³ /ha in soybean and 62.6 m³ /ha in wheat. The same variation was found in the case of eroded land amounts, being of 2.32 t/ha on black field, 1.52 t/ha in maize crop, 1.49 t/ha in soybean and 0.77 t/ha, respectively, in wheat crop (Table 2).

Under irrigation, runoff and losses have registered much higher values, finding the same graduation of soil protection by vegetation, water and soil losses increasing from cereals to row crops. At the same time with water and soil losses, significant humus and nutrients amount have been removed. The lowest humus and macroelements losses were found in wheat, as a result of a shorter vegetation period and of the higher degree of soil covering and the highest losses were found in sugar beet (Table 3).

If under un-irrigated, soil losses found in all tested crops maintained within allowable limits - as a result of a reasonable land management compared to the anti-erosion requirements - by applying additional water to crops, according to registered rainfall during the vegetation period and to the adopted irrigation regime, we could notice that in the case of row crops the eroded soil amounts exceeded the allowable limits (maize - 6.32 t/ha, beet - 6.67 t/ha, soybean - 5.95 t/ha) (Table 3). For the conservation of soil fertility under irrigation, it was necessary to be adopted other measures with anti-erosion character which complete the effect of the above-mentioned. During the investigation, it was also followed the effect of rainfall which could appear at short time intervals after irrigation.

Table 2

Runoff and soil losses registered in different crops under un-irrigated on lands with a slope of 11 % at Podu-Iloaiei, Iasi county

Data	Rainfall causing runoff (mm)	Soybean		Winter wheat		Sugar beet		Maize		Bare	
		Runoff water (m^3/ha)	**Eroded soil** (t/ha)	Runoff water (m^3/ha)	**Eroded soil** (t/ha)	Runoff water (m^3/ha)	**Eroded soil** (t/ha)	Runoff water (m^3/ha)	**Eroded soil** (t/ha)	Runoff water (m^3/ha)	**Eroded soil** (t/ha)
9 - 12 III	zăpadă	13,4	0,21	5,6	0,06	14,2	0,19	12,3	0,19	14,2	0,18
21. VI	14,2	8,6	0,21	4,2	0,08	9,7	0,22	9,0	0,22	9,8	0,24
12. VII	27,3	9,8	0,19	6,8	0,08	10,4	0,19	7,9	0,21	11,9	0,31
13. VII	14,5	6,7	0,12	5,2	0,06	7,2	0,15	6,8	0,11	8,9	0,24
14. VII	22,7	11,6	0,22	8,5	0,15	12,5	0,25	11,5	0,22	14,8	0,32
31. VII	33,7	11,5	0,14	8,9	0,10	10,8	0,13	10,8	0,19	16,4	0,38
1. VIII	14,9	6,4	0,09	7,5	0,09	8,2	0,10	7,5	0,11	8,2	0,12
4. VIII	48,4	13,6	0,25	11,8	0,12	13,2	0,27	12,4	0,18	16,8	0,38
7. VIII	21,5	5,4	0,06	4,2	0,03	4,9	0,04	5,2	0,09	7,4	0,15
Total	197,2	87,0	1,49	62,6	0,77	91,1	1,54	83,4	1,52	108,4	2,32

Table 3

Runoff, soil, humus and macro elements losses registered in different irrigated crops (1.1- 31.VIII)

on lands with a slope of 11 % at Podu-Iloaiei, Iasi county

Crop	Depth of irrigation (mm)	Runoff water (m^3/ha)		Eroded soil (t/ha)		Humus (kg/ha)		Total nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium (kg/ha)	
		U	I	U	I	U	I	U	I	U	I	U	I
Soybean	2 x 600	87,0	178,3	1,49	5,95	83	184	11,1	16,0	0,41	0,78	0,76	1,74
Wheat		62,6	84,5	0,77	1,71	23	52	2,2	4,6	0,09	0,22	0,28	0,50
Beet		91,1	179,8	1,54	6,67	96	206	11,5	18,2	0,48	0,88	0,79	1,95
Maize		83,4	175,1	1,52	6,32	89	195	11,2	17,8	0,47	0,83	0,78	1,85

U - unirrigated; I - irrigated

By applying watering norms of 700 m^3/ha, with intensities of sprinkled water lower than the final infiltration speed of water into soil, runoff and soil losses had relatively reduced values. For the assessment of the risk of a higher erosion in the case of rainfall after watering application, the next day 250 m^3/ha have been also applied with the same intenseness. After irrigation, losses have considerably increased (149 m^3/ha in beet crop and 151 m^3/ha in maize crop). A significant evolution was registered by soil losses, which increased over 4 times, reaching 0.58 t/ha and 0.73 t/ha, respectively. The same phenomenon was also found when lower watering norms have been applied, at relatively reduced time intervals, with intensities of sprinkled water greater but not exceeding the value of final infiltration speed of water into soil.

The study on the humidity regime and on balance of soil moisture pointed out that under un-irrigated the water stock has frequently decreased under the value corresponding to the minimum threshold and sometimes, even under the one of wilting coefficient, the crop level being greatly influenced by the evolution of the rainfall regime compared to phonological phases.

For establishing the effect of irrigation on erosion and yield, during the experiments, the irrigation regime has been studied in two variants, by the application of different irrigation norms. The diminution in irrigation norms was done by applying the same number of watering amounts, with differentiated watering norms of 20 mm, lower than the ones necessary to soil moistening at the value of field capacity on the entire thickness of soil active layer. We also gave up to watering application within the intervals between main critical phases for water, even if soil moisture decreased under the value of the minimum threshold established at 50 % of range of available moisture content.

Compared to the optimal regime (Table 4), irrigation norms of 800 and 1200 m^3/ha, respectively, have been applied, split by two watering amounts. The results obtained showed that in variants irrigated with the lowest norms, runoff did not register a significant evolution compared to the one registered under un-irrigated and yield increases were important (Tables 5 and 6). In wheat, during May-June, as an effect of irrigation, the runoff water amounts increased from 62.6 m^3/ ha to 71.3 m^3/ ha. A very important aspect is that in the case of applying an irrigation norm until 800 m^3/ ha, split in two watering amounts, additional soil losses were not registered compared to un-irrigated variant. We must say that the water amounts, allowable as concerns the erosion control, have been applied on a terrace arranged slope, managed on the general direction of a contour line, in a fertilized crop, found in a good rotation.

Table 4

Elements of the irrigation regime applied in wheat and maize crops in 2004 on sloping lands (i_t = 11%)

Elements of irrigation regime	Grâu de toamnă				Porumb pentru boabe			
	Depth of irrigation (m^3/ha)	Number of watering application	Application time	Irrigation rate (m^3/ha)	Depth of irrigation (m^3/ha)	Number of watering application	Application time	Irrigation rate (m^3/ha)
Optimum	700	3	1. V; 20 V, 2. VI	2100	3	700	10 V, 3. VI, 23. VI	2100
Deficit	400 (600)	2	6. V; 2. VI	800 (1200)	2	400 (600)	10 V, 5. VI	800 (1200)

In maize, in the context of the same minimum measures for anti-erosion protection, irrigation norms until 800 m³/ha, split in two watering applications, resulted in increasing runoff water volumes by 28 % and in slight increase in soil losses.
The application of some watering norms of 40 mm, with intensities of sprinkled water lower by 10 % than the value of the final infiltration speed, which ensured soil moistening on the depth until which the greatest part of the root mass developed determined, according to the degree of soil covering by plants, corresponding to the growing technology and the vegetation stage, maximum runoff of 1.5 mm in the case of wheat and until 3 mm in the case of maize, but their size is insignificant (0.16 t/ha). Increasing watering norms until 60 mm caused, on the average, the runoff increase from 0.9 to 1.85 mm in wheat crop and from 1.7 to 4.5 mm in the case of maize crop.
If in case of wheat crop, soil losses were not produced, in maize crop it was found an increase of these losses from 0.16 to 0.35 t/ha, average values for one watering application.
As concerns the number of watering applications, the results of our investigations pointed out that maintaining under control the erosion process required that irrigation norms higher than 40-50 mm should be split in two or three watering applications.
The determination of time of watering application was based on the idea of runoff limitation and rainfall capitalization, accepting the creation of a water stress at periods between critical phases for water. Because winter wheat took well into account rainfall stored at cold periods of the year, getting efficient crops was conditioned by a corresponding water stock in soil at phonological phases ear formation- flowering and grain filling. In case of maize we maintained humidity at values close to the best ones at the depth until 40-50 cm, at the phenological phase panicle appearance- grain formation. A significant aspect concerning the erosion diminution on sloping irrigated lands was represented by the corresponding framing of watering applications in the dynamics of rainfall regime (*1*).
The proper determination of amounts and time of directed water supply in soil, according to plant demands was done by necessary but not sufficient measures for the capitalization of soil agro-productive potential on sloping lands, both yields obtained and the erosion process depending on the manner of how the irrigation water was spread (*2*).
As concerns the watering uniformity one must say that it was not much influenced by land sloping.
The results of our investigations showed that on lands with a mean slope of 11 %, under conditions of adopting elementary measures for soil erosion prevention and control and spreading reduced watering norms, which represented 57 % of the value of those necessary to increase humidity at the level of field capacity on the entire active soil layer and intensity diminution by 10-13 % compared to the established infiltration speed, ensured runoff limitation, concomitantly to the increase of labour productivity as a result of diminishing the duration of watering application.

Table 5

Influence of irrigation and fertilizers on wheat crop on sloping lands (Podu-Iloaiei - 2004)

Fertilization	Unirrigated				Irrigated M = 2 x 400 m^3/ha				Irrigated M = 2 x 600 m^3/ha			
	Yield		Dif.	Signif.	Yield		Dif.	Signif.	Yield		Dif.	Signif.
	kg/ha	%	kg/ha		kg/ha	%	kg/ha		kg/ha	%	kg/ha	
N_0 +0 P_2O_5	1990	100	-		2840	100	-	-	3080	100	-	-
N_{70}+70 P_2O_5	3280	165	1290	xxx	4380	154	1540	xxx	4700	153	1620	xxx
N_{100}+100 P_2O_5	3860	194	1870	xxx	5060	178	2220	xxx	5370	174	2290	xxx
N_{130}+100 P_2O_5	4140	208	2150	xxx	5320	187	2480	xxx	5600	182	2520	xxx
N_{70}+70 P_2O_5 + 30 t/ha manure	4270	215	2280	xxx	5460	192	2620	xxx	5780	188	2700	xxx
Mean	3508	100	-	-	4612	131	1104	xxx	4906	140	1398	xxx
LS	LS 5 %		327 kg/ha		LS 1 %		444 kg/ha		LS 0.1 %		607 kg/ha	

The economic efficiency of reduced norm irrigation (2 x 400 m³ /ha), applied at critical phases for water was materialized, according to the applied level of fertilization, into significant crop increases in winter wheat, comprised between 54 % and 92 % (Table 5). In maize crop, the average yield increase was of 31 %, with variations between 53 % and 98 % at fertilized variants (Table 6).
Besides the need of observing the anti-erosion requirements, increasing irrigation norms could not be justified economically. Spreading extra water volumes, of 400 m³ /ha did not result in a clear yield increase, increases of 5.8 % - 8.4 % in wheat and of 4.9 % - 6.9 % in maize did not cover the expenses caused by increasing irrigation norms and did not justify water, soil and nutrients losses.

Table 6

Influence of irrigation and fertilizers on maize crop on sloping lands (Podu-Iloaiei, 2004)

Fertilization	Unirrigated				Irrigated M = 2 x 400 m^3/ha				Irrigated M = 2 x 600 m^3/ha			
	Yield		Dif.	Signi	Yield		Dif.	Signif.	Yield		Dif.	Signi
	kg/ha	%	kg/ha		kg/ha	%	kg/ha		kg/ha	%	kg/ha	
N_0 +0 P_2O_5	3511	100	-		4591	100	-	-	4877	100	-	-
N_{70}+70 P_2O_5	5321	152	1810	xxx	7032	153	2441	xxx	7522	154	2645	xxx
N_{100}+100 P_2O_5	6367	181	2856	xxx	8301	181	3710	xxx	8711	179	3834	xxx
N_{130}+100 P_2O_5	6693	190	3182	xxx	8805	192	4214	xxx	9340	192	4463	xxx
N_{70}+70 P_2O_5 +30 t/ha manure	6894	196	3383	xxx	9071	198	4480	xxx	9519	195	4642	xxx
Mean	5757	100	-	-	7560	131	1803	xxx	7994	139	2237	xxx
LS	LS 5 %		421 kg/ha		LS 1 %		610 kg/ha		LS 0.1 %		835 kg/ha	

On sloping irrigated land, the systems of anti-erosion tilling was necessary, even if watering was applied in such way that it could prevent runoff.
If there is only one variant as concerns the direction of ploughing, about depth, one must have in view the lowest soil surface mobilization and soil loosening at depth for increasing the infiltration capacity and accumulation of higher water amounts.
In order to point out the effect of changing soil physical state on water and soil losses under irrigation, watering application was done on differently tilled areas and on untilled ones (stubble). The highest water and soil losses were found on plough tilled field and the lowest losses were found on chisel tilled areas, as a result of cumulated effect of crop residues which

increased soil roughness and loosening, creating good conditions for water infiltration. In case of untilled variant, the presence of crop residues did not result in a great diminution of runoff water, due to a leveled and less permeable area, but diminished greatly soil losses compared to the ones registered on ploughed areas. High runoff (4.9 mm) and soil loss values (1.33 t/ha) on ploughed areas, even under conditions of a relatively reduced water norm (40 - 60 mm), showed that supply watering applications after this way of soil tilling could be dangerous. That is why it was necessary to apply supply watering for sequential crops after the harvest of the previous crops.

These experiments showed that increasing watering norms was not adequate, because, soil protection by plants lacking, water and soil losses increased highly at all the variants.

Getting high yields concomitantly to maintaining soil productive capacity on irrigated sloping lands did not mean that one might neglect the environment protection.

The chemical analyses carried out on irrigating water have pointed out a normal concentration of dissolved ions, which corresponded to quality criteria (Table 7).

Table 7

Soluble salt content of irrigation water and runoff water under different crops, Podu-Iloaiei, Iasi county

Crop	pH	Cl^- mg ‰	SO_4^{2-} mg ‰	CO_3^{2-} mg ‰	HCO_3^- mg ‰	Na^+ mg ‰	K^+ mg ‰	Ca^{2+} mg ‰	Mg^{2+} mg ‰	N_t %	TSSC mg‰
Irrigation water											
	7,6	14,1	113,7	23,5	1818	29,4	3,2	14,7	0,6	0,61	162,4
Runoff water											
Bare	8,2	23,4	127,1	31,6	337,2	100,5	2,5	16,3	9,7	0,56	647,2
Wheat	8,2	21,6	124,8	22,4	306,6	90,2	3,4	16,5	8,9	0,66	592,3
Maize	8,3	30,8	129,7	29,0	322,5	110,4	4,2	17,2	9,2	1,25	650,9
Soybean	8,3	22,9	142,3	33,1	315,6	100,9	4,2	18,1	9,9	1,12	645,0
Sugar beet	8,3	31,7	126,5	22,3	356,3	100,7	5,7	16,7	10,3	1,40	667,3

As a result of high concentration of soil solution, determined both by proper chemical properties and by those which came of substances applied for increasing soil fertility and with phyto-sanitary purpose, at liquid runoff it was found a great increase in total soluble salts content (TSSC), by 4 times higher than the content presented in irrigation water as well as a pH level increase (Table 7). Among anions, significant changes were found at chlorine ions, which concentration increased by 1.5 - 2.0 times and at bicarbonic ions, presented in runoff water at a lower concentration by 6 times (Table 7). As concerns cations, it was found out an increase in the concentration of sodium and manganese ions, being find in runoff water at higher amounts by over 3 times and by l6 times, respectively. The analyses conducted did not point out important qualitative differentiations of runoff water under different crops, only the total nitrogen content being lower by 56 % at black field, as a result of unfertilization and by 47 %, respectively, in case of winter wheat due to shorter vegetation period. The high content of soluble salts in runoff water at soil surface was an important warning requiring the adoption of the whole measures able to limit the runoff volume by at least two reasons. On the one hand, to get maximum effects by fertilizers and pesticides application and on the other hand, to prevent the pollution of soil, surface water and especially, ground water, which represents the main drinking water source for the villages in the area.

Conclusion

The rainfall regime in 2004 pointed out the climate characteristic of the Moldavian Plain, such as, even if there was quantitatively sufficient for ensuring water for plants requirements, by the distribution in time, rainfall did not result in optimum conditions for crop development and less on sloping lands.

For a sustainable capitalization of cultivated sloping lands, by irrigation it is necessary that ecological demands should prevail to the detriment of economic reasons.

Under climatic conditions of this area, on lands with a slope of 11 %, an optimum ratio: water consumption - crop - anti-erosion control requires spreading to wheat and maize crops some irrigation norms until 800 m^3 ha.

Spreading reduced watering norms, at critical phases for water, which ensure corresponding soil wetting until the depth of 35 - 40 cm in wheat and 40 - 50 cm in maize on arable slopes of the Moldavian Plain is justified economically and from the point of view of natural capital conservation requirements.

References

1. Rieul L., Ruelle P., 2003 - *Irrigation - guide pratique*, Cemagref.
2. Tiercelin J. R., 1998 - *Traite d'irrigation*, Tec&Doc, Lavoisier

THE MEASURING DEVICE FOR THE DETERMINATION OF TRACTION FORCES BY CULTIVATE

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Abstract

There are two ways how to determine the total operating resistance of a machine, viz. either by calculations or by field-laboratory experiments. As compared with the calculation, the field experiments provide more accurate results. To determine the operating resistance, it is possible to use the strain gauge measuring systems. This paper presents a method of the determination of total operating resistance of agricultural machinery and describes a measuring device designed at the Department of Agricultural, Alimentary and Environmental Engineering of the Faculty of Agriculture, Mendel University of Agriculture and Forestry Brno. The device enables to measure this type of resistance.

Key words: total traction resistance; traction force; evaluation device; measuring device

Introduction

A mobile energy vehicle (tractor) transmits its engine power to the machine, working equipment possibly, by means of running gear – traction forces. The total operating resistance of agricultural machinery, e. g. of ploughs, cultivators etc. significantly influences the power consumption and, therefore, also the consumption of fuels. The determination of this value enables to define an optimum shape of working tools as far as their minimal resistance to soil penetration is concerned. A decrease in energy consumption is another effect of such an accurate shape design. Its value also indicates the degree of soil compaction, which is an important factor of preservation of soil quality and positive soil properties and/or characteristics. These properties can show a marked effect on successful cultivation of crops.

The value of operating resistance can be determined by two methods, either by calculations or by measurements performed in the course of field-laboratory experiment.

1. Determination of machinery resistance by calculations

From the energetic point of view, a correct assembling of the vehicle-machine set is based on a good knowledge of total machine resistance. The greatness of the traction force, traction output possibly, must be sufficient to overcome this resistance. The value of traction resistance can be determined by means of different calculation methods. In spite of its relative inaccuracy, the following equation for calculation of ploughing resistance is the mostly used in agricultural practice:

the following equation for the calculation of tillage resistance of a plough, which can be used also for designing of other agricultural machines.

This equation has the following form:

$$\boxed{F = F_1 + F_2 + F_3 = f \cdot G + k \cdot a \cdot b \cdot n + \varepsilon \cdot v^2 \cdot a \cdot b \cdot n} \qquad [N]$$

where:
F_1…. represents the passive plough (machine) resistance during driving
- G… plough gravity [N]
- f… rolling coefficient [-]

F_2… represents the effective resistance required for slice cutting and deformation
- a … …ploughing depth [m]
- b … …width of one ploughing unit [m]
- n … …total number of working units (blades) [-]
- (a.b) …projection of the working unit (tiller blade,…) to the plane, which is perpendicular to the machine driving direction
- k … specific soil resistance [Pa]
  - The specific soil resistance is a force, which is required for the cultivation of a unit surface soil as measured in the plane perpendicular to the driving direction.
  - Its value is influenced by a number of factors, e. g. soil moisture, soil type, momentary vehicle speed, tool shape etc.

F_3 … represents the force, which is required for the slice mobilization and its throwing aside
- ε …Coefficient, which is dependent on the shape of the plough surface, soil properties and travelling speed [$N.s^2.m^{-4}$]
- v … travelling speed [$m.s^{-1}$]

Using the estimated traction force "F" it is possible to calculate the tractor's traction output:

$$\boxed{P = F \cdot v} \qquad [W]$$

where:

F … traction force [N]
v … travel speed [$m.s^{-1}$]

This relationship is valid provided that the traction force direction is identical with direction of travel speed. In case that the angle of these two vectors is „α" , it is necessary to take into account the size of this angle.

Then it is valid, that:

$$F = F` \cdot \cos\alpha$$

where:

F` …measured value of the traction force [N]
α … angle of direction of the traction force towards the travel speed [°]

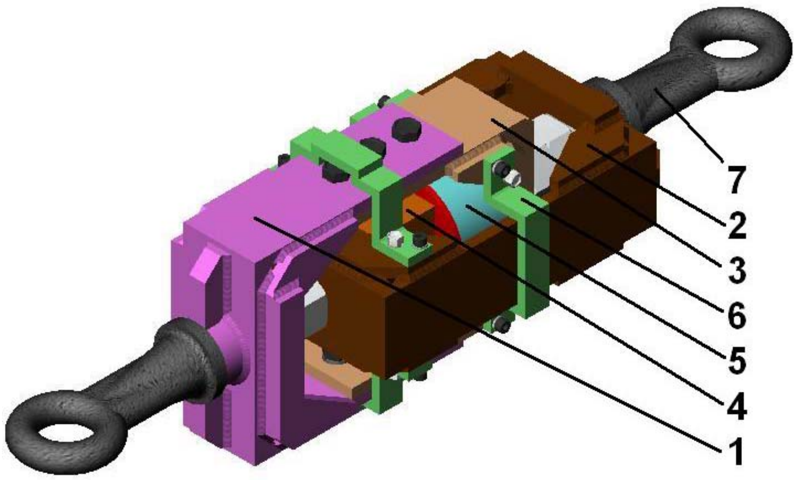
2. Determination of machine resistance by measuring

When measuring total resistance of agricultural machinery it is necessary, first of all, to connect it with the tractor. In case of a trailing machine it is possible to place the measuring device into the tractor-machine joint in such a way that the direction of traction force and traction resistance are the same as the travelling speed of the machine set. In case of mounted machines, it is necessary to use another tractor, which pulls the first one (pulling the agricultural machinery). Most frequently the machine resistance is recorded by means of strain gauge measuring systems produced by different home and foreign manufacturers. The measuring of the traction force is based on the change of physical properties (electric resistance) of tensometers resulting from their deformation caused by the load. Such a change is transmitted via a converter and an amplifier into the evaluating unit where it is converted to into the value of traction force.

3. Proposal of the measuring device and the implementation of measurements

To carry out the measurements, the firm TEVAS, specialized in production and assembly of strain gauges systems was selected. As the strain gauges of this manufacturer are used mainly all for measurements of pressure forces, it was necessary to convert the pressure into tensile forces. A special measuring device MČB1 (Fig.1), was designed and manufactured to provide such a conversion. Regarding the price, the measuring device was fabricated from conventional steel profiles.

The tensile force is transferred through the rings "6" (fitted to pull bars by nuts) and the pull bars "3, 4, 5". These pull bars compress the strain gauge member "1". The member is bolted to one pull bar and over a silent block to a second pull bar. Because of assembly reasons, one of the pull bars had two parts, which were connected with dowel bolts.



The silent block is necessary for deadening of side forces evoked by hitching of device. It is also helpful for eliminating of spurious impacts, which could cause the damage of strain gauge. Prevention of device failure due to recoil is assured by rubber stopper.

The bearing is needful for stabilizing of both pull bars and for the reciprocal movement under forcing load.

Fig. 1: Measuring device MČB1: 1, 2, 3 – pull bars , 4 – strain gauge member, 5 – silent block, 6 – bearing, 7 – ring,

The evaluation device (Fig. 2) is another important part of the measuring device. Values recorded in the course of measurements are stored in this device and later on transferred by a cable and a serial port into the computer. The data can be analysed and evaluated using the MS Excel programme. The measured values are stored in specified intervals throughout the period, which can be also preset. The output value represents the traction force [N]. The evaluation device can be also connected with inductive sensor of revolutions.

Fig. 2: Evaluation device

4. Verification of the measuring device – results

The testing measurements were performed using a measuring device. The results of these test measurements, which confirm functionality of this device, are presented in Fig. 3. The time interval of force recording, which was chosen for test measurements, was 10 ms. The total number of recordings was 200 so that the overall duration of measurements was 20 seconds.

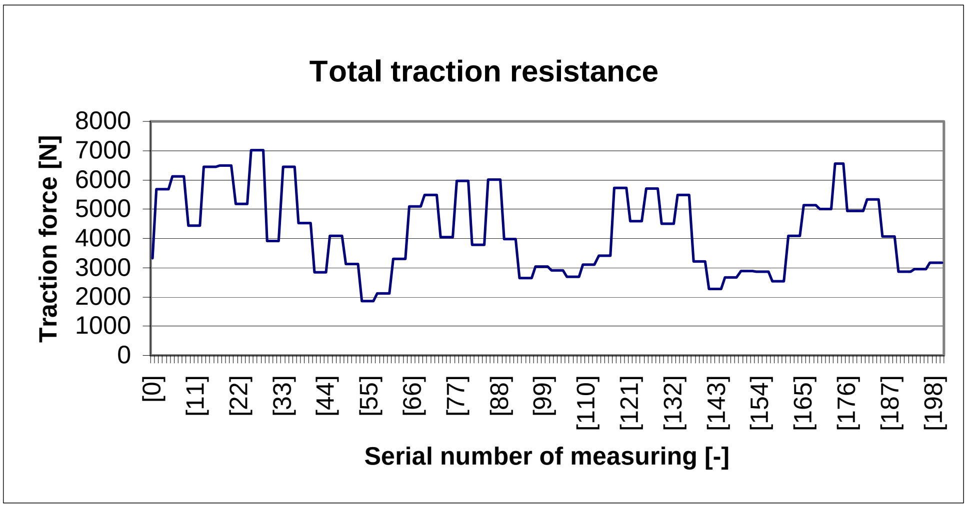


Fig.3: Dependence of the traction force (i. e. the total machine resistance) on the time of measuring

5. Results

The measuring device MČB1 can measure the total traction resistance of machines. After completion with an inductive sensor of revolutions for the 5th wheel, the device could serve for the evaluation of working speed of the whole set of machines. The presented measuring device will be used for experimental measurements at the Department of Agricultural, Alimentary and Environmental Engineering. The obtained values can be also used for comparisons of parameters of functional groups of machines supplied by different manufacturers.

Acknowledgement

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References

[1] NEUBAUER, K. et al.: Zemědělské stroje (Agricultural Machinery), Praha, Státní zemědělské nakladatelství v Prague, 1989,720 pp.

[2] FRIEDMAN, M. et al.: Zemědělské stroje I. Teorie a výpočet (Agricultural Machinery I. Theory and Calculations), Prague, Státní zemědělské nakladatelství v Praze, 1973, 350 pp.

[3] SEMETKO, J. et al.: Mobilné energetické prostredky 2 (Mobile energetic vehicles), Bratislava, Príroda, 1985, 560 pp..

Internet references:

[1] http://www.tevas.cz/

A NEW APPROACH TO ASSESS THE RISK OF SOIL COMPACTION IN ARABLE SOILS

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Summary

The increasing size of arable crop enterprises in Europe as well as a higher proportion of contract work increases the demand for higher traction force machinery. This, however, inevitably leads to higher axle loads with the potential of harmful soil compaction. In order to secure the various soil functions, such compactions have to be avoided. Any measures of remediation are either time consuming or expensive. Therefore, prevention of soil compaction must be based on the precautionary principle and mathematical modelling might be used as a decision support for farmers or advisers. The aim of this project is to evaluate the risk of soil compaction based upon site specific data including information on soil, climate and husbandry. This approach to assess the risk of soil compaction of arable land is than integrated in the REPRO software package.
The first step is to estimate the soil strength in response to mechanical stress, based upon a new calculation method using data on bulk density and aggregate density for separate spatial units within a field. The calculation of the soil pressure caused by each agricultural implement is based on Koolen et al. (1992). The estimations of the carrying capacity and the soil stress takes into account the changes of the soil moisture during the year. Additionally, a soil compaction index (SCI) is calculated for the separate pass, which allows an estimation of the risk of soil compaction on a particular site and under given soil conditions. The results for the separate pass are than integrated for an assessment of the risk of soil compaction on the farm level.

Keywords: soil compaction index, soil pressure, soil compaction, aggregate stability

1. Introduction

The increasing size of arable crop farms in Europe as well as contract work on larger farms increases the need for farm machinery with larger traction force. The reason for this tendency reflects the economies of scale in arable farming. The need for greater traction forces as well as larger holding tank capacities in harvesters and combines inevitable causes higher axle loads. As a consequence, the risk of harmful compactions of agricultural soil especially under wet conditions and little carrying capacity has increases dramatically.
Compaction severely restricts a number of important ecological soil functions. Air capacity decreases and the gas exchange is restricted (Ball und Robertson, 1994; Horn und Rostek, 2000). Another likely consequence of soil compaction and the establishment of platy and coherent soil structure is a reduced water infiltration with water run-off and erosion (Horn et al., 1995). In some cases even yield decrease has been observed (Voorhees, 2000). Soil compaction may persist for considerable long time periods (Alakukku, 1996). As a

consequence of those results it is absolutely imperative to avoid soil compaction and thus to maintain the various soil functions. General advice to reduce the risk of soil compaction is easy. However, a sound quantitative risk assessment based upon site specific soil, weather and husbandry details is extremely difficult, because of the complicated interrelated interactions. Therefore the only feasible approach is to use mathematical modelling, which incorporates the fundamental processes for analysis and recommendation, thus limiting the need for expensive and time consuming measurements. The new approach to assess the risk of soil compaction of arable land presented in this paper is a modul in the REPRO software, developed between the universities in Halle and Freising, Germany, is a complex computer model, which quantifies a number of material and energy fluxes on the farm level. Those results are than translated into ecological and economic indicators. Depending on application range and/or data availability single REPRO modul might be used. Additionally, the modular design of REPRO allows the incorporation of new parts, like in this case the one on soil compaction.

Other modelling approaches on soil compaction have mainly focused on the effect of single pass (O`Sullivan et al., 1999). In contrast, we understand the risk of soil compaction as a component in a complex farming system, which requires an understanding of the site specific soil, weather and husbandry conditions. Therefore the incorporation in REPRO is important, because REPRO provides all necessary information on time and type of husbandry activities and all details on machinery are available. Combined with the long term weather data on a specific site, this approach allows for the calculation of soil compaction risk for a specific farm. The REPRO modul can be used by skilled farmers and in the extension services.

2. Model structure

2.1. Estimation of aggregate stability

Depending on the soil depth, different figures for the soil strength are used. The soil structure and geometric is safeguarded in the highest subsoil layer directly adjacent to the top soil (35 cm depth) by limiting soil stress below precompression stress. This also limits tyre rolling resistance (Carman, 2002). Any measures of remediation in this soil layer are either time consuming or extremely expensive.

In contrast, in the topsoil (20 cm) the precompression stress is not as important as minimum standards of soil structure characterized by an air capacity (AC) above 8 vol. percent and a saturated hydraulic conductivity above 10 cm d^{-1}. If information on the particle density (PD) and the water content at matrix potential of -6 kPa (m_W) (according Paul, 2004) of a particular soil is available, it is possible to calculate the maximum bulk density (BD_{TS}) for this soil layer.

$$BD_{TS} = (100 – AC) / (m_W + 100 / PD) \qquad (1)$$

This approach secures the important soil functions when farmers change from traditional ploughing to conservation tillage practices.

A multiple linear regression equation allows determining the level of precompression stress ($\log \sigma_P$) using the input variables aggregate density/bulk density ratio (AD/BD) and dry bulk density at a matrix potential of -6 kPa (Rücknagel et al., 2005)

$$\log \sigma_P = -3.15 * AD/BD + 0.60 * BD + 4.49 \qquad (2)$$

The calculation of the soil strength in the topsoil (20 cm) is based on the bulk density of formular (1). If no analysis for the bulk density and the aggregate density are available, the model can run with standard figures based on textural classes. In order to estimate the effect of traffic during the entire year it is necessary to have information about the precompression stress and the soil strength during dryer soil conditions. According to Bradford and Gupta (1986), Lebert (1989), Arvidson (2001), Arvidson et al. (2003), Berli et al. (2003) and Keller et al. (2004), who estimated the precompression stress at higher matrix potential we use a regression approach calculate a correction factor (a) to the precompression stress of the subsoil and the soil strength in the top soil. This correction factor (a) is based on the precompression stress and the water content in percent of field capacity (FC),(3).

$$a = 2.83 + -0.93 * \log \sigma_P + -0.03 * FC + 1.68 * 10^{-7} * FC^2 + 0.009 * \log \sigma_P * FC \quad (3)$$

This regression model is defined for a precompression range between 1.40 to 2.30 and a water content above 60 percent of field capacity. If the observed figures are out of this range, the minimum or maximum figures of the model are use.

2.2. Calculation of soil stress

The calculation of the soil pressure σ_z (major principle stress) using wheel load (P) and inflation pressure (q) in a soil depth z caused is based on Koolen et al. (1992).

$$\sigma_z = q *(1-\cos^{\upsilon} (\arctan ((1/z) * (P/\pi\, q)^{1/2}))) \quad (4)$$

This formular (4) was validated based on 117 measurements of Hammel (1994), Gysi et al. (1999), Arvidson et al. (2000), Weisskopf et al. (2000), Horn et al. (2003), Trautner u. Arvidson (2003) and Keller et al. (2004). The soil stress was calculated for 20 cm and 35 cm soil depth. The concentration factor (υ) in formular (4) was calculated with a linear regression model and refers to a soil depth of either 20 or 35 cm. In this model the concentration factor decreases with increasing precompression stress and decreasing water content in percent of field capacity. The calculations (5) and (6) are again defined for a precompression range between 1.40 to 2.30 and a water content above 60 percent of field capacity. If the observed figures are out of this range, the minimum or maximum figures of the model are use. This limitation is necessary, since the analysis of the available data did not allow any conclusion about the concentration factor out of the observed data range.
The concentration factor for the soil layer 20 cm and 35 cm is calculated according to formulars (5) and (6).

$$\upsilon_{20\,cm} = -2.0 * \log \sigma_{p\,20\,cm} + 0.03 * FC_{20\,cm} - 3.2 \quad (5)$$

$$\upsilon_{35\,cm} = -2.0 * (\log \sigma_{p\,20\,cm} + \log \sigma_{p\,35\,cm}) / 2 + 0.03 * (FC_{20\,cm} + FC_{35\,cm}) / 2 - 3.2 \quad (6)$$

For the soil layer 35 cm the precompression stress and the soil water content of the adjacent soil layer above is also included in the formular.

2.3. Soil water content

The estimation of the soil water content is based on data of the German Meteorological Service (DWD). This information is available for a large number of meteorological stations in Germany. The DWD calculates the soil water content on a daily bases in a soil depth of 0 – 60 cm for the crops winter wheat, sugar-beet, corn and pasture using the water balance model AMBAV. Specific soil physical data from the locations of the meteorological stations are used in the model. The model can run with average soil moisture data and with site specific data if available. For the purpose of this project, we use the average soil water content of the years 1992 to 2002 under winter wheat and sugar beet for the meteorological station Halle/Saale is given in figure 1.

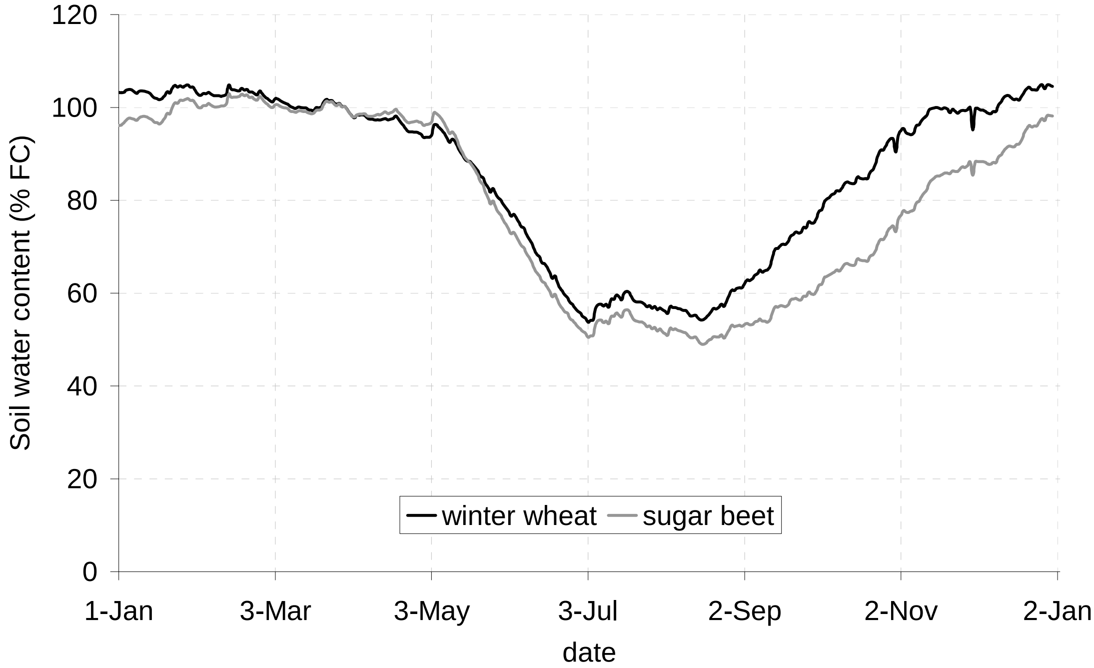

Fig.1: Average soil water content (1992 to 2002) according to the calculations of the German Meteorological Service (DWD) in 0 – 60 cm soil depth cm under the crops winter wheat and sugar beet for the meteorological station Halle/Saale.

2.4. Assessment

First we calculate the difference of the estimated soil pressure (log σ_z) and the soil strength or the precompression stress (log σ_P) for each pass in the depth 20 and 35 cm, respectively (7).

$$SCI_{SP} = \log \sigma_z - \log \sigma_P \qquad (7)$$

This index (SCI_{SP}) allows to assess the soil strength in 20 cm or the precompression stress in 35 cm for each single pass. Figures above zero indicate a higher soil pressure than the estimated soil strength or precompression stress. If the figures for SCI_{SP} are negative, soil compaction is unlikely and further calculations are continued with SCI_{SP} equals zero.
This calculation is done for every pass of any kind. Given the fact, that the passes on a particular field are either in permanent traffic lanes or random, it is not possible to simply add the SCI_{SP} of the various passes during a growing season. We than distinguish between passes in traffic lanes like fertilizer and pesticide application or random passes like tillage, harvest seeding etc.
The SCI_{PTL} of the passes on the permanent traffic lanes is calculated according to figures (8). In this formula SCI_{MEAN} is the average figure for the passes in permanent traffic lanes and SCI_{MAX} the maximum figure.

$$SCI_{PTL} = ((SCI_{MEAN} + SCI_{MAX}) / 2 + SCI_{MAX}) / 2 \qquad (8)$$

The calculation of the random passes (not in permanent traffic lanes) takes into account that apart from different SCI_R the area affected varies with the implement and tyre type (9). Those SCI_R are grouped with steps of 0.1. For each group we add the wheel tracked area (A_{GR}) base on the area of each pass (A_i):

$$A_{GR} = \sum A_i \qquad (9)$$

In order to account for crossover of passes the wheel tracked area is multiplied by 0.75. Maximum figure in each group is 1. The SCI_R is than calculated from the averaged of mean each group (SCI_{GRM}), multiplied with the wheel tracked area, starting with group with the highest averaged index (10). This procedure is continued until the entire area is taken into account, which translates into a proportion figure of 1.

$$SCI_R = \sum (SCI_{GRM} * A_{GR}) \quad (10)$$

In the last calculation step, the index figures fort the area in permanent traffic lanes (A_{PTL}) and the area with random passes (A_R) are add up with respect to the area affected (11).

$$SCI_{TOTAL} = SCI_{PTL} * A_{PTL} + SCI_R * A_R \quad (11)$$

The final assessment of the soil compaction index SCI_{TOTAL} is based on the use of a scoring function (Fig. 2). On the y-axes the figure is set between zero and one. With one representing the most favourable ecologic condition and zero the most unfavourable ecologic conditions. This approach is used to compare or aggregate different assessments in the REPRO model. The scoring function itself is characterized by two important points, which are based on the average slope of the virgin compression line of 0.20. The slope represents the compressibility of the soil in the range of the virgin compression range of the stress-bulkdensity function and. This describes the increase in bulk density after precompression stress. The first point of the scoring function represents an increase in bulk density of a maximum of 0.05g cm^{-3} which equals a soil compaction index of 0.25. In the scoring function a figure of 0.75 is attributed. The second point of the scoring function represents of soil compaction index of 0.45, which equals a score of zero. An increase of the soil compaction index up to 0.45 corresponds with an increase in bulk density of 0.05 to 0.09 g cm^{-3}.

3. Examples for the application of the model

The model was used in a long-term tillage field trial at Bernburg, Saxony-Anhalt, Germany. The experimental site is locate in the “Magdeburger Börde”. The field experiment was started in 1996 as a trial with large plots to represent practical tillage conditions. The soil type at the experimental site is a chernozem on loess sediments. The entire husbandry including the tillage operations were conducted with machinery used on practical farms (Tab. 1). The treatments “plough” and “cultivator” were used as examples to calculate the soil compaction index for 20 cm and 35 cm soil depth.

Tab. 1: Machinery, wheel load and inflation pressure used in the field trial in Bernburg.

No.	maschinery (Working wide)	wheel load (kg)	inflation pressure (bar)
1	six – row sugar – beet harvester (2.7 m)	9400	2.35
2	*John Deere 6810* with pesticide atomizer (30.0 m)	2360	1.45
3	pesticide atomizer (30.0 m)	3480	1.45
4	*John Deere 8300* with cultivator (5.0 m)	3230	1.25
5	*John Deere 7810* with plough (2.1 m)	2850	1.75
6	*John Deere 7810* with seedbed combination (4.0 m)	2880	0.80
7	*John Deere 2266 E* harvester (6.0 m)	5150	1.95
8	*Zetor 5245* with roller (10.0 m)	1030	1.30

The soil compaction index for the trial in Bernburg in Tab. 2 are on a fairly low level. An analysis of all different operations revealed highest soil compaction index for a depth of 20 cm after the application of fertilizer and pesticides. Soil tillage, seeding operations and mechanical weeding produced only small soil compaction index figures. In general, the risk of soil compaction is higher for operations using permanent traffic lanes.

Tab. 2. Soil compaction index for the different single procedures and the total averaged over the years 1997 to 2002 for the two treatments "plough" and "cultivator" in soil depth 20 cm and 35 cm.

	20 cm		35 cm	
	plough	cultivator	plough	cultivator
tillage	0.15	0.08	0.13	0.00
seeding	0.06	0.04	0.00	0.00
fertilization	0.24	0.21	0.00	0.00
pesticide application	0.23	0.20	0.00	0.00
mechanical weed control	0.10	0.04	0.00	0.00
harvest	0.21	0.15	0.00	0.00
passes on traffic lanes	0.24	0.21	0.00	0.00
random passes	0.13	0.08	0.04	0.00
total	0.13	0.08	0.04	0.00

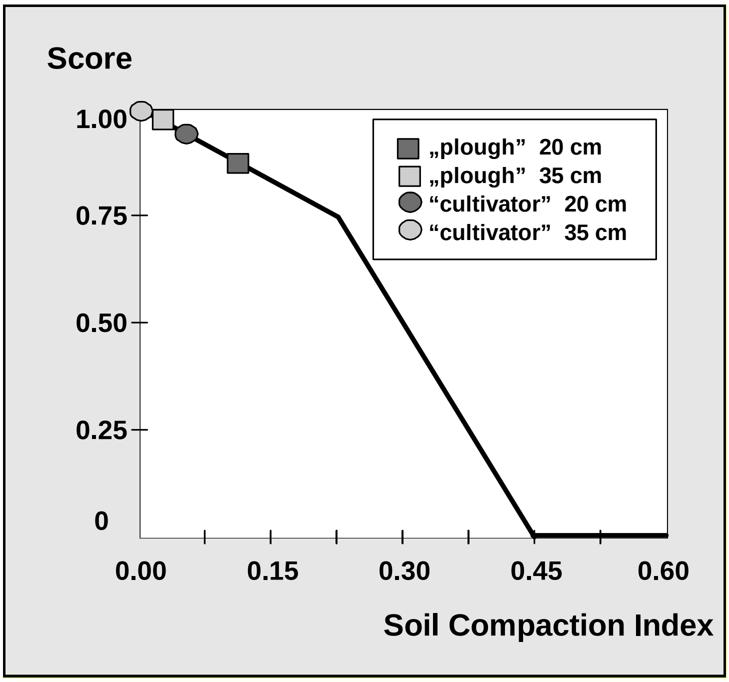

Fig . 2: Assessment of the soil compaction index for the „plough" and "cultivator" treatment in the soil tillage trial in Bernburg, 1997 – 2002.

The soil compaction index in the treatment "plough" are slightly higher then in the treatment "cultivator". We argue , that the reason for this observation are the higher concentration factor due to the lower precompression stress in the top soil of the “plough” treatment. According to the results presented, we hypothesis, that there is little risk of soil compaction after ploughing in the soil layer 35 cm. The soil compaction index indicates for both tillage treatments a small likelihood of soil compaction. Since the proportion of the traffic lane represents only three percent of the total area, the effect of the higher figure for the soil compaction index for the traffic lanes is negligible.

The assessment of the soil compaction index for the period 1996 to 2002 is shown in figure 2. In the soil layer 20 cm it ranges between 0.87 and 0.92 for the “plough” and “cultivator” treatment, respectively. In 35 cm the “plough” treatment averages 0.96 and the “cultivator” 1.00.

The low soil compaction index in the treatment “cultivator” in 20 cm depth indicates, that after six years without loosening the figures comply with minimum standards of soil structure. This conclusion is further confirmed by measurements in spring and autumn 2003, with analysis of the bulk densities in the soil layer 18 – 24 cm, which produced bulk densities between 1.41 g cm^{-3} and 1.43 g cm^{-3} and air capacities from 7.2 to 11.7 vol. % .

Literatur

Alakukku, L., 1996. Persistence of soil compaction due to high axle load traffic. II. Long-term effects on the properties of fine-textured and organic soils. Soil Till. Res. 37, pp. 211-222.

Arvidson, J., Trautner, A., van den Akker, J.J.H., 2000. Subsoil compaction – risk Assessment and economic Consequences. Reiskirchen, Catena, Advances in Geoecologie 32, pp. 3-12.

Arvidson, J., 2001. Subsoil compaction caused by heavy sugarbeet harvesters in southern Sweden. I. Soil physical properties and crop yield in six field experiments. Soil Till. Res. 60, pp. 67-78..Arvidson, J., Sjoberg, E., van den Akker, J. J. H., 2003. Subsoil compaction by heavy sugarbeet harvesters in southern Sweden. III. Risk assessment using a soil water model. Soil Till. Res. 73, pp. 77-87.

Ball, B.C., Robertson, E.A.G., 1994. Effects of uniaxial compaction on aeration and structure of ploughed or direct drilled soils. Soil Till. Res. 31, pp. 135-148.

Berli, M., Kirby, J.M., Springmann, S.M., Schulin, R., 2003. Modelling compaction of agricultural subsoils by tracked heavy construction machinery under various moisture conditions in Switzerland. Soil Till. Res. 73, pp. 57-66.

Bradford, J. M. Gupta, S. C., 1986. Compressibility. In: Klute, A. (Ed.), Methods of soil analysis. Part 1: Physical and mineralogical methods. Second Edition. Madison, Wisconsin, USA, pp. 479-492.

Carman, K., 2002. Compaction characteristics of towed wheels on clay loam in a soil bin. Soil Till. Res. 65, pp. 37-43.

Gysi, M., Ott, A., Flühler, H., 1999. Influence of a single passes with high wheel load on a structured, unploughed sandy loam soil. Soil Till. Res. 52, pp. 141-151.

Hammel, K., 1994. Soil stress distribution under lugged tires. Soil Till. Res. 32, pp. 163-181.

Horn, R., Domzal, H., Slowinska-Jurkiewicz, A., Ouwerkerk van, C., 1995. Soil compaction processes and their effects on the structure of arable soils and environment. Soil Till. Res. 35, pp. 23-36.

Horn, R., Rostek, J., 2000. Subsoil compaction processes – state of knowledgement. Reiskirchen, Catena, Advances in GeoEcologie 32, pp. 44-54.

Horn, R., Way, T., Rostek, J., 2003. Effect of repeated tractor wheeling on stress/strain properties and consequences on physical properties in structured arable soils.

Soil Till. Res. 73, pp. 101-106.

Keller, T., Arvidson, J., Dawidowski, J.B., Koolen, A.J., 2004. Soil precompression stress II. A comparison of different compaction tests and stress-displacement behaviour of the soil during wheeling. Soil Till. Res. 77, pp. 97-108.

Koolen, A.J., Lerink, P., Kurstjens, D.A.G., van den Akker, J.J.H., Arts, W.B.M., 1992. Prediction of aspects of soil-wheel systems. Soil Till. Res. 24, pp. 381-396.

Lebert, M., 1989. Beurteilung und Vorhersage der mechanischen Belastbarkeit von Ackerböden (in German). Bayreuth: Bayreuther Bodenkundliche Berichte, Band 12.

O`Sullivan, M.F., Henshall, J.K., Dickson, J.W., 1999. A simplified method for estimating soil compaction. Soil Till. Res. 49, pp. 325-335.

Paul, R., 2004. Verfahren zur Ermittlung der Schadverdichtungsrisiken auf ackerbaulich genutzten Böden. (in German) Jena: Thüringer Landesanstalt für Landwirtschaft, Zwischenbericht 46.02.

Rücknagel, J., Hofmann, B., Paul, R., Christen, O., 2005. Estimating precompression stress of structured soils on the basis of aggregate density and dry bulk density (in preparation.)

Trautner, A., Arvidson, J., 2003. Subsoil compaction caused by machinery traffic on a Swedish Eutric Cambisol at different soil water contents. Soil Till. Res. 73, pp. 107-118.

Voorhees, W.B., 2000. Long-term effect of subsoil compaction on yield of maize, Reiskirchen, Catena, Advances in GeoEcologie 32, pp. 44-54.

Weiskopf, P., Zihlmann, U., Wiermann, C., Horn, R., Anken, T., Diserens, E., 2000. Influence of conventional and onland-ploughing on soil structure. Reiskirchen, Catena, Advances in GeoEcologie 32, pp. 73-81.

SOIL QUALITY MANAGEMENT FOR DECREASING PRODUCTION LOSS UNDER EXTREME CLIMATIC CONDITIONS

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Abstract

The requirements of soil tillage throughout the last century in Hungary can be characterized as a fight against extreme climatic and economic situations. Climate plays a direct role both in crop production and soil tillage effectiveness. Climatic extremities may have several risky consequences, such as extreme temperatures and precipitation, the rise and frequency of drought and flood. Only reason that, why soil quality deterioration has become a more important soil management problem during the last seven years is because of the extensive water-logging that occurred in 1998 and 1999 and the severe drought that occurred in year 2000 and 2003. Both of these stresses resulted in decreased crop yields, presumably because of the increasing soil structure damage. The economic pressure plays an indirect role in soil tillage practice. It can be stated that the soil quality conservation is regulated by the market conditions. In this paper we discussed about the soil quality problems such as compaction, structure deterioration, moisture loss and organic matter decrease as well as improvement and maintenance. Soil looseness deterioration by tillage-pans may improve by loosening and maintain by structure conservation methods. However the dust formation may prevent and alleviate by less soil disturbance including mulch tillage. Our goal for the next decades is to create and maintain harmony between soil quality conservation and crop production. Our objectives were to assess the long-term tillage effect on several soil quality indicators. The secondary objective was to summarize the land use factors for decreasing the soil sensitivity to the climatic extremities.

Keywords: soil quality, climate, moisture, soil structure improvement, crop production.

Introduction

During the last few decades, the requirements of soil tillage in Hungary can be characterized as a fight against severe climatic and economic conditions. In Hungary climate is continental, although extreme phenomena have occurred more frequently in recent decades. Climatic extremities may have numerous risky consequences, such as extreme temperature fluctuation and heavy precipitation, and the rise in the frequency of drought and flood (Láng, 2003). These symptoms require effectual reactions including adaptable land management and tillage methods to alleviate the unfavourable climatic effects. The usual tillage practice, by its negative impacts on soil quality, does not serve the future requirements. The undesirable tillage consequences, listed by Birkás et al. (2004): 1. a compaction process occurs by the repeated pressing of the tools at the same depth, and the compacted layer extends to the top- and subsoil; 2. the compacted layer restricts the rooting depth and increases both soil and plant sensitivity to drought; 3. compacted layer restricts the water infiltration and may promote water-logging harms; 4. during the secondary tillage the recompaction can occur prior to planting; 5. if water and air penetration were restricted, decomposition of the stubble residues and nutrients are limited; 6. a less adoption to the soil moisture content promotes cloud and dust formation; 7. repeated mechanical stresses cut or neglect soil biological mellowing; 8. in a soil disturbed frequently, the organic material content has been decreased, thus the workability, loading capacity are deteriorated; 9. a soil, disturbed roughly shows higher CO_2 emission to the atmosphere; 10. a soil, becoming poor in organic matter shows a higher sensitivity to the climatic extremities.

According to classical point of view, the need for tillage is to provide suitable soil conditions for plant growth. The new goals in soil tillage are to reduce the harmful climatic effects and to meet crop demands with less mechanical damage to the soil quality condition. In other words, the purpose for tillage is to create and maintain a harmony between soil quality and crop production (Birkás et al., 2004).

Material and methods

This study is based on data of monitoring and the long-term experiments. The monitoring started in 1976 following the periods of the tillage practice, and covered 10,000 ha in 41 districts (including Hatvan) of Hungary. Tillage impacts on soil quality were examined in Gödöllő, on a sandy loam, brown forest soil (Chromic Luvisol) from 1991 to 2002 (5 variants) and in Hatvan on a loam (Calcic Chernozem) from 2002 (6 variants). Tillage treatments including direct drilling, disking, cultivatoring, ploughing and loosening were evaluated. Based on the annual repetition of these treatments, four soil quality conditions were identified, as they were settled, loosened shallowly (in Gödöllö relation was disk-pan compacted), ploughed (in Gödöllő variant was plough-pan compacted) and loosened. These correspond to four land use variants, namely maintaining, intensive, ploughing and loosening. In the first place three fertilization levels and biculture (maize-wheat sequence) was used and in the second trial an optimal fertilization level was applied, and the crop sequence – wheat-maize – was improved by catch crops (mustard, rye, pea). During the period from 1991 to 2004, 6 years were average (1991, 1993, 1995, 1996, 2002, and 2004), 6 were dry (1992, 1994, 1997, 2000, and 2003) and 3 were rainy (1998, 1999, and 2001). The tillage effects on soil quality factors, including soil condition, agronomical structure (aggregate and dust rata) water management, and humus content, were determined according to the accepted standards (cit. Birkás*,* 2000; Gyuricza*,* 2000). Soil compaction and water content were measured to a depth of 600 mm using 10 replications at each measuring points. Measuring soil strength and water content for each 25 mm increment with an electronic penetrometer (Daróczi and Lelkes, 1999). Analysis of variance (Sváb, 1981) was used to determine the statistical significance among tillage treatments and other factors. Preliminary results were published both in Hungarian and international relation (Birkás and Gyuricza, 2004; Birkás et al., 2004).

Results

An example of the soil compaction observed 10 to 35 cm below the surface is shown in Figure 1. At the beginning of the 12-year trial, plough-pan-compaction from previous tillage practices was observed at a depth of 25 to 30 cm. This zone had a penetration resistance of 3.75 MPa. After the sixth year, disk-pan compaction became also evident, reaching the critical penetration resistance (3.5 MPa). The disk-pan compaction continued to increase during years 6 to 12, reaching a maximum of 5.5 MPa. Meanwhile, the disk-pan became extended to the soil surface because of a reduction in the disking depth. The compaction also became extended to the former plough-pan, resulting in a joint compacted layer at a depth of 22.5 to 32.5 cm. In our trial, on a soil prone to compaction, the loosening was repeated annually, and thus a favourable penetration resistance (1.90 to 2.6 MPa) could be maintained to a depth of

35 cm (Fig. 2). From a critical viewpoint, the disking and ploughing used regularly in the practice, and often on wet soils can be considered the primary cause for tillage-pan formation.

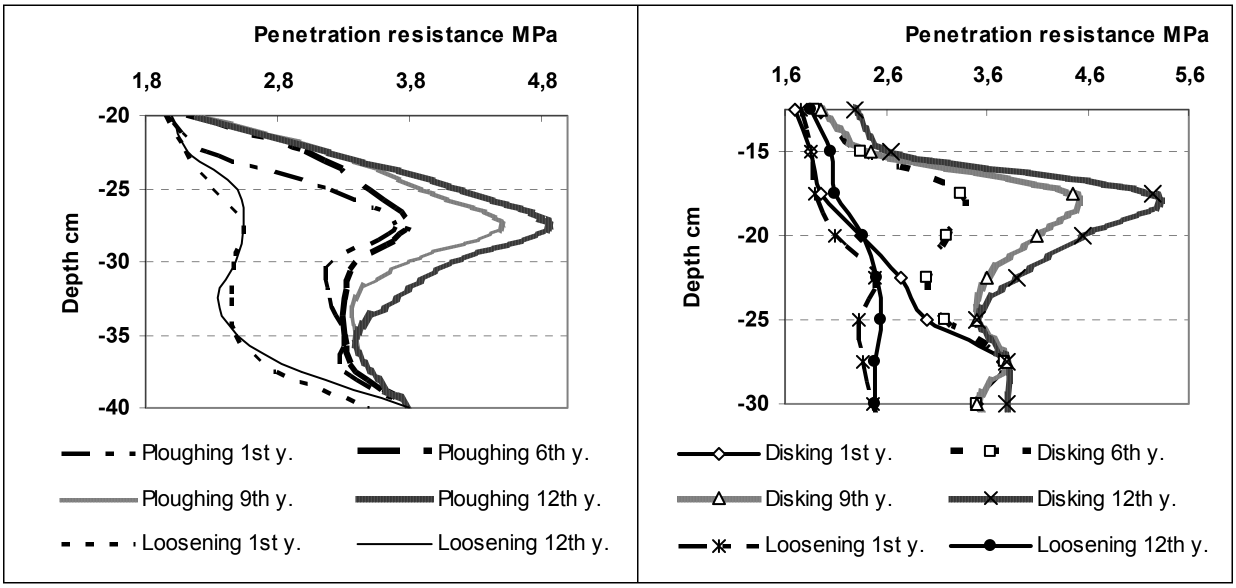


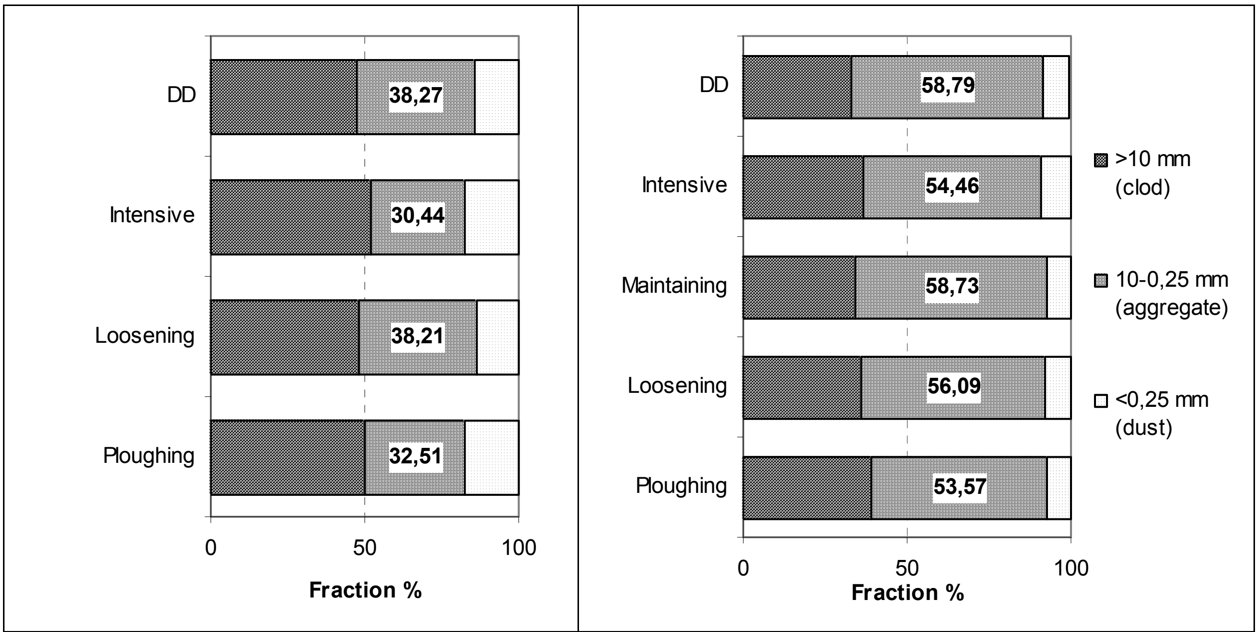
Figure 1 Soil condition changes during 12 years tillage under disking, ploughing and loosening (Gödöllő 1991-2002)

Six categories of the soil compaction were identified within 1000 ha of arable land according to their depth and characteristics within the soil profile. Figure 2 summarises the effect of tillage-pan compaction on soil quality under dry and wet periods.

Depth	Function for crops	Wet period	Dry period
surface	capturing, passing	water stagnation on the pans; soil silting	drying; cracking
0-10	seedbed (germination)		
10-20	root zone (nutrition and water uptake; physical and bio-chemical processes)		
20-25			
25-35			
35-45			
45-55			
subsoil	water intake, infiltration and storage	retarded infiltration and storage	water restriction

Figure 2 Tillage-induced soil compaction occurrences on the fields, and its impact on water management in dry and wet periods

Soil compaction had a major obstacle for soil quality improving tillage during the 1990s. The harmful climatic effect succeeded strongly in the tillage pan-compacted soils both in Gödöllő experiments and in arable fields, by means of water supply limit. However it had lower impacts on soils were loosened to a depth of 40 cm. Consequently, as the results supported in Hatvan experiment, the drought effect may decrease successfully in any soils prone to compaction. The disking is commonly used for primary and secondary tillage. Although this is often the most economical practice that may increase environmental risks through disk-pan compaction on wet and humid soils or cloud and dust formation on dry soils (Fig. 3).



Gödöllő (12th year)	Hatvan (2nd year)

Figure 3 Soil disturbance impacts on soil agronomical structure

The fundamental importance of soil structure is to determine the level of compaction, both in tilled and in undisturbed layer. The soil agronomical structure is closely related to land use systems. In Gödöllő experiments the rata of the cloud : aggregate : dust were 52:30:18 in the disked soil with 24 times under twelve years, while in the ploughed soil resulted of 50:33:17 %. The structure showed more favorable rate in soils were disturbed moderately with loosening (48:38:14) and used of direct drilling (47:38:15). Regeneration of the structure has only been begun in the loam soil of Hatvan trial. However the rate of the aggregate (59) both in DD and maintaining variant refers to the necessity of soil conservation land management. It is concluded, that prevention of the soil quality deterioration may promote structure degradation and it may give a chance to alleviate the climatic harms on arable fields.

The soil moisture balance (that is rate of the utilization and the loss or rate of the intake and the loss) can be influenced by the soil condition (Dexter and Birkás, 2004). The drought effect succeeded strongly in the tillage pan-compacted soils at Gödöllő experiments, by means of water supply limit, however it has lower impacts on soils were loosened to a depth of 35-40 cm (Fig. 4). The rank of soil condition in Gödöllő experiment was determined by the soil moisture content rate in average of the years as follows: Loosened = Settled (DD) > Ploughed > Loosened shallowly (Disk pan-compacted). Cover % of the surface had a lower impact on water conservation, because stubble residues rate were changed between 0 and 30 % at the variants (Fig. 5). In Hatvan experiment the rank of the water management was not habitual, such as: Ploughed (0 %) > Settled (80 %) > Loosened shallowly (45 %) > Loosened (25 %). It is concluded, that the water management – as a balance of water intake and loss – was strongly affected by soil condition (Várallyay, 1997), however, the percentage of the surface cover (see in brackets) with residues has only been a modifying factor.

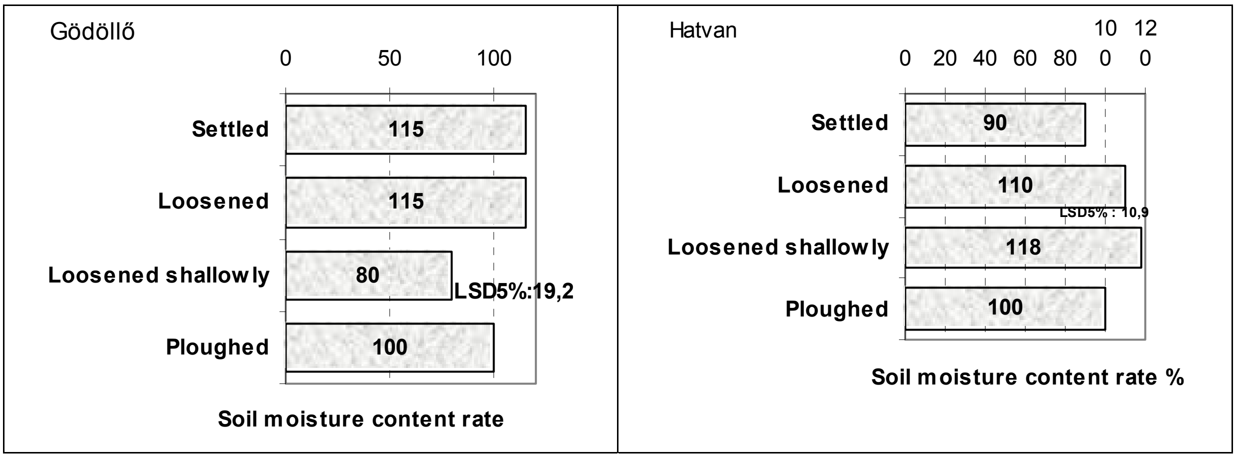


Figure 4 Soil moisture content rates in average of the years (Gödöllő 12 years, Hatvan, 3 years)

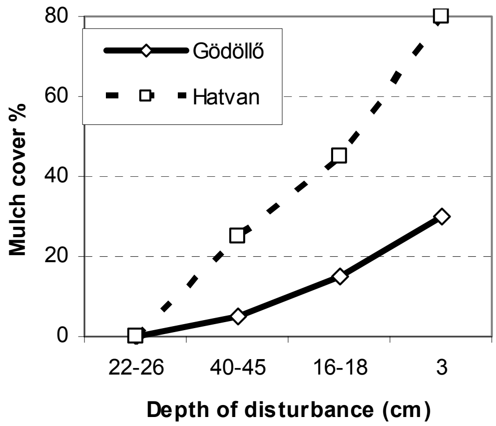


Figure 5 Depth of soil disturbance (cm) and cover % of soil surface at two arable sites

The impact of soil compaction on crop yield will vary depending upon crop sensitivity and where the compaction is most severe within the soil profile (Fig. 6).

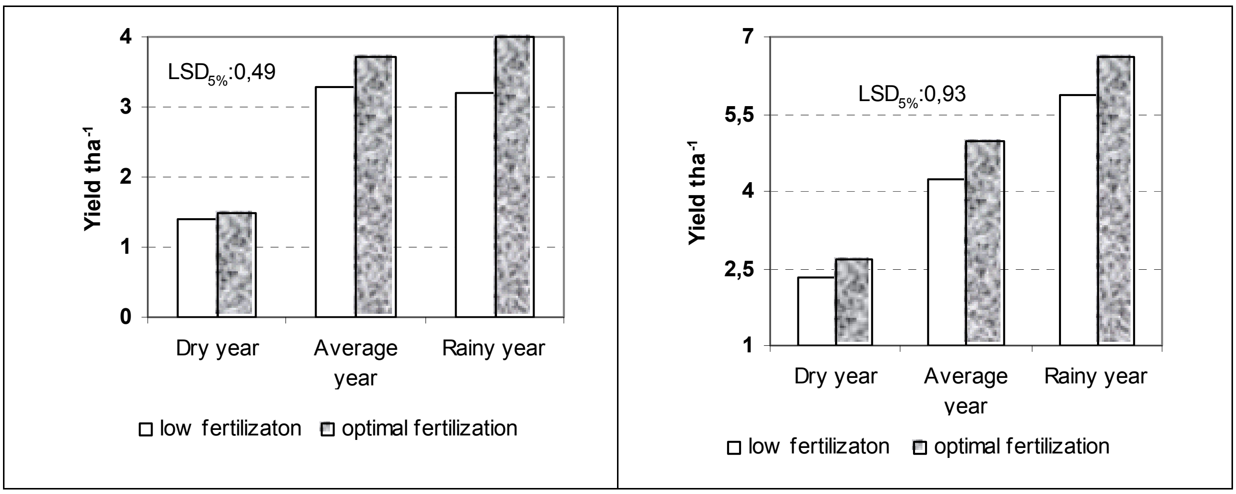


Figure 6 Maize yields in a disk pan-compacted and in a loosened soil at low and optimal fertilization level (Gödöllő, 1992-2002)

Maize is a crop sensitive to compaction especially that occurred near to surface. As disk-pan compaction gets wider, becomes a yield-decreasing factor mainly in dry years. It is stressed that the compaction effect can not be moderated by use of fertilization. The drought effect is also succeeds on soils well loosened to a depth of 40-45 cm, but the rate of the yield decrease can normally be compensated. The maize yield differences between years can also be decreased on soils prone to compaction (Fig. 6, 7).

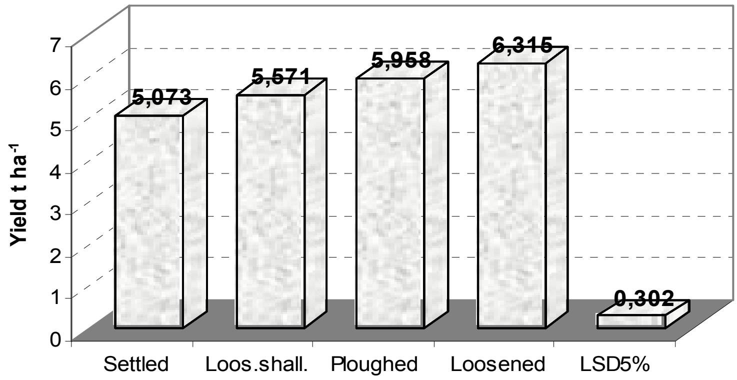


Figure 7 Yield of maize at different soil conditions (Hatvan, 2003)

Different soil conditions were evaluated in the drought year of 2003 with maize sowing to the wheat mulch. Figure 7 shows the yield and the soil tillage rank and supports the importance of the loosened condition in a dry growing season.

The importance of soil quality to characterize land use effects on the organic matter, were demonstrated under four different systems. The data showed very good correlation between land use and humus content (Fig. 8). The humus content rate was higher when conservation practices, including the incorporation or mulching with plant residues were used regularly. The use of intensive management where plant residues are under-ploughed or removed resulted in 7 and 18% decrease in the humus content related to the maintaining system. That is, as the tillage intensity increased, the original humus content began to lessen.

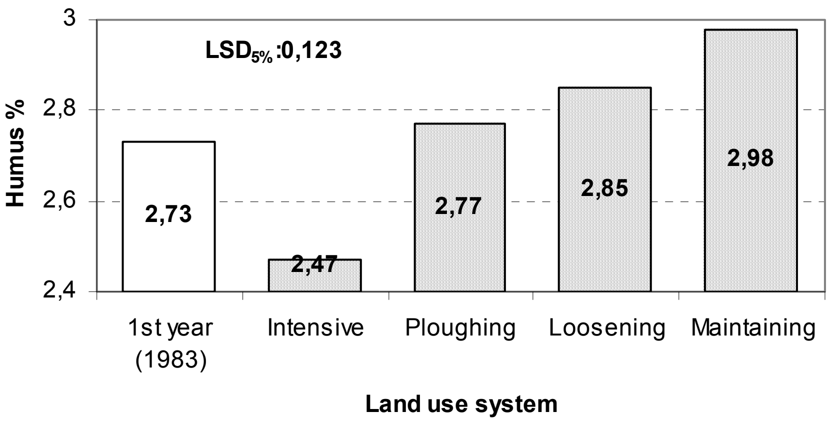


Figure 8 Land use impacts on humus content of soil (Hatvan, 2003)

Fourteen land use factors for improving soil quality condition and the regenerative capacity are summarized in Table 1. Seven of them (mulching, organic materials managing and recycling, promote soil mellowing and maintaining a favourable water management and reducing chemical loads) have beneficial biological effects in soils. The others refer to the soil tillage technique. For harmony between land use and soil quality, several important goals are, such as to reduce physical loads and soil disturbance, to prevent and alleviate soil compaction and pulverization harms and to maintain or improve the water management.

Table 1 Factors improving soil quality condition in a land use system

BIOLOGICAL IMPACTS	SOIL	TILLAGE IMPACTS
(1) Mulching with natural materials (2) Stubble residues incorporation and recycling (3) Organic material management (4) Crop rotation with high biological effect (5) To promote soil mellowing (6) Optimised water-, air and heat management (7) To reduce chemical loads	Conserving, maintaining and/or improving the physical, biological, chemical properties and the physical, biological condition and the regenerative capacity	(1) Surface forming for soil and moisture conservation (2) To reduce physical loads (3) To prevent and alleviate soil compaction harms (4) Less soil disturbance for structure conservation (5) To prevent dust formation and to improve aggregate stability (6) To maintain/improve water absorbing and holding capacity of soils (7) To control weed, pest and disease infestation

These factors will provide the basis for adaptable land management strategies and can help harmonize the goals of improved soil conservation with the demands of crop production considering the frequency in climatic extremities. This strategy aims to enhance soil quality while providing economically viable crop production without increasing the risks of climatic impacts.

Conclusions

Our result shows that, how tillage and land use systems affect soil compaction, agronomical structure, water management and humus content reflecting the state of soil quality condition.
1) Long-term trials evaluating the occurrence, extent and alleviation of tillage-induced compaction showed that declining of soil condition has environmental and economical consequences that may increase the sensitivity to the drought. However, to improve or to maintain a favourable soil quality may be an effective solution to alleviate harmful climatic effects.
2) For the improvement of soil quality fourteen factors were stressed. Seven of them have biological effects on soils, and the other seven generally refer to improvements in land use including tillage. Based on these results, we recommend that even greater efforts be made to encourage the adoption of soil conservation to promote soil quality.
3) The field experiments and monitoring gave useful information related to adaptability on climatic extremities. These factors are connected with the land use management, such as: (1) Conserving soil physical and biological condition and fertility. (2) Prevention of tillage faults promoting structure degradation. (3) Alleviation of tillage faults occurring in tillage and growing seasons. (4) Reasonable management with soil organic materials. (5) Management with stubble residues. (6) Maintaining the soil water management. (7) Soil surface conservation by mulch and tillage. (8) Harmonization between soil tillage, fertilization and crop sequence. (9) Improve the preceding crop effect with catch crops. (10) Appropriate crop protection by the harmony between soil tillage and crop sequence.

References

Birkás, M., 2000. Soil Compaction Occurrence and Consequences in Hungary; Possibilities of the Alleviation. DSc Thesis, Hung. Acad. Sci., Budapest, (in Hungarian).

Birkás M., Gyuricza Cs. 2004. Land use and climatic effects. In: Talajhasználat–Műveléshatás–Talajnedvesség (Szerk. Birkás M., Gyuricza Cs.), Quality-Press Nyomda & Kiadó, Budapest, pp. 10-45, (in Hungarian).

Birkás M., Jolánkai M., Gyuricza C., Percze A. 2004. Tillage effects on compaction, earthworms and other soil quality indicators in Hungary. Soil Till. Res. Special Issue "Soil Quality as an Indicator of Sustainable Tillage Practices" (ed. Karlen, D.L.) 78.2. 185-196.

Daróczi, S., Lelkes, J., 1999. Szarvas-Type Penetronik penetrometer (in Hungarian), Gyakorlati Agroforum, 10. 7. 16-18.

Dexter, A. R., Birkás, M. 2004. Prediction of the soil structure produced by tillage. Soil Tillage Research, "Soil Physical Quality" (ed. Dexter, A. R.), 79. 2. 233-238.

Gyuricza, C., 2000. Evaluation of Some Physical and Biological Aspects of Sustainable and Conventional Soil Tillage. PhD Thesis, Gödöllő, (in Hungarian).

Láng, I. 2003. Introductory reflections to the joint research project 'Research of the effects of the global climatic change carried out in Hungary, and reactions to it'. "AGRO-21" Füzetek, 31. 3-8. (in Hungarian)

Sváb, J., 1981. Biometrical Methods in Research Work. Mezőgazdasagi Kiadó, Budapest (in Hungarian)

Várallyay, G., 1997. Sustainable Development – A challenge for rational land use and soil Management. In: Land Use and Soil Management, Filep, Gy. (Ed.), Agr. Univ. Debrecen, 1-33.

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RECENT RESEARCH IN ROMANIA ON DIRECT DRILLING AND REDUCED TILLAGE

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Introduction

Research on direct drilling started in Romania in the sixties (Sarpe, 1966, 1980, 1981), and were later developed in various areas of the country (Hulpoi a.o., 1973; Catargiu, 1979; Ionescu a.o., 1979; Nistor a.o., 1979; Popa a. Popa. 1982; Gus a.o., 1986; Nicolaescu a.o., 1997; Lazaroiu a.o., 2004; Pusca a.o., 2004; Sarpe, 2004). Later, attention concentrated on less radical techniques: replacing plough by disk (Les, 1972; Budan a. Popa, 1972; Hulpoi a.o., 1973; Pintilie, 1970; Dinca 1971; Pipie 1971; Pop a.o., 1979, Picu a.o., 1979), chisel (Panzariu a.o.,1986; Zahan a. Mate, 1986), paraplough (Rotea a. Suraianu, 1992; Trasca a. Trasca, 1994) or rotavator (Nistor a.o., 1979), and alternation during the crop rotation of ploughing and disking (Les a. Preoteasa, 1978; Sin, 1987; Vines, 1982). Results showed, under very different soil and site conditions, either yields either to those with conventional tillage, yields somewhat lower but well compensated by the reduction in tillage costs, or significantly lower yields with also lower profits. Data on changes in soil properties under various tillage systems have been also published by Canarache a. o. (1978, 1979, 1980, 1986, 1987), Dumitru a.o. (1983, 1999), etc. Soils of Romania were classified according to their suitability for various tillage systems (Canarache, 1997), and some 50 percent of the arable area of the country was considered suitable for conservation tillage.

In the present paper, after this listing of existing literature, results of a recent field experiment carried out in four locations will be discussed.

Material and methods

Soils and climates of the four sites where these field experiments were carried out are described in Table 1. As it may be seen, there is a large variety of these conditions. There is a warm and dry climate in the first two sites, warm and moderately dry in the third one, and warm but humid one in the fourth one. Soils are medium-textured and loose Chernozems, with a moderate humus content, slightly alkaline, in the first two sites. They is a fine-textured and compact Chernozem, with a moderate - high humus content, slightly acid, in the third one. In the fourth experimental site, the soil is a medium-textured, Luvisol, with clay accumulation and compactness of genetic origin in the subsoil, it has a moderate - high humus content but only in a thin topsoil layer, and is acid.

The field experiment was conducted for three years, since October 2001 to September 2004.

The investigated treatments (Table 2) were not exactly the same in the four experimental fields, the idea being mainly to adjust them to the local conditions. In the first three sites there was a control plot, with conventional tillage and in the first two sites there was a no-till plot, in the third there was a plot with all till work in one pass. These experimental treatments were in fact established in the first three sites, in the fourth one, due to weather and other local conditions, it could be implemented only conventional. In these two sites other two more plots were added, with reduced tillage (paraplough, chisel and/or disk), details being shown in Table 2. Additionally, there were also treatments (subplots) with irrigation in Valu lui Traian and fertilisation in other three sites, but results from these treatments are not presented in this paper, only the irrigated and the optimum fertilisation treatments being considered. In the fourth site subplots were different fertilisers types and doses.

The experimental design was a split plot one, with four replications.

Table 1. Climate, soils, relief and ground water characteristics in the four experimental sites

Land characteristics		Experimental locations			
		Valu Traian	Braila	Draganesti	Armenis
Climate					
Yearly average temperature (^{0}C)		11.5	10.5	10.9	10.2
Yearly precipitation (mm)		430	513	571	780
Location					
Longitude		44^{0}10	45^{0}15	44^{0}04	45^{0}12
Latitude		28^{0}32	27^{0}16	25^{0}32	22^{0}19
Physiography		Dobrudja Tableland	NE Danube Plain	S Danube Plain	SV Western Piedmont
Soil		Vermic Chernozem	Vermic Chernozem	Cambic Chernozem	Stagnic Luvisol
Clay content (%)	0-20 cm	34	32	50	24
	40-80 cm	32	31	52	28
Bulk density (g cm^{-3})	0-20 cm	1.25	1.20	1.30	1.20
	40-80 cm	1.20	1.28	1.42	1.50
Saturat. hydr. cond. (mm h^{-1})	0-20 cm	9.1	7.5	8.0	6.00
	40-80 cm	34.6	6.0	4.4	0.80
Humus content	0-20 cm	2.96	2.42	3.22	3.62
	40-80 cm	1.60	1.58	1.78	0.40
pH	0-20 cm	8.42	8.22	5.82	5.52
	40-80 cm	8.59	8.50	7.02	5.36
Relief		flat	flat	flat	flat
Ground water		deep	deep	deep	deep

Crops in the experimental fields were specific to the respective areas: grain maize, sunflower and winter wheat in the first three sites, grain maize and potatoes in the fourth one. In Valu Traian it was possible to grow each crop in each of the three years, while in the other experimental fields only one crop was grown each year. Weather conditions in 2003 were extremely dry, and consequently it was not possible to grow wheat in neither of the three sites. In Braila and Armenis these droughty conditions made also impossible the seeding of wheat in the autumn of that year, replacing it in 2004 by grain maize. In 2004 the weather was characterised by precipitation above the average and well distributed over the year, extremely favourable for all crops and all of the experimental sites.

Results and discussion

Crop yields in the experimental fields (Table 2) were relatively high, according to the local soil and climate conditions, to the specific weather of each year, and to the level of management performed. They were somewhat lower in Braila in the first two years, very droughty years, as it was not possible, for technical reasons, to apply optimum irrigation. They were also lower in Armenis, where the climate is not adequate for two crops (grain maize and sunflower). Crop yields were much higher in Valu Traian and Draganesti, where irrigation was used, and applied according to the need of crops for water. Under the extremely favourable weather of 2004, crop yields were very high, some of the highest every met in the respective areas.

Table 2. Experimental treatments and crop yields (kg ha^{-1}) obtained

Experimental site	Year	Crop	Treatment					
			Conventional	Paraplough	Chisel	Disk	No-till*	LSD 5%
Valu Traian	2002	Maize	8630	-	7870	6250	4490	330
		Sunflower	3150	-	2970	2700	2150	940
		Wheat	5180	-	5200	5010	3380	450
	2003	Maize	8710	-	6620	5090	3360	470
		Sunflower	2100	-	2070	2040	1640	190
	2004	Maize	8660	-	7660	5970	3790	510
		Sunflower	2260	-	2240	2110	1750	170
		Wheat	5650	-	5170	3870	2690	440
Braila	2002	Maize	3230	4440	-	4060	2640	700
	2003	Sunflower	2670	2300	-	2240	2228	440
	2004	Maize	10530	8460	-	9870	10100	510
Draganesti	2002	Maize	9730	-	11370	-	7590	330
	2003	Sunflower	1915	-	1930	-	1950	600
	2004	Wheat	6165	-	6140	-	6355	60
Armenis	2002	Maize	3400	-	-	3150	-	170
	2003	Potatoes	23600	-	-	22500	-	500
	2004	Maize	4990	-	-	4590	-	250

*all tillage works implemented at one pass

Conventional tillage was the most productive. Reduced tillage using paraplough or chisel lead to crop yields somewhat lower, 98 percent, as an average, when compared to the control treatment, while reduced tillage with disking lead in Valu Traian to an average crop yield of only 80 percent, but in Armenis of 94 percent. From these data chiselling may be recommended for practice.

No-tillage resulted in a significant decrease of all crop yields, in all three locations where it was studied, the average yield being only 57 percent of the control in Valu Traian, 87 percent in Braila, and 94 percent in Draganesti where all tillage works implemented at one pass. Such unexpected results in Valu Traian and Braila, where soil conditions should have been favourable to no-till, have to be attributed to the non-adequate equipment for direct drilling available at present in this country, as well as to the high weeding of the experimental plots that could not be dealt with during the relatively short period of three years. On the contrary, in Draganesti, where soil characteristics are less favourable for conservative reduced tillage, the good results of this system were related to use of adequate equipment and to less weeding of the experimental plots.

Negative differences in crop yields were generally compensated by the lower costs (by 10 - 20 percent) of the no-till or reduced tillage techniques. Consequently, in Braila there was an increase in the net profit of some 10 percent when using no-till or reduced tillage systems.

Table 3 refers to determination in the experimental plots, in 2002, of the leaf area index of the grain maize plants. These data, which were obtained having in view a possible later use of simulation modelling, are well correlated with the crop yields obtained in the different experimental sites and in the different treatments.

Table 3. Leaf area index for grain maize in 2002 for grain maize

Site	Treatment	Leaf area index at different days				
Valu Traian (seeding day 25.04)	day	05.06	07.06	10.07	30.07	20.08
	conventional	0.36	0.87	2.60	2.19	1.14
	chisel	0.32	0.66	2.32	1.50	1.01
	disk	0.11	0.30	0.93	0.83	0.53
	no-till	0.04	0.15	0.32	0.47	0.20
	LSD 5%	0.12	0.26	0.24	0.22	0.31
Braila (seeding day 27.04)	day	07.06	27.06	22.07	12.08	02.09
	conventional	0.41	2.05	2.05	1.69	1.24
	paraplough	0.40	2.00	1.58	1.40	1.35
	chisel	0.28	0.63	1.30	1.30	1.30
	no-till	0.09	0.25	0.90	1.15	1.08
	LSD 5%	0.07	0.27	0.37	0.38	0.42
Draganesti (seeding day 27.04)	day	23.05	18.06	19.07	20.08	-
	conventional	0.08	1.90	3.18	2.42	-
	chisel	0.09	1.79	3.32	2.48	-
	reduced till	0.08	1.83	3.17	2.66	-
	LSD 5%	0.01	0.02	0.03	0.04	-
Armenis (seeding day 24.04)	day	06.06	16.07	05.08	26.08	16.09
	conventional	0.28	1.41	2.63	2.74	2.94
	disk	0.25	0.88	2.03	2.13	2.18
	LSD 5%	0.01	0.01	0.01	0.02	0.01

Values of the main soil physical and chemical characteristics of interest in studies on tillage systems are shown in Table 4. They refer to the upper soil layer only, the one that could be affected by tillage operations. Data for the third year of this experiment are given.

Table 4. Changes in soil properties in 2004 for the experimental sites and treatments

Site	Treatment	Bulk density (g cm^{-3})			Saturated hydraulic conduct. (mm h^{-1})			Aggregate water stability (%)			Humus content (%)			Available P_1O_5 (mg kg^{-1})		
		Depth (cm)														
		0 - 5	5 - 20	20 - 40	0 - 5	5 - 20	20 - 40	0 - 5	5 - 20	20 - 40	0 - 5	5 - 20	20 - 40	0 - 5	5 - 20	20 - 40
Valu Traian (seeding day 25.04)	conventional	1.22	1.41	1.40	55	22	10	4	5	8	3.14	2.91	-	58	49	-
	chisel	1.20	1.41	1.35	61	20	17	3	4	10	3.30	2.92	-	61	44	-
	disk	1.36	1.42	1.35	14	13	16	4	5	16	3.28	2.83	-	65	49	-
	no-till	1.28	1.46	1.42	29	15	15	4	5	12	3.43	3.05	-	68	51	-
	LSD 5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Braila (seeding day 27.04)	conventional	1.12	1.26	1.32	47	25	21	3	3	5	2.81	2.62	-	39	30	-
	paraplough	1.16	1.37	1.29	25	15	16	3	3	3	2.86	2.77	-	39	29	-
	chisel	1.37	1.34	1.31	6	11	17	3	3	4	2.79	2.54	-	38	19	-
	no-till	1.42	1.35	1.29	6	17	18	3	3	4	2.87	2.65	-	47	23	-
	LSD 5%	0.09	0.07	0.05	0.4	0.3	0.2	0	1	2	0.17	0.15	-	-	-	-
Draganesti (seeding day 27.04)	conventional	1.20	1.31	1.41	80	40	12	31	32	50	3.73	3.58	-	32	30	-
	chisel	1.21	1.41	1.42	68	29	20	33	33	42	3.66	3.40	-	32	30	-
	reduced till	1.20	1.34	1.37	79	49	30	32	33	50	3.83	3.61	-	54	47	-
	LSD 5%	0.05	0.06	0.03	-	-	-	6	3	3	-	-	-	-	-	-
Armenis (seeding day 24.04)	conventional	1.14	1.20	1.30	27	36	12	8	10	8	3.83	3.69	-	23	15	
	disk	1.22	1.37	1.54	23	25	5	17	19	16	3.66	3.40	-	28	25	
	LSD 5%	-	-	-	0.3	0.9	0.5	4	1	1	0.05	0.73	-	7	2	-

They show that there was some increase in bulk density, with a corresponding decrease in hydraulic conductivity, in the no-till and sometimes in the reduced tillage plots, but only for the Valu Traian, Braila and Armenis sites, where the original soil was quite loose. This increase in soil compactness is normal for such tillage techniques, and it is not high enough to be detrimental for soil quality. There were no significant changes in aggregate water stability or humus content, such results being expected for a rather short interval, only three years, of this experiment. Nevertheless, there are changes concerning the available phosphorus content, namely some accumulation of this component in the upper (5 cm deep) soil layer in the no-till treatment, resulting from the absence of soil mixing under such a technique and from the insolubility of phosphorus.

Conclusions

Results from a field experiment carried out during three years (2002 - 2004, years with very different weather) in four locations with different soil and climate conditions showed that:

- crop yields (grain maize, sunflower, winter wheat, potatoes) were in the reduced tillage treatments similar to the control, conventional tillage, but were unexpectedly lower in the no-till treatment; this fact could be resulting from unadequate direct drilling equipment available, and from the intense weeding of most of the experimental plots;
- the net profit was nevertheless a little higher in the no-till (and of course in the reduced tillage ones) treatments as compared to the control plot, this resulting from the much lower cost of the tillage operations;
- following this three years experiment, there was some increase in bulk density and decrease in hydraulic conductivity in the no-till treatments, but this increase was not high enough to become detrimental; there was no significant changes, during this short lapse of time, in aggregate water stability or humus content; there was some concentration of available phosphorus in the upper soil layer.

From these data it results that reduced tillage, mainly chisel, should be recommended to farmers in this stage, where direct drill equipment is not available and soil weeding is high.

Literature

Budan Gh., Popa F. (1972). Effects of various crop-raising techniques on maize yields in the Great BrailaIsland (in Romanian). An. ICCPT, vol. 38: 253 - 365.

Canarache A. (1979). Changes in physical properties of soils as affected by various management practices. 8th ISTRO Conference, Hohenheim - Germany, vol. 1, pp. 51 - 56.

Canarache A. (1987). Romanian experience with land classification related to tillage. Soil & Till. Res., 10: 39 - 54.

Canarache A. (1997). Differentiating soil tillage systems as depending on soil and land characteristics in Romania. (in Romanian). In: “Alternatives in soil tillage”, Cluj-Napoca, vol. 2, pp. 215 - 223.

Canarache A., Dumitru E. (1986). Concerning direct and long-lasting effects of soil tillage on soil physical properties (in Romanian). Probl. Agrofit., vol. 8, no. 3, pp. 195 - 208.

Canarache A., Florescu C.I., Dumitriu R., Dumitru E., Vasiulescu P., Trandafirescu T., Opris M., Postolache T., Hera Cr., Sin Gh., Sipos Gh. (1978). Changes of physical properties of the Fundulea Leached Chernozem as affected by various technological factors (in Romanian). An. ICCPT, 43: 265 - 277.

Canarache A., Postolache T., Vasilescu P., Trandafirescu T. (1980). Changes in soil physical properties under soil tillage practices on the Marculesti Vermic Chernozem (in Romanian). In: “50 years of research at the Marculesti experimental station”, pp. 168 - 204.

Catargiu D. (1979)/ Results on soil tillage system within a four-years crop rotation (in Romanian). An. ICCPT, 44: 245 - 253.

Dinca D. (1971). Effects of ploughing depth on wheat and maize yields on a Reddish-Brown soil (in Romanian). An. ICCPT, 37: 181 - 193.

Dumitru E., Dumitriu R., Sarpe N. (1983). Contributions to changes of physical properties of the Fundulea Leached Chernozem under no-tillage (in Romanian). Public. SNRSS, 21A:. 80 - 86.

Dumitru E., Enache R., Gus P., Dumitru M. (1999). Long-lasting effects of agricultural practices on the soil physical status (in Romanian). Ed. Risoprint, Cluj-Napoca, 205 pp.

Gus P., Rusu T., Bogdan I. (2004) Research on effects of minimum tillage on crop yields, weeding and plant diseases for wheat, maize, soybeans, rape and potatoes (in Romanian). In: "14th Herbology Symposium", Bucharest - Romania, pp. 256 - 270.

Gus P., Sarpe N., Sebok P., Mester Al., Antal A., Mihaly M. (1986). Effects of soil tillage systems on crop yields in the Cluj area conditions (in Romanian). Pr. Agrofit., nr. 8, pp. 195 - 207.

Hulpoi N., Nicolae C., Pintilie C., Damian L., Pipie Fl., Olaru V. (1973). Effects of soil tillage techniques on waterlogging-affected soils on wheat and maize yields (in Romanian). An. ICCPT, 39: 121 - 132.

Ionescu Fl., Stratula V., Sfarlogea D. (1979). Specific tillage for Reddish-Brown soils, reducing energy consumption (in Romanian). Pr. Agrofit., no. 1, pp. 145 - 161.

Lazaroiu A., Teodorerscu D., Perianu P., Sin Gh., Babiciu I. (2004). Result of experiments with techniques of reduced tillage for field crops in the Danube Plain (in Romanian). In: "14th Herbology Symposium", Bucharest - Romania, pp. 171 - 184.

Les M. (1972). Experiments with tillage depth for winter wheat in the area of Brown Chernozemic soils in Moldova (in Romanian). An. ICCPT, 38: 179 - 184.

Nicolaescu M., Mihai Al., Lup A. (1997). Research on effects of reduced tillage techniques on irrigated wheat, maize and soybean yield (in Romanian). An. ICCPT, 64: 210 - 221.

Nistor D., Popa A., Neamtu T., Nistor D. (1979). Soil tillage system for field crops on sloping land (in Romanian). Pr. Agrofit., no. 1, pp. 217 - 230.

Panzariu D., Patras J., Sarbu Gh., Panzariu M., Stefanescu Al. (1986). Research on techniques of soil management within a four-years crop rotation, under irrigation, on the Leached Chernozem in Podu Iloaiei (in Romanian). Pr. Agrofit., nr. 8, pp. 227 - 246.

Picu I., Hulpoi N., Tianu Al., Eliade Gh., Stefanic Gh., Tianu M. (1970). Effects of tillage depth on several irrigated crops (in Romanian). Pr. Agrofit., no. 1, pp. 117 - 143.

Pintilie C. (1970). Relationships between soil physical properties and wheat yields as depending on tillage and fertilising techniques (in. Romanian). An ICCPT, 36< 115 - 126.

Pipie Fl. (1971). Effects of soil tillage on maize yields (in Romanian). In "Maize cropping in the Tisa Plain", Oradea, pp. 35 - 43.

Pop L., Matei I., Nedelcu P., Gangioveanu I., Triculete Al. (1979). Research on maize cropping on flowing sands (in Romanian). Pr. Agrofit., no. 1, pp. 303 - 318.

Popa A., Popa Gr. (1982). Erosion control cropping systems on sloping land (in Romanian). Pr. Agrofit., nr. 4, pp. 341 - 349.

Pusca I., Tabara V., Sarpe N., Dragoi Gh. (2004). Research on cropping according to conventional and no-tillage within a 4 years rotation and a monocrop maize field (in Romanian). In: "14th Herbology Symposium", Bucharest - Romania, pp. 185 - 190.

Rotea I., Suraianu V. (1992). Research on winter wheat development as depending on tillage techniques and nitrogen fertilisation (in Romanian). Lucr. St. SCCASS Braila, 1: 129 - 135.

Sarpe N. (1980). Results and prospective of cropping maize with no tillage in the area of Chernozemic soils in Romania (in Romanian). Probl. Agrofit., no. 2, pp. 119 - 131.

Sarpe N. (1981). Cropping maize without tillage as to reduce consumption of labour and fuel (in Romanian). An. ICCPT, 37: 195 - 202.

Sarpe N., Segarceanu O., Mate S., Vladutiu I. (1966). A new technique for cropping maize with a minimum of tillage and with herbicides (in Romanian). Rev. GAS, Bucharest, no. 3, pp. 10 - 14.

Scurtu D. (2004). Experimental data on effects of tillage of Suceava Chernozems on crop yields, weeding and soil properties (in Romanian). In: "14th Herbology Symposium", Bucharest - Romania, pp. 301 - 311.

Sin Gh. (1987). Research on crop rotation, soil tillage and seeding techniques (in Romanian). An. ICCPT, 55: 317 - 343.

Sin Gh., Pinmtilie C., Petcu Gh. (2004) Results of research on reducing soil tillage and weeding (in Romanian). In: "14th Herbology Symposium", Bucharest - Romania, pp. 249 - 256.

Trasca Fl., Trasca G. (1994). Contributions to studying soil tillage on the acid, heavy-textured soil in Albota (in Romanian). Lucr. St. SCCPT Albota, 2: 191 - 198.

Vines Gh. (1982). Experimental results on soil tillage under irrigation for the main field crops at the Marculesti Research Station (in Romanian). Pr. Agrofit., nr. 4, pp. 125 - 149.

Zahan P., Mate St. (1986) Research on soil tillage and seeding for the main crops on soils affected by waterlogging in the Tisa Plain (in Romanian). Pr. Agrofit., nr. 8, pp. 209 - 225.

INVESTIGATION POSSIBILITY TO BREAK PLOW PAN DURING PLOWING BY A COMBINED PLOW

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Abstract

Nowadays using combined machine in tillage systems is unavoidable. Moldboard plows are being widely used in Iran without conducting necessary pre-investigations. The research indicated that continuos use of these plows caused plow pan or plow sole at the depth range of 25-35 cm. Farmers wrongly apply the same solution as alleviating deep hard pan to break plow pan by using subsoiler in the most cases. These two layers are not the same, because of many reasons including causes, effects, depth, strength and durability.

The aim of this research was to improve the common moldboard plow for breaking the plow pan during plowing. Therefore a new combined plow was developed by attaching similar shanks to chisel plow on behind of moldboard. The shanks supposed to work 7-10 cm deeper than moldboard plow. The performance and effect of new combined plow for breaking plow pan was evaluated in the field.

Hence the parameters such as bulk density, penetration resistance, soil failure profile, soil disturbed area, draft and specific draft were measured and compared between two plows.

The results indicated that combined plow could break the pan by improving the soil physical properties as well as soil failure and disturbed area. However the combined plow increased the draft slightly but due to larger soil disturbed area, this difference decreased in specific draft. It seems that the combined plow would quickly used by farmers due to simplicity of mechanisms and benefits.

Keywords: Moldboard – Plow pan – Combined plow – Tillage – Plowing

Introduction

Nowadays Reducing tillage operation and number of pass in the field are major concern due to significant effects on consuming energy, cost and soil structure. Moldboard plows are being vastly used by farmers, without any carful consideration to soil type, climate, and product. Tillage is the highest mechanized operation in our country with using moldboard plow in more than 90% of cultivated area. The number of these plows has been estimated to be about 230,000 till 2004 (12). Therefore any change or improvement will be greatly respected.

The invention and application of some combined machines for performing tillage operation has been considered from almos 100 years ago such as chisel with rotivator, disk with land leveler or chisel with roller (3).

Loghavi and Hosseinpour (2002) attached a deep roller to moldboard plow for combining primary and secondary tillage operation. It was indicated that the avareges of draft, drowbar pull and clod mean weight diameter with combine plow were significantly lower than operation with moald board plow and tandom disk seperately. Also the area profile produced with combined plow was more uniform than with plow and disk (8).

Chisel plow has been used in combination with different secondary tillage implements, such as disks, for a long time. In this machine chisel shanks are combined with even or concave disks behind them or in a combination with round coutler for residue cutting (1).
Chisel are also used in combination with bedders, in 2 type of disk and wing, and in front of them for soil breaking (3). The combined machines of secondary tillage, such as cultivator with roller or spike tooth harrow with roller, were considered and used vastly in the field (1).
In other research a combined plow including disk plow and chisel plow were developed and used in the country (4).
Jori (2002) noted that for a sustainable tillage system, new combined machines such as disk with cultivator, riper or chisel are needed and should be considered. The diameters for chisel shanks or riper was determined including appropriate point of blade of 25° rake angle with a length of 240mm and width of 80mm (7).
The effect of some combined tillage machines on cold breaking, bulk density and soil uniformity were investigated. In this research, combined machines such as spike tooth harrow with disk, disk with roller and cultivator with spike tooth harrow were used (10).
Spoor and Godwin (1978), in a research located two shallow share in two depth of 16 and 24cm in front of main share and developed a cambined subsoiler. It was concluded that draft was significantly decreased and soil disturbed area was increased (11).
Milked et al., (1994) developed a combine machine with a winged share 30 cm width in front of main shares. The results indicated that adding shallow winged share in all treatments increased soil disturbed area and improve critical depth (9).
Therefore the primary aim of this research was a combined plow development to be able breaking plow pan during plowing with current moldboard plow. The secondery aims were passes control, avoiding un nessasary subsioling, soil structure preservation and provide a suitable area for root development.

Materials and Methods

In this research for a combined machine considered by placing arms similar to chisel behind of moldboard plow breaking plow pan during plowing. These shanks were placed in a way to be able to break soil in deeper layer than moldboard plow working depth of about 35cm. Therefore with considering working depth, the shanks similar to chisel plow were selected and attached. As arms only affect soil in furrow and behind of bottom, they only work in depth range of 7-10 cm in soil (Figure 1 shows the sketch design of a unit). Hence, there was no need for using arms with high strength such as subsoilers or heavy chisel plows. Required draft for such a arm would be significantly lower than chisel plow.

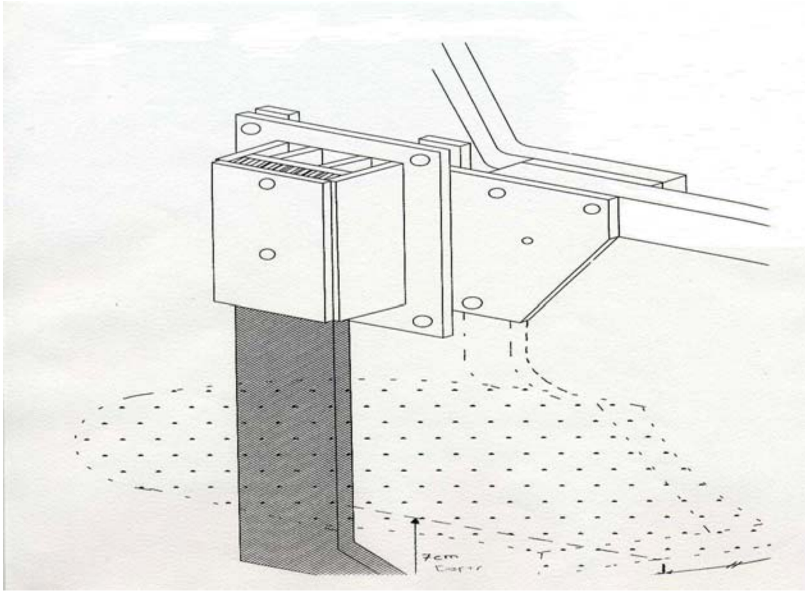

Figure 1. Unit sketch of combined plow

In this machine share type due to contact with soil was more important than arms. Different types of shares including sweep, shovel, knife and etc. Have special use. For land preparation and soil loosening which was the aim of this research shovel type are more applicable. Therefore after testing different dimentions shovel with cutting width of 5-7 cm, was chosen. The chassis were modified in a way to have enough strength for placing arms and do not disturb plow equilibrium and were located in the direction of draft center and draft line. Also the chasis enabled arm position to change vertically for depth adjustment (Figure 2 shows the machine with chassis and depth change possibility).

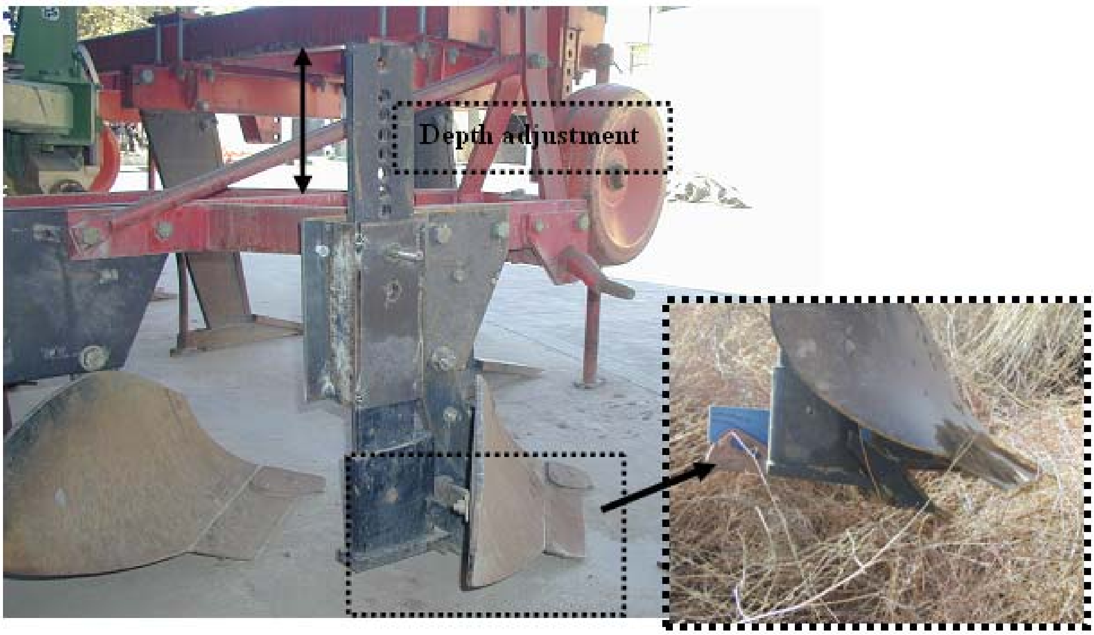

Figure 2. Combined plows with depth adjustment

Therefore in a time when there is no need for arm to be used it is possible to raise them and become inactive.
The combined machine was field tested and effect on plow pan breaking was investigated. Hence some factors such as bulk density on dry basis, soil failure profile, soil disturbed area, penetration resistance, draft and specific draft were determined and compared to those of moldboard plow. For this purpose a feild with dimension of 10.20 m^2 and wheat residue with silty loam clay soil texture were selected.

Results and disscusions

1. Bulk density

Data analysis indicated that combined machine could decrease bluk density significantly in depth lower than 25 cm where working depth of moldboard plow finished. The attached shanks were also able to break soil in depth range of 25-35 cm. Figure 3 shows that bulk density decreased in the depth below moldboard plow limit after using combined machine.

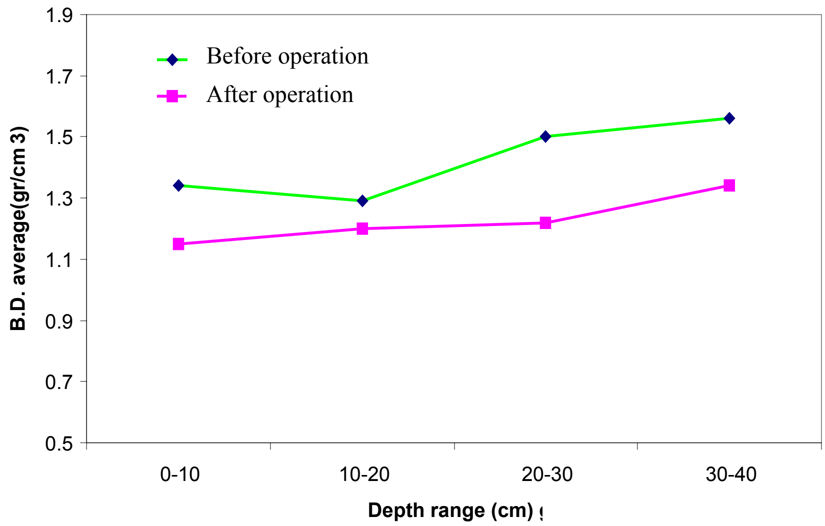

Figure 3. Bulk density before and after operation

2. Penetration recistance

Penetration recistance by SP 1000 penetrometer in 10 locations for each field was measured. Figure 4 shows the results after using combined plow and moldboard plow. It is clear that penetration resistance was increased significantly bolow 25 cm depth after using moldboard plow which was proof of exsisting plow pan. The combined plow could affect this layer and decreased penetration resistance in depth range of 25-35 cm.

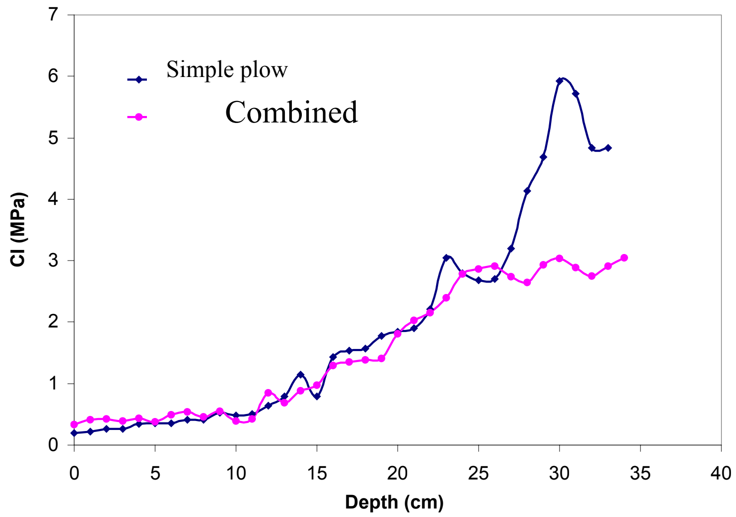

Figure 4. Penetration resistance for both plows

2. Soil failure profile

Soil failure profile for both combined and simple plows were determined with 3 replications. Figures 5, 6 and 7 shows the results. It was indicated that combined plow increased soil disturbed area particularly at depth. Figure 8 also shows these profiles in the field.

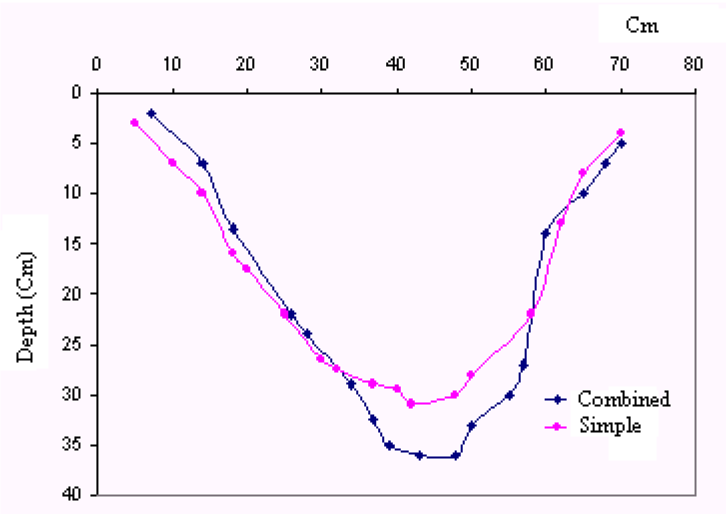

Figure 5. Soil failure profile for both plows Rep. 1

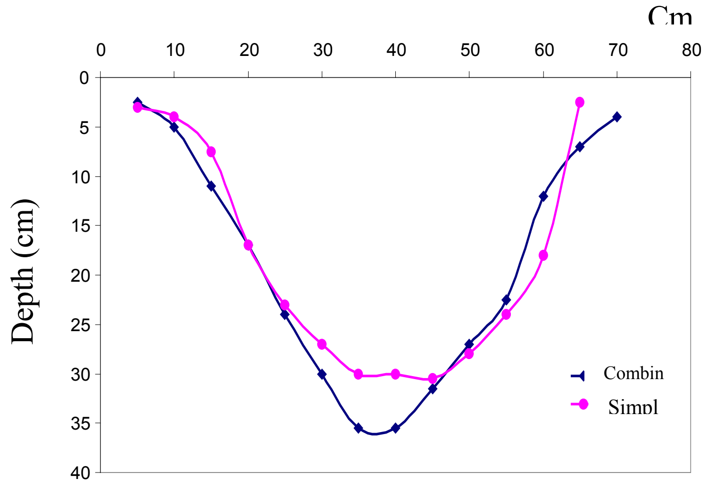

Figure 6. Soil failure profile for both plows Rep. 2

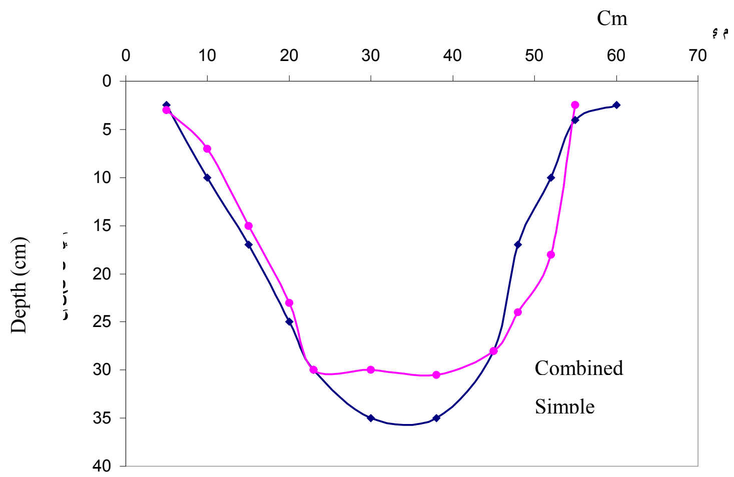

Figure 7. Soil failure profile for both plows Rep. 3

Figure 8. Soil failure profile for both plows in the field

3. Soil disturbed area

Calculating soil disturbed area using integral method proved that combined plow increused the area which provide suitable condition for root development.
This would also decrease specific draft despite increasing draft for cambined plow. Figure 9 shows the comparison between combined and simple plows.

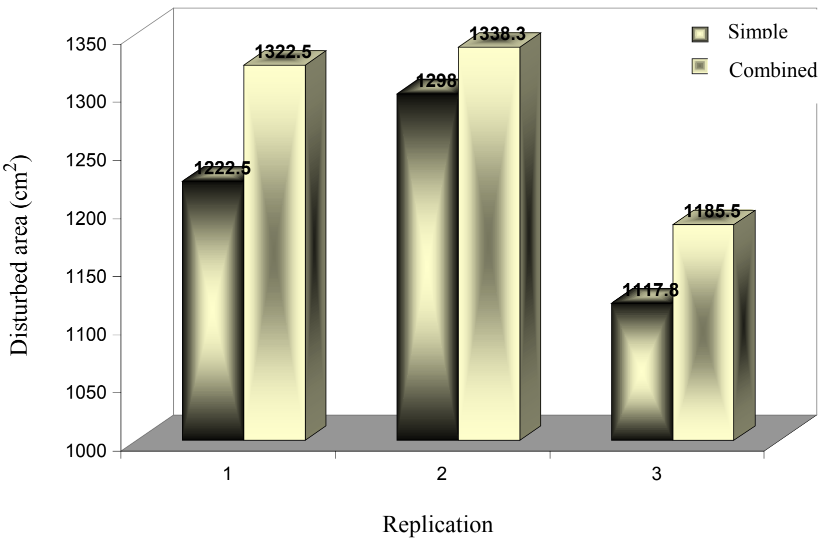

Figure 9. Soil disturbed area for both plows

4. Draf

Draft resistance was measured for beth plows using loadcell. The results nothed that combined plow increased the draft to about %14. It is clear that draft would be much higher by using moldboard plow and subsoiler seperately. Table 1 shows the draft for both plows in different replications.

Table1. Draft (KN) for both plows in different replications

	Simple	Combined
Rep.1	18.32	22.48
Rep. 2	19.84	22.13
Rep. 3	19.45	21.73
Average	**19.20**	**22.44**

5. Specific draft

To evaluate tillage machines, specific draft should be considered as soil disturbance is the major concern. Having draft and soil disturbed area enabled to calculate specific draft for beth treatments.
The sepecific draft was claculated to be 147.9 and 185.3 KN/m^2 for simple and combined plows respectively. It can be concluded that the difference was decreased to about %4 between plows in specific draft.

Conclusions

1. The results showed that combined plows affect the plow pan.
2. Deacreasing bulk density and penetration resistance in the depth of plow pan would support the performance.
3. Although the draft increasing draft about %15 by combined plow, but with inerecasing soil disturbed area, decreased to%9 in specific draft.
4. Combined plow can be easily used by farmers due to simplicity of mechanisms and adjustments and would save energy, cost and time by avioding subsoiling.

References

ASAE Standards.(1999). American Society of Agricultural Engineering. 46th edition. MI 49085-9659. USA.

Bïrkas, M., M. Jolankai, C. Gyuricza, and A. Percze. (2004). Tillage effects on compaction, earthworms and other soil quality indicators in Hungary. Soil and tillage Research, 78 (2004): 185-196.

Fundamentals of Machine Operation. (1976). Tillage. American. Deere & Company Moline. Illions.

Ghazavi, M. A. (1999). Design and development of a combined plow for country condition. The first Agr. Machinery and cech. Crof. Karaj, Iran.

Javadi, A. (2003). Design and development of a combined plow to bereak plow pan during plowing. Final research report. Agr. Eng. Res. Ins. of Iran.

Jori, I.J.(2002). Standard Selection for Disc–Ripper. ASAE annual meeting. 28-31 July. Chicago. . USA

Loghavi, M. and Hosseinpoor. A. (2002). Attaching a roller to moldboard plow for primary and secondany tillage operation. Proceeding of second Agr. Mach. And Mech. Canference, Karaj. Iran.

Milked, L. N., R. D. Grisso, L. L. Bashford and A. M. Khurst,(1994). Bi-level subsoiler performance using tandem shanks. Applied Engineering in Agriculture. 5(1): 24-28.

Ozturk, I. and S. Bastaban,(1993). A research on effect of tillage implement and machines on soil aggregation, porosity and surface smoothness in seedbed preparation. Int. Conf. On Mechanization and Energy in Agriculture. Kusadasi. Turkey.

Spoor, G. and R. J. Godwin,(1978). An experimental investigation in to the deep loosening of soil by rigid tines Agr. Engny. Res. 23: 243-258.

Unon. (2003). Mechanization development centre, Ministry of Agriculture. Iran.

EFFECT OF DIFFERENT CROPPING SYSTEMS ON THE QUALITY OF HEAVY *CAMBISOL*

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Abstract

Two complex research were carried out at the Lithuanian Institute of Agriculture's Joniskelis Research Station on an *Endocalcari-Endohypogleyic Cambisol* to identify the effects of legumes grown as the main crops and catch crops as well as the effects of their biomass incorporated as green manure on the intensity of nutrient circulation cycle in the agrocenose and on minimisation of soil degradation and filtration water pollution. Experimental evidence suggest that with red clover (*Trifolium pretense* L.) and sown lucerne (*Medicago sativa* L.) biomass the soil received 179,7 and 349,0 kg ha^{-1} nitrogen, which determined a narrower ratio of carbon to nitrogen of the incorporated biomass compared with that of vetch and oats mixture (*Vicia sativa* L., *Avena sativa* L.). Growing of cereals for three years after various legume preceding crops resulted in a significant reduction (on average 10.3 %) in total nitrogen content compared with the previous level. More intensive soil aeration during soil preparation for cereals promoted organic matter mineralization and reduction in humus content, especially in the plots applied with mineral nitrogen fertiliser. Compared with the previous level, a positive humus balance 3.4 %, remained in the soil when cereals had been grown for three years after legume preceding crops and 40 t ha^{-1} of manure had been incorporated.

Red clover grown as a catch crop accumulated in the aboveground and underground biomass 114.6 kg ha^{-1} of biological nitrogen or 76.4 kg ha^{-1} of nitrogen fixed from the atmosphere, which had a positive effect on the quality of filtration water. Here the soil contained much less N_{min} - 36.7 and 21.4% than after *Poaceae* (Bernhart) or *Brassicaeae* (Burnett) family plants that do not fix nitrogen and for the intensification of vegetation of which small nitrogen rates (N_{30}) were used in the form of mineral fertiliser.

Key words: legume crops, catch crops, nitrogen, organic carbon, filtration water

Introduction

Biologization in agriculture is one of the chief factors maintaining soil productivity and assisting in finding solutions to environmental problems (Filip, 2002; Bučienė, 2003). A balance between organic matter synthesis and decomposition settles down in natural ecosystems, however due to anthropogenic action mineralization of organic matter intensifies (Pupalienė and Stancevičius, 2003; Crews and Peoples, 2004). Perennial legumes are one of the crops stabilizing decomposition processes. By fully exploiting the whole growing season perennial legumes withhold nutrients in the surface layer of soil and accumulate a high potential of biogenic elements in the phytomass (Schubert, 1995; Ambus and Jensen, 2001). Janušienė and Žekonienė suggest that the use of overground biomass of perennial plants as green manure is much more effective than that of annual plants, since a lot of nutrients are introduced in the soil with the well-developed root system (Žekonienė and Janušienė; 1999). Moreover, legume plants fix atmospheric nitrogen and can dispense with mineral nitrogen fertilizers, which consequently results in a lesser ground water pollution (Wallgren and Linden, 1994). Legumes can be used as catch crops to prevent or minimize post-harvest leaching of nutrients (Baniuniene *et al*., 2004). The content of nutrients in the filtration water percolated through the soil is largely dependent on plant development, soil type, and texture. One of the ways to minimize nutrient leaching, especially that of nitrates, into ground water is cultivation of plants with a longer growing season and introduction of catch crops after main crops harvesting into agrosystems (Hamel *et al*., 2004).

Materials and Methods

Two experiments were conducted to ascertain the effects of legumes grown as the main crops and catch crops on soil fertility and cereal productivity. The research "The effects of legumes grown as the main crop and their biomass on the accumulation of biogenic elements and productivity in cereals grown after legumes and in the soil" was conducted following the experimental design: factor A. Preceding crops for cereal sequence (winter wheat- winter wheat-spring barley): red clover (*Trifolium pratense* L.), sown lucerne (*Medicago sativa* L.), vetch and oat mixture (*Vicia sativa* L., *Avena sativa* L.), factor B. Organic manure: 1. without manures, 2. Ist crop without manures, 3. Ist crop -green manure, 4. Ist crop- 40 t ha^{-1} of farmyard manure (Table 2).
The research "The effects of legume catch crops differing in biological characteristics on the accumulation of biogenic elements in cereals, soil and filtration water" following the experimental design: A factor: cereal backgrounds: winter wheat (*Triticum aestivum* L.), spring barley (*Hordeum vulgare* L.). Treatments of factor B – catch crops whose biomass was incorporated as green manure are presented in Table3. Red clover (*Trifolium pratense* L.) and Italian ryegrass (*Lolium multiflorum* Lamk) were undersown in a winter wheat crop upon resumption of vegetative growth, and in spring barley –shortly after sowing, white mustard (*Sinapis alba* L.) as post-crop was direct drilled by a stubble drill after cereal harvesting (on the same day). The next year spring barley was grown on both backgrounds after incorporation of catch crops biomass as green manure.
Samples for $N_{min.}$ determination were taken from the 0–40 cm soil layer in the main crops in spring upon resumption of winter wheat vegetative growth and before spring barley sowing, in catch crops after cereals harvesting, prior to incorporation of catch crops biomass as green manure and after biomass incorporation in spring before barley sowing. Mineral nitrogen (NO_3 + NH_4) was measured by distillation and colorimetry (in 1 N KCl extraction), organic carbon –by Turin methods. To measure nutrient leaching, wells-pjezometers were set up after cereal harvesting in each background in two replications to collect filtration water. In water samples N-NO_3 and N-NH_4 , and total nitrogen contents were determined calorimetrically by the analyser 'FIA Star 5012 system', NH_4-N – by gas diffusion, total N (having performed organic matter mineralization with potassium persulfate) and N-NO_3 –by cadmium reduction methods. Carbon content in the underground and overground biomass was determined by the analyser "Heraeus". The share of nitrogen fixed by legume bacteria from the atmosphere in plant biomass was calculated by multiplying nitrogen content by the coefficient (0.63) provided by Chopkins – Piters.

Results and Discussion

The effects of legumes grown as the main crops on the retention of biogenic elements in the soil. The largest amount of nutrients in the agrocenose was returned into the circulation cycle with the heaviest underground lucerne and clover biomass, while the lowest amount with the mixture of annual plants (Table 1). The importance of legumes in agrocenoses is paramount due to biological nitrogen fixation (Crews and Peoples, 2004). In the phytomass of clover and lucerne nitrogen fixed from the atmosphere accounted for the largest share 66.2 and 156.5 kg $ha^{-1.}$ Seeking to balance nutrient transport in the ecosystem, the soil was additionally incorporated with overground biomass of legumes for green manure. Incorporation of these nutrients is significant in compensating for the amount of nutrients removed with the yield. The content of atmospherically fixed symbiotic nitrogen in plant overground mass incorporated as green manure was lower than that in underground mass. The highest content of symbiotic nitrogen was introduced with lucerne and clover overground biomass 72.1 kg and 50.5 kg $ha-^{1}$, respectively, or 3.2 and 2.2 times more than with annual plants mixture.

Table 1. The role of legumes in introducing biogenic elements in the biological circulation of matters, (1996, 1997, 1999)

Crop	Dry matter t ha^{-1}	N, kg ha^{-1} total	N, kg ha^{-1} fixed	N:P:K	C:N
Underground mass					
Red clover	9.2±1.04*	99.6±14.9	66.2±10.0	1:0.2:1.1	24
Sown lucerne	13.7±1.12	234.8±35.1	156.5±23.4	1:0.1:0.7	18
Vetch and oats mixture	5.3±0.51	38.8±7.5	25.9±5.0	1:0.2:2.2	35
Overground mass and farmyard manure					
Red clover	3.2±0.58	80.1±5.7	50.5±3.6	1:0.1:0.9	12
Sown lucerne	3.9±0.32	114.2±10.9	72.1±6.9	1:0.1:0.9	10
Vetch and oats mixture	3.8±0.21	36.0±3.4	22.7±2.1	1:0.2:2.5	32
Farmyard manure FYM)	47.9±0.92	152.0±19.6	-	1:0.2:1.4	18

Carbon to nitrogen ratio determining transformation direction and intensity of incorporated organic matter in the soil differed between individual plant species and within the same species in overground and underground parts. For lucerne residues this ratio was the narrowest 18, and for vetch and oats mixture this ratio was the widest 35. Having incorporated in the soil nitrogen-rich plant overground mass, whose C:N ratio was narrower, organic matter mineralization sped up.

Having incorporated nitrogen-rich lucerne and clover overground mass as green manure, mineral nitrogen content in the soil when cereals were grown in the first year was 9.1 and 6.5 % higher than in unfertilised soil (Table 2).Statistical analysis suggests that in the first year, having incorporated organic fertiliser, $N_{min.}$ depended not only on the incorporated dry matter, nitrogen content, C:N ratio, but also on soil total nitrogen and humus content. Moreover, in heavy loam cambisols organic matter mineralization was significantly affected by soil bulk density and aeration porosity. $N_{min.}$ correlation with carbon and nitrogen ratio of incorporated organic matter was strong r = -0.97 described by a relationship y = 48.88 -0,40x. The content of free humic acids (HA-1) in the soil had a significant effect on mineral nitrogen increase.

Table 2. The effects of legumes and their overground mass incorporated in the soil on $N_{min.}$ variation in the soil, mg kg^{-1}, (1997-2001)

Fertilisation (factor B)	Preceding crops (factor A)					
	Red clover		Sown Lucerne		Vetch and oats mixture	
	I-st member	II-nd member	I-st member	II-nd member	I-st member	II-nd member
Without fertilisers	6.2	5.7	6.6	6.1	5.7	5.6
Ist crop without fertilisation 2nd, 3rd-according to $N_{min.}$	6.3	5.6	6.5	6.1	5.7	5.7
Ist crop-green manure, 2nd, 3rd-according to N_{min}	6.6	6.2	7.2	6.8	5.7	6.3
Ist crop – FYM 40 t ha^{-1} 2nd, 3rd-according to $N_{min.}$	6.6	6.4	7.0	6.8	5.9	6.5
LSD_{05} for I-st member F_A-0.42; F_B-0.49; F_{AB}-0.85; LSD_0 for II-nd member F_A-0.36; F_B-0.42; F_{AB}-0.72						

Averaged data suggest that when cereals had been grown for three years in succession (w. wheat-w. wheat –s. barley) after legume preceding crops and their biomass and farmyard manure had been incorporated the content of total nitrogen consistently declined by on average 10.3 % in all treatments. When estimating only the preceding crops, it was identified that the greatest reduction in the total nitrogen occurred after clover and lucerne, 14.8 and 9.3 %, respectively, whereas a slightly less reduction was identified after vetch and oats mixture 7.5 %, compared with the data of the respective preceding crop before the trial establishment. When estimating fertilisation treatments, the greatest reduction in nitrogen content (11.0 %) occurred in the plots applied only with mineral nitrogen fertiliser. Significant reductions in nitrogen were also recorded for the other treatments: in unfertilised treatment 10.3 %, in the treatment applied with manure 9.6 %, and the treatments fertilised with green manure 8.8 %. The most dramatic reduction in the total nitrogen content was identified when cereals had been grown after clover and had been fertilised with mineral nitrogen fertilisers and without mineral fertilisation by 17.8 and 14.8 %, respectively, compared with the previous data. When cereals were grown after annual mixture as preceding crop, the total nitrogen content in the soil in the analogous treatments declined by 6.7 and 8.2 % compared with the data before the trial establishment. Such results were determined by a markedly lower yield of cereals after this preceding crop and lower nitrogen removal than that after perennial legumes.

After cereals growing a significantly higher total nitrogen content remained after lucerne preceding crop 0.127 %, which was by 10.4 and 2.4 % more than after clover or mixture (Table 3). Furthermore, after various preceding crops the total nitrogen content in the treatments fertilised with green manure and especially with farmyard manure, tended to increase compared with unfertilised treatments. The highest content of total nitrogen after cereals growing was identified after lucerne preceding crop when fertilising with lucerne biomass and farmyard manure 0.128 % or 11.3 % more than in the control treatment. Statistical analysis suggests that the relationship between the total nitrogen content after cereals growing and the dry matter content of organic matter incorporated was moderate (r=0.42*).

Table 3. The influence of preceding crops and organic manure on the variation of total nitrogen and carbon in the soil (0–20 cm), after growing cereals (%), 1996–2002

Treatments	After growing of cereals			
	Total nitrogen	Organic carbon	C:N	Humus
Average after preceding crops (factor A)				
Clover	0.115	1.14	9.9	1,97
Lucerne	0.127	1.23	9.7	2,12
Vetch and oats mixture	0.124	1.20	9.7	2,07
Average in fertilisation treatments (factor B)				
Without fertilisers	0,122	1,17	9,6	2,02
Ist crop without fertilisation 2nd, 3rd-according to $N_{min.}$	0,121	1,18	9,8	2,02
Ist crop-green manure, 2nd, 3rd-according to N_{min}	0,124	1,18	9,5	2,03
Ist crop – FYM 40 t ha^{-1} 2nd, 3rd-according to $N_{min.}$	0,123	1,24	10,1	2,13
LSD_{05} fact. A	0,005	0,024		0,040
LSD_{05} fact. B	0,005	0,028		0,047

Before the trial establishment the highest organic carbon content in the 0-20 cm soil layer was identified after lucerne 1.25 %, after clover and annual mixture less by 1.16 and 1.18 %, respectively or by 7.2 and 5.6 % less than after lucerne.
After a tree-year cereal link growing the content of organic carbon markedly declined after lucerne (1.6 %) and clover (2.6 %), and after vetch and oats mixture it slightly increased (2.1 %), compared with the previous values. This resulted from the fact that cereals left less plant residues and at the same time less organic carbon in the soil compared with perennial grasses. Moreover, an increase in soil aeration during the soil preparation for cereals activated soil microbiological processes and increased mineralization of readily decomposed humic substances that accumulated after perennial grasses. Annual mineral nitrogen fertilisation of cereals negligibly declined (1.7 %) carbon content in the soil. This resulted from the stimulating effect of nitrogen fertiliser on organic matter mineralization which causes deficiency of carbon assimilated by soil micro-organisms.The content of organic carbon increased only for the treatment fertilised with farmyard manure, which made up on average 3.3 % through all preceding crops, compared with the previous level.
After the cereal crop rotation link on the backgrounds of legume preceding crops the highest carbon content 1.23 %, like at the beginning of the experiment, remained after lucerne preceding crop, its content there was 7.9 % higher than after clover and 1.7 % higher than after vetch and oats mixture. On average, after all preceding crops, incorporation of different amounts of organic matter had a diverse effect on the variation of organic carbon content. The highest increase in the organic carbon content occurred in the plots fertilised with farmyard manure, significant difference compared with the unfertilised treatment made up 6.0 %. When estimating individual fertilisation treatments, the lowest organic carbon content was identified for the plots of unfertilised clover and vetch and oats mixture crops. A trend of organic carbon increase was identified after clover and annual mixture preceding crops in the treatments fertilised with green manure.
Results of the correlation-regression analysis suggest that the variation of organic carbon after a three-year cereal crop rotation link was dependent on the dry matter incorporated with the overground and underground biomass of preceding crops r=0.56** and nitrogen content present in them r=0.60**. The relationship of organic carbon content (y) in the soil with the C:N ratio of organic matter incorporated was weak and insignificant, however significantly

correlated with soil carbon content (x_1) before the trial establishment and total nitrogen (x_2). The relationship of these indicators is described by the linear regression:

$y = 0.99 + 0.15x_1$; $r = 0.59^*$;

$y = 0.33 + 7.06x_2$; $r = 0.77^{**}$.

The relationship between organic carbon variation and soil physical properties was nonessential, though a slight carbon increasing trend was identified with a reduction in soil bulk density and an increase in aeration porosity and in the content of valuable structural soil aggreagates 0.25-10.00 mm in size. The ratio of carbon to nitrogen (C:N) in the soil at trial establishment differed inconsiderably (8.7–8.9) in different backgrounds, however, it was inappreciably higher after lucerne. Growing of cereals which are demanding in terms of nitrogen for three years in succession resulted in a substantial increase in the carbon to nitrogen ratio, by on average 10.2 %, compared with this ratio before the trial establishment. This was determined by disproportional variation of soil total nitrogen and carbon. Having compared C:N changes after different legume preceding crops it was found that the greatest increase in this ratio occurred after clover (15.1 %) due to the reduction in total nitrogen, compared with the previous data. On average in all fertilisation treatments owing to the same reason C:N was the greatest in unfertilised and fertilised with only nitrogen fertiliser treatments. The lowest soil C:N was found when fertilising with only nitrogen fertilisers or fertilising with nitrogen under the effect of green manure, whereas in the treatment fertilised with manure the soil carbon to nitrogen ratio increased by 12.5 %, compared with the data before the trial establishment. This increase resulted from the increase in carbon.

The effects of catch crops differing in biological characteristics on the accumulation of biogenic elements in the soil and filtration water. Catch crops increased the total productivity of both agrosystems: on the background of wheat dry matter content increased from 21.4 to 41.3 %, on the background of barley – even more 41.0 – 85.5 %. Of all catch crops red clover increased the productivity of agrocenoses most appreciably, dry matter yield of clover biomass was the highest 1.8 and 1.3 times higher than that of white mustard or Italian ryegrass (Table 4).

Table 4. Effect of catch crops with different biological properties on the cycle of biogenic nitrogen metabolism, (2002-2003)

Inter crops	Underground biomass			Overground biomass		
	Incorporation DM t ha^{-1}	N kg ha^{-1}		Incorporation DM t ha^{-1}	N kg ha^{-1}	
		total	fixed		total	fixed
White mustard	1.28±0.336	16.3±6.03	-	1.13±0.354	32.0±10.06	-
Red clover	2.49±0.160	55.7±3.97	37.2±2.64	2.03±0.665	58.9±17.28	39.2±11.53
Perennial ryegrass	1.84±0.404	30.1±6.94	-	1.59±0.739	26.9±11.84	-

The underground mass of all catch crops (white mustard, red clover, and Italian ryegrass) was higher by 13.3; 22.7; 15.7 %, respectively than overground mass, unlike for most crops grown as the main crops. This resulted from the fact that when root system of catch crops had fully formed, the growing period for the development of overground biomass was too short (Baggs et al., 2000).The catch crops differed in the accumulation of biogenic elements in underground and overground plant parts. The highest contents were accumulated of nitrogen and potassium, while the lowest content of phosphorus. Of all catch crops grown, clover phytomass was significantly distinguished for nitrogen accumulation 114.6 kgha^{-1} or 76.4 kg ha^{-1} atmospherically fixed nitrogen. Such amount of biological nitrogen is valuable from the ecological viewpoint, since it can meet N needs of cereals grown after clover. However, white mustard and Italian ryegrass applied with low starter rates of nitrogen fertiliser (N_{30}) accumulated twice as less nitrogen in their biomass (48.3 and 57.0 kg ha^{-1}, respectively).

In the 0-40 cm soil layer after harvesting of cereals significantly higher concentrations of all forms of available nitrogen compounds and total mineral nitrogen were identified on the background of spring barley, compared with that of winter wheat (Table 5). Such results were determined by a higher nitrogen removal with winter wheat yield and undersown crops had only negligible effect. In the autumn, upon completion of catch crops growing season, the content of mineral nitrogen in the soil was 0.49 mg kg^{-1} or 14.5 % higher, compared with the previous level, however, no marked differences between cereal backgrounds remained. The highest mineral nitrogen content was identified in the soil sown with white mustard fertilised with N_{30} (on average on the backgrounds 4.34 mg kg^{-1}) and Italian ryegrass (on average in the backgrounds 5.11 mg kg^{-1}). The lowest nitrogen content (2,3 mg kg^{-1}) in the soil was found in the treatments grown with nitrogen-fixing red clover as a catch crop. Similar data were obtained in Sweden and other countries (Wallgren and Linden, 1994).In the spring of the following year, after incorporation of catch crops biomass in the soil, a considerably higher mineral nitrogen content (15.86 mg kg^{-1} or 71.4 kg ha^{-1}) was identified compared with the autumn period.

Irrespective of the type of catch crops, winter wheat declined soil nitrogen level, a more significant decline occurred in total and mineral nitrogen concentration in filtration water, compared with spring barley. Moderately strong correlation between N_{min} content (x) mg kg^{-1} in the soil (0-40 cm) and total N concentration (y_1) mg l^{-1}in filtration water (0-80 cm soil layer): y_1=33.87-3.606x+0.211x^2; η=0.65; D=42 %; x extr.=8.6. Catch crops differed in their effects on nutrient leaching. On barley background these differences were especially distinct: both white mustard and Italian ryegrass grown as catch crops and fertilised with N_{30} increased the concentration of all forms of nitrogen in filtration water, compared with unfertilised.

Table 5. Effect of the catch crops with different biological properties on the change of $N_{min.}$ in the soil mg kg^{-1}, (2002-2004)

Inter crops (factor B)	Cereal background (factor A)					
	Winter wheat			Spring barely		
	after harvesting of cereals	before incorporatio n of catch crops	before barley sowing in spring	after harvesting of cereals	before incorporatio n of catch crops	before barley sowing in spring
Without catch crops	2.99	3.59	14.95	3.72	4.07	17.40
White mustard	2.99	5.05	15.60	3.72	3.63	17.15
Red clover	2.72	1.71	11.95	4.59	2.89	14.85
Perennial ryegrass	2.69	4.37	18.20	3.78	5.84	16.75
$LSD_{05\ a}$fter harvesting of cereals F_A-0.434; F_B-0.611; F_{AB}-0.868						
LSD_{05}before incorporation of catch crops F_A-0.851; F_B-1.200; F_{AB}-1.700						
LSD_{05} before barley sowing in spring F_A-1.355; F_B-1.916; F_{AB}-2.710						

On the background of winter wheat a more marked increase in mineral nitrogen content was identified only for the Italian ryegrass treatment. Averaged data indicate that when white mustard or Italian ryegrass were grown as catch crops and were fertilised with N_{30}, N_{min} concentration in filtration water (0-80 cm soil layer), increased by 21.3 and 49.7 %, respectively. Catch crops increased organic carbon reserves, especially after red clover, where they increased 3.5 %, compared with the control treatment.

Conclusions

Sown lucerne was best at compensating by bioegenic elements the nutrients removed with cereal yield: nitrogen – 69.5 % fixed from the atmosphere and 108.8 % biological nitrogen incorporated with underground plant mass. This coefficient for red clover and vetch and oats mixtures was significantly lower 40.2 and 17.8 %, respectively.
Catch crops differed in their effects on nutrient leaching: both white mustard and Italian ryegrass grown as catch crops and fertilised with N_{30} increased the concentration of all forms of nitrogen in filtration water, compared with unfertilised
Growing of cereals for three years after various legume preceding crops resulted in a significant reduction (on average 10.3 %) in total nitrogen content compared with the previous level. More intensive soil aeration during soil preparation for cereals promoted organic matter mineralization and reduction in humus content, especially in the plots applied with mineral nitrogen fertiliser. Compared with the previous level, a positive humus balance 3.4 %, remained in the soil when cereals had been grown for three years after legume preceding crops and 40 t ha^{-1} of manure had been incorporated.

Referentes

Ambus P., Jensen E.S. (2001) Crop residue management strategies to reduce N-losses – Interaction with crio N supply. Communications in Soil Science and Plant Anglysis, 32 (7-8), 981-996.
Baggs E., e*t al* (2000) The fate of nitrogen from incorporated cover crop and green manure residues. Nutrien Cycling in Agroecosystems, 56 (2), 153-163.
Baniūnienė A., ir kt. (2004) Sideracinių augalų veikimas bulvių sėjomainoje. Žemdirbystė: mokslo darbai LŽI, LŽŪU. Akademija, 87, 61-72.
Bučienė A. (2003) Žemdirbystės sistemų ekologiniai ryšiai, Klaipėda, Lietuva, 178 .
Crews T.E., Peoples M.B. (2004) Legume versus fertilizer sources of nitrogen: ecological tradeoffs and human needs. Agroculture Ecosystems & Environment, 102 (3), 279-297.
Filip Z. (2002) International approach to assessing soil quality by ecologically – related biological parameters. Agriculture, Ecosystems and Environment, 88, 169-174.
Hamel Ch., *et al* (2004) Nutrient dynamics: Utilizing biotic-abiotic interactions for improved management of agricultural soils. Journal of crop improvement TM progress in production and productivity, 11, 209-239.
Pupalienė R., Stancevičius A. (2003) Įvairaus intensyvumo žemdirbystės sistemų poveikis dirvožemio agrocheminėms savybėms. Žemdirbystė: mokslo darbai LŽI, LŽŪU. Akademija, 83, 19-29.
Schubert, S. (1995). Nitrogen assimilation by legumes-processes and ecological limitations. Fertilizer Research, 42; 99-107.
Wallgren B., Linden B. (1994) Influcence of different catch crops and ploughing times on soil mineral nitrogen. In: Proceedings of 13th International Conference, Aalborg, Denmark, 215-220.
Žekonienė V., Janušienė V. (1999) Intensyvios ir tausojančios žemdirbystės agrobiologinis vertinimas lengvos granuliometrinės sudėties dirvožemiuose. Žemdirbystė: mokslo darbai LŽI, LŽŪU. Akademija, 66, 61-70.

CONSERVATION TILLAGE SYSTEMS – SOIL – NUTRIENT – AND PESTICIDE LOSS

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1. Abstract

In Austria due to the cultivation of corn, sugar beets, sunflowers, soybeans, potatoes, including wine and fruit, about 450,000 hectares of farmland are at potential risk of erosion. For this reason the cause of soil erosion and the possibilities for reduction and prevention will be investigated.
From 1994 to 2004 eight different tillage systems were tested at three locations in Lower Austria. Five tillage systems were tested in Tulln – located 30 km from Vienna. The systems included conventional tillage with a plow as well as mulch and direct drilling of cover crops in autumn. No-till and ridge tillage was tested, also. The Institute of Hydraulics and Rural Water Management of the University of Natural Resources and Applied Science Vienna (Prof.A.Klik, Ph.D.) measured surface runoff, soil loss, nitrogen, phosphorus, and herbicide loss. Mycotoxins were analysed in an institute in Tulln. Between 1994 and 2004 the average soil loss at the three locations dropped from 16.2 t/ha/year (conventional tillage) to 4.2 t/ha/year with conservation tillage in cover crops, and to 2.2 t/ha/year with direct drilling systems. Nitrogen and Phosphorus losses showed similar tendencies. Herbicide loss declined by 1.9 % at the application rate in conventional tillage; 1.2 % in conservation tillage and 0.5 % in direct drilling systems.

2. Introduction and Problem Definition

In Austria 450,000 hectares of land are potentially in danger of erosion. This problem and the Austrian program for the promotion of an environmentally just and natural habitat protecting agriculture (OEPUL) led to a change in the way the farmers think. Besides the ecological aspects, economical obligations are becoming more and more important. While soil conservation tillage methods are becoming increasingly accepted, many farmers generally remain skeptical. Reasons for the new cultivation trends are shown below:

- Lowering of production costs
- Fewer passes - less work time - less soil compaction
- Increased productivity - cultivation of larger area possible
- Reduction of fuel consumption
- Lower machinery use
- Prevention of wind - water – tillage erosion
- Increased humus content
- Improved water retention

- Better yields
- Lower CO_2 release from the soil (climate - and soil alliance, Kioto - Agreement)

A reduction in the work time for cultivation from 5–8 hours per hectare to a proven 3-5 hours and less can be achieved, at the same time fully using the ecological advantages. The costs can hardly be reduced through minimizing cultivation, because cover crop management expenditures offset any savings. However, the value of the washed away nutrients plus the better cultivation measures for winter cover crop variations and mulch seeding supplement need to be calculated.

3. Material and methods

Different cultivation systems were examined at three locations in Lower Austria in the dry Hungarian climate (Pannonicum) and in the moderate transition climate. The climate is characterized by an annual precipitation amount of 500 mm in the Hungarian Climate (Pannonicum), 650 mm in the transition climate and by an annual average temperature of 8.5 °C - 9.5 °C.
Besides the conventional seed bed preparation with plow and chisel plow, different cover crops such as yellow mustard, California bluebell (Phacelia tanacetifolia), oil radish, clovers, green rye, buckwheat followed by mulch and direct seed were tested. Two tests of minimal cultivation using only a disk harrow and a No-Till variation were examined for yield achievement and the Mycotoxin content.
The conventional seeding was accomplished with use of a plow and cultivator plus harrow or rotary harrow for seedbed preparation. The mulch seeding was accomplished after two passes with the chisel plow followed with the cover crop. After mulch cultivation with a rotary harrow or seedbed combination implements, the direct drilling with cover crop management was just like the mulch seeding, yet the seedbed preparation was omitted (ZeroTillage). All three aforementioned systems were cultivated with a direct seeding machine.

4. Test results and discussion

4.1. Soil erosion tests

Following in Table 1 are the results of the three locations: Mistelbach (wine quarter, 30 km north of Vienna), Tulln (30 km west of Vienna) and Pyhra around St. Pölten (50 km west of Vienna). Mentioned are the three cover crops and tillage links, which were also tested for soil erosion. Besides the soil loss in t/ha/year the table also refers to the nutrient losses of Nitrogen and Phosphorus separate from the herbicide shift. The calculated grain yields - corn crop rotation (Mistelbach 1 x sugar beets, 1 x sunflowers, and Tulln 1 x sugar beets instead of corn in the crop rotation) are likewise represented in Table 1. No fall cover crop was done with the conventional seeding. The mulch seeding, added in mid-August, consisted of 7.5 kg vetchling, 11 kg winter tares, 3.7 kg buckwheat, 1.1 kg Egyptian clover, 1.1 kg Persian clover, and 0.4 kg yellow mustard as fall cover crops. The direct seed of 3 kg yellow mustard and 7 kg California bluebell were sown at the aforementioned date.

Table 1: Measured yearly erosion and yield 1994 – 2004 Mistelbach, Tulln, Pyhra (Klik 2004)

Cultivation method	Conventional Tillage	Mulch Seeding	Direct Drilling
Soil loss t/ha/Year	16.2	4.2	2.2
Nitrogen loss kg/ha/year	23	8	4.5
Phosphorus loss kg/h/year	13.8	3.2	1.9
Herbicide loss % sprayed active substance	1.9	1.2	0.5
Yield in % Conventional	100	100	101

As shown in Table 1, notable reductions in soil, nutrient, and herbicide erosion are determined. The yields do not differ significantly. Note that detailed results of registered yield reductions of 15-20 % with direct drilling of sugar beets are not represented. All other cultivated plants react to the changed cultivation yield-neutral, as long as the seeding machine slot in the course of the cultivation can be closed. Otherwise this can cause a problem if the soil is too damp or too dry. Implements such as rotary clod breaker or two sloping disks are necessary during planting in order for seeds to be covered with soil.

4.2. Cultivation tests Tulln

Five soil conservation method trials, listed in Table 2, were set-up in two locations around the Tulln area. In addition to conventional cultivation methods with plow and chisel plow, cultivation using two passes with a disk harrow was tested. One test link was minimal tilling with a single disk harrow. For this method a seed bed was prepared with a rotary harrow or seed bed combination implements, but when the NoTill method (zero Tillage) is used the soil will not be cultivated. Here several centimeters of soil were worked by direct drilling with a disk coulter from a seed drill, in the spacing drill there was no soil preparation. Ridge tillage was chosen for the 5th system, similar to potato cultivation. This plot will be worked in the conventional method, drawing ridges out in front of the growing corn, so 1° C higher soil temperature may be obtained.

Next to the yield results in kg/ha 1999-2004 in Table 2, are the analysis of Microtoxin Desoxynivalenol (DON) and Zearalenon (ZON) level in µg per kg grain. The results from cultivated corn in the Tulln area from both trials are combined. Grains were picked for the crop rotation-corn for example- in 2000 soybeans were chosen.

Table 2: Cultivation test results Tulln 1999 – 2004

Tilling method	% Yield	ZON		DON		
	Conventional	1999	2001	1999	2001	2004
Conventional Chisel Plow -CT	100	28	79	505	2477	824
Chisel Plow 2 x -CP	100	12	514	323	2170	1257
Disc harrow 1 x – Reduced Tillage - RT	93	12	20	302	1542	1080
No Till -NT	92	25	nd	600	519	374
Conventional – Ridge Tillage by corn -RiTi	98	24	64	419	3229	387

nd… not detectable

The Mycotoxin levels from 2002 and 2003 in the submitted trials were below the detectable level.

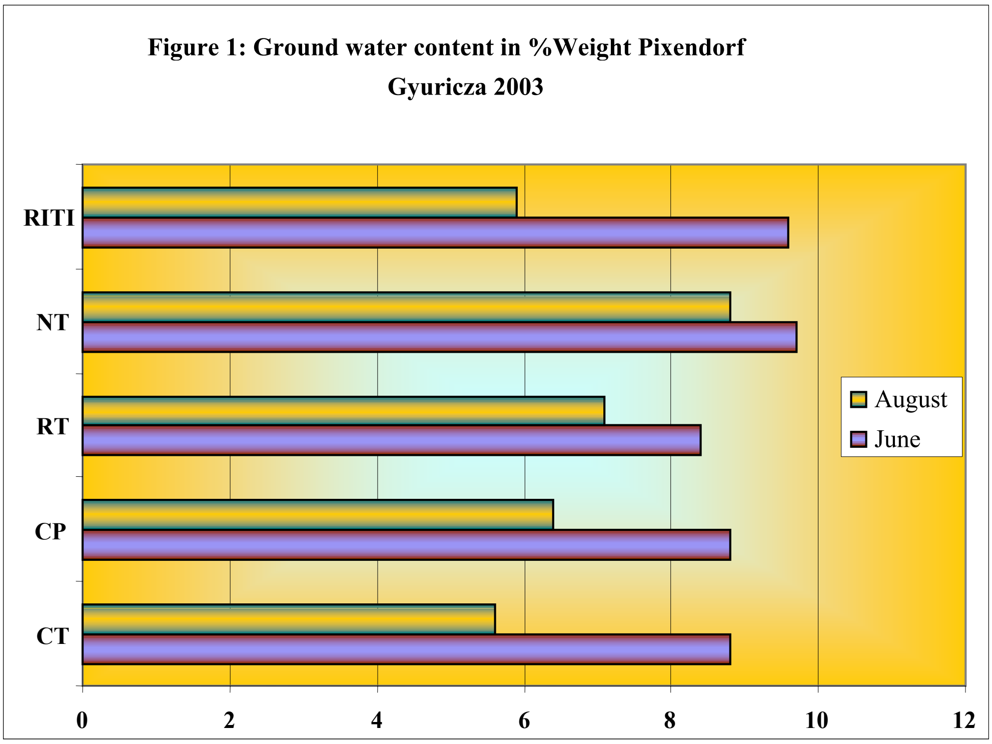
Mycotoxin guidelines for Austria:

DON: 500 – 1500 µg per kg grain
ZON: 50 - 150 µg per kg grain

DON……Deoxynivalenol
ZON…….Zearalenon

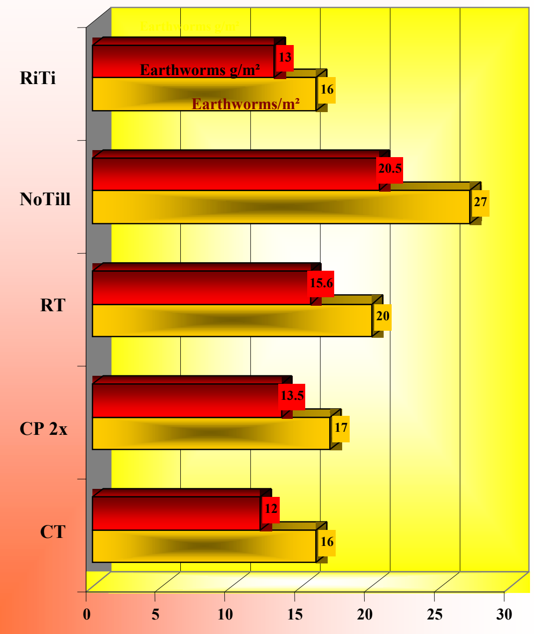
The yields are significantly lower with minimal tilling. This setback is due to the cultivation of sugar beets. Problems arose by the closing of the seed-slots with No-Tilling, which led to a reduced number of sugar beet plants. Moreover, it was not possible to fight the arising field bindweed (Convolvulus arvensis) with the active substance Glyphosate. Similar difficulties with the locking of the seed-slots can also occur with the cultivation of corn.
Despite the shown problems it seems in practice possible to use these methods if certain principles are paid attention to such as minimum soil cultivation methods and the use of proven ecological advantages. According to practical data, profit losses are only in the first change-over years, reaching a normal level later, whereby the aforementioned advantages can be used.
Cover crop management is also very demanding. Successfully creating a cover crop results in being able to cultivate early, in August. Deep-root cover crops should be selected, in order to move nutrients from the lower-lying soil layers. The use of volunteer cereals should be considered to reduce "Green bridges". These bridges transfer yellow dwarf viruses from aphids to winter barley or soil-born diseases. Particularly with grain, straw residues from corn crop rotations are carefully worked into the ground before the cultivation of the cover crops to prevent the formation of Mycotoxin from Fusarium. If this is not carried out damp conditions must be acheived for the cultivated plant bloom which leaves a very high level of Fusarium risk, which is almost impossible to control chemically. The nuisance of a significant increase in Mycotoxin in the harvested crop is the end result. If the index values are exceeded the harvested crop can not be sold for human or animal consumption, the only application options for the crop are composting or thermal energy.
Water consumption of the fall cover crop is often feared. Mutiple year measurings in the dry areas of Lower Austria have shown that the plant coverage in the fall used water in the spring as well through the increased amount of organic substances that can be saved in the soil. This pushed the water balance to zero. The water is stored in the organic matter and it can be used as needed during dry periods, which can result in unexpected profits. The hot, dry year of 2003 was a very good example of this theory.
In Figure 1 below it is clearly recognizable that the water content in the 5 trial groups in June did not differ substantially. Larger differences arose however in August when there was less cultivation, a noticable increase in the amount of moisture could be noted in the soil. This extremely dry year also yielded significant increased returns from the minimized cultivation.

CT……..Conventional Tillage
CP……..Chisel Plow
RT.........Reduced Tillage (Disc Harrow)
NT……..No Tillage
RiTi……Ridge Tillage



The number and the weight of the earthworms at 0 – 30 cm pro m² are shown in Figure 2.

Figure 2: Number and Weight of Earthworms 0-30 cm
Gyuricza April 2004



Notice the influence of soil cultivation on earthworms in Figure 2. When the soil cultivation is more intensive fewer earthworms survive in the soil crumbs. Intensive soil cultivation generally has a negative effect on the all of the biological activity in the soil, which also affects the antiphytopathogene potential. The rate of decomposition of the organic substance is greater when the soil is more active. Additionally, if this is superficially shallowly trained, the diseases present in the crop residue will transfer less.

EFFECTS FOLLOWING TWELVE YEARS OF IRRIGATED PERMANENT RAISED BED PLANTING SYSTEMS IN NORTHWEST MEXICO (MEX)

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Introduction

The utilization of planting systems intended for surface/gravity irrigated wheat production systems that permit major tillage reductions and retention of crop residues on the soil surface is very rare in both developed as well as developing countries. The main constraint that has limited application of reduced tillage and surface retention of crop residues has been associated with the difficulty in irrigation water distribution within the field, particularly when loose residues are left of the surface, for the widely practiced flat planted, flood/basin irrigation production technology commonly used for irrigated, wheat-based production systems. Lack of appropriate seeding implements, in addition, has also been a major constraint especially for small/medium scale farmers.

The Yaqui Valley is located in the state of Sonora in northwest Mexico and includes about 255,000 ha of irrigated land using primarily gravity systems irrigation systems to transport irrigation water to fields from canals (over 80% of water supplied by canals) and deep tube wells (around 20% water supply from wells). Over the past 25 years, more than 95% of the farmers have changed from the conventional technology of planting most of their crops, especially wheat (bread wheat – *Triticum aestivum* L and durum wheat – *Triticum turdigum* L. *var durum*), on the flat with basin/flood irrigation, to planting all crops, including wheat which is the most widely grown crop, on beds. Irrigation water is delivered through the fields by furrows between the beds, which range in width from 70-100 cm, center bed to center bed (Aquino, 1998).

A single row is planted on top of each bed for row crops like maize (*Zea mays L.*), soybean (*Glycine max L.)*, cotton (*Gossypium hirsutum L.*), sorghum (*Sorghum bicolor* Moench), safflower (*Carthamus tinctorius*) and dry bean (*Phaseolas vulgaris*) with 1-2 rows per bed planted for crops like chickpea (*Cicer arietinum*) and canola (*Brassica sp)* but 2-3 rows, spaced 15-30 cm apart depending on bed width, are used for wheat. Wheat yields for the Yaqui Valley have averaged over six tons per ha for the past several years. Farmers growing wheat on beds obtain about 8% higher yields with nearly 25% less operational costs as compared to those still planting conventionally on the flat, using border/basin flood irrigation (Aquino, 1998).

Most farmers practice conventional tillage by which the beds are destroyed after the harvest of each crop by several tillage operations before new beds are formed for planting the succeeding crop. This tillage is often accompanied by widespread burning of the crop residues although some maize and wheat straw is baled-off for fodder and, when turn-around-time permits, some crop residues are incorporated during tillage. In addition, most farmers apply over 75% of the total N fertilizer to wheat (average N rate for wheat is about 275 kg N ha^{-1}) as an incorporated, basal application prior to planting which results in a low, apparent N uptake efficiency estimated to be about 30-35% (Meisner et al, 1992).

There has been intense farmer interest in the development of new production technologies that will allow marked tillage reductions combined with retention of crop residues which may lead to potential reductions in production costs, improved input-use efficiency, more rapid turn-around-time between crops and more sustainable soil management while allowing continued use of the more inexpensive gravity irrigation system. Therefore, a long term experiment was initiated in 1992 in the Yaqui Valley to compare the common, farmer practice based on extensive tillage to destroy the existing beds with the formation of new beds for each succeeding crop versus the permanent raised bed system where new beds are initially formed after a final tillage cycle and are then reused as permanent beds with only superficial reshaping as needed before planting of each succeeding crop (Sayre and Moreno Ramos, 1997). The discussion below will focus on wheat crop results from this long-term trial.

Materials and methods

The long-term experiment has been conducted at the CIANO/CIMMYT experiment station located near Cd. Obregon, Sonora, Mexico (lat. 27.33° N long., 109.09° W, 38 m above sea level). The soil type is described as coarse, sandy clay, mixed montmorillonitic typic calciorthid, low in organic matter (<0.8%) and slightly alkaline (pH 7.7-8.2). Long term weather data for the wheat growing period (November to May) are as follows: maximum and minimum temperatures are 26.7 and 8.7°C respectively, average growing season rainfall is 49.3 mm and average daily pan evaporation is 4.9 mm.

The long-term experiment was initiated in the summer of 1992 and involves a two crop, annual rotation with wheat planted in late November and harvested in early May and either maize or soybean planted in late May to early June and harvested in October. Since the initiation of the experiment, twelve wheat crops have been planted and harvested in the winter season and eight maize crops (1992, 1994, 1996,1997 1999, 2000, 2001, 2002 and 2003) plus three soybean crops (1993, 1995 and 1998) have been planted and harvested in the summer season for a total of 23 crops. Soybean has not been planted during the last five, summer crop cycles after a new biotype of white fly has invaded the area and rendered soybean production uneconomical.

The trial has been managed as a randomized complete block with three replications using a split plot treatment design with main plots including combinations of tillage and crop residue management (tillage/residue management). One main plot treatment was the check treatment to compare the main farmer practice in the region using conventional tilled beds where, during or after harvest of each crop, the crop residues are chopped removed or burned, then the existing beds are destroyed by one or two disk harrowing followed by use of a disc or moldboard plow or a field chisel to a depth of 20 to 30 cm, then one to two disk harrowing, leveling and finally formation of new beds prior to or during the planting the next crop.

The three other main plot treatments involved permanent beds, which were established by a final, series of normal tillage operations prior to planting the maize crop during the summer cycle of 1992, including a deep sub-soiling, followed by the formation new beds. Since then the only tillage used for these treatments has been the passage of a winged shovel with a residue-cutting disc coulter in the furrows between the beds to reshape the sides/shoulders of the beds as needed after harvest and before planting the succeeding crop. No tillage disturbance has occurred on the surface of the beds except that caused by the single or double disk seed openers.

The four, tillage/residue management treatments included in the trial are as follows:

- Conventional tillage with formation of new beds for each crop; all crop residues incorporated
- Permanent beds; all crop residues burned
- Permanent beds; crop residues baled-off for fodder leaving approximately 30 to 40% in the field
- Permanent beds; all crop residues retained

All crop residues were chopped before incorporation or when retained on the surface, depending on the treatment. When residues were baled-off for fodder the maize residue was chopped before baling but the wheat residue was not chopped. Only the wheat residue cut by the combine harvester was baled of fodder, leaving the standing stubble (20-30 cm) intact. Whenever soybean was grown, however, its residue was not removed/burned because of the comparatively low amount of residue (2 – 3 t ha$^{-1)}$).

Wheat seeding each year occurred within 2-4 days for all tillage/residue management treatments and each year all treatments were planted within the optimum time for wheat planting for the region (last week of November). Obviously, the potential turn-around time for the permanent bed treatments would have been shorter than for the conventional tilled treatment but, in order to reduce potential confounding effects caused by widely different planting dates between treatments each year, plantings were synchronized to the extent possible, always within the optimum planting period. A prototype planter developed by the CIMMYT wheat agronomy program and equipped with notched, double disc openers with the seed drop located between the double discs followed by a rubber press wheel was used for seeding.

Nitrogen management comprised the sub-plot treatments and involve both rate and timing aspects as follows: 1) no applied N; 2) 50 kg N ha^{-1} applied at planting plus100 kg N ha^{-1} applied at the first node stage; 3) 150 kg N ha^{-1} applied at planting; 4) 100 kg N ha^{-1} applied at planting plus 200 kg N ha^{-1} at the first node stage; 5) 300 kg N ha^{-1} applied at planting; 6) 150 kg N ha^{-1} applied at first node stage and; 7) 300 kg N ha^{-1} applied at first node stage. Urea was the N source used and the differential treatments were only applied to the wheat crop. A rate of 150 kg N ha^{-1} (also urea) was applied across the whole experiment when maize was planted in the summer. No N was applied when soybean was planted in the summer. All N was banded in the bottom of the furrow, through any surface residues. In addition, 20 kg P ha^{-1} was broadcast applied prior to planting both winter and summer crops and incorporated by tillage in the conventional tilled treatment and before bed reshaping for the permanent bed treatments.

Since wheat is planted only in rows on top of the beds with the wheat bed-planting system, whether with tillage or with permanent beds, machinery access (or people or draft animals access) to the field becomes possible by trafficking in the furrow bottoms between the beds. This allows fertilizers, especially N fertilizers, to be banded when and where the crop can most efficiently use them, and more importantly, the N fertilizer can be banded through the surface residues, dramatically reducing potential, surface N volatization losses. This is in contrast to broadcast application of N fertilizer on the soil surface for post-emerge N applications commonly used for the traditional, solid stand wheat planting on the flat with flood/basin irrigation.

Bed width was 75 cm and two rows of wheat, 25 cm apart, were planted on top of each bed while one row of maize or soybean was planted in the center of each bed. Each sub plot was 8 beds wide (6 m) and 13 m long (78 m^2).

The spring wheat cultivar, Rayon 89, was planted at a rate of 100 kg ha^{-1} for the 1993 – 1997 winter crops, the spring durum wheat variety, Altar 84, was planted at the rate of 130 kg ha^{-1} for the 1998 and 1999 crops and unreleased, bread wheat advanced lines were planted from the 2000 to 2004 crop cycles at 110 kg ha^{-1}. Yield and yield components (only yield is reported here) were collected from the center two beds (19.5 m^2 harvested area) and samples of both grain and straw were collected for Kjeldahl N analysis (N uptake data not presented here).

The trial was seeded into moisture each year following a pre-seeding irrigation. Seeding depth was from 5-8 cm to insure seed placement in moist soil from the pre-seeding irrigation. This is a common strategy used by farmers in the region as part of their weed control strategy. At the time of planting, usually 13 – 17 days after the irrigation, the first flush of weeds are controlled by a shallow tillage at the time of planting with the conventional tillage system. For the experiment, pre-seeding irrigation was also used each year for wheat, but weeds in the permanent bed treatments were controlled by application of 3 l ha^{-1} glyphosate immediately after planting. In most years, no further weed control was needed but appropriate post-emergence, selective herbicides were used when required.

Post-emergence, auxiliary irrigations were applied when approximately 50% of available water was depleted in the 0-60 cm soil profile. Normally three to four post-emerge irrigations were applied.

Results and discussion

It is common that conversion from conventional tillage to a reduced or zero till seeding system with residue retention may require several crop cycles before potential advantages/disadvantages begin to become apparent (Blevins et al, 1984) and the results from this long-term trial confirm this observation.

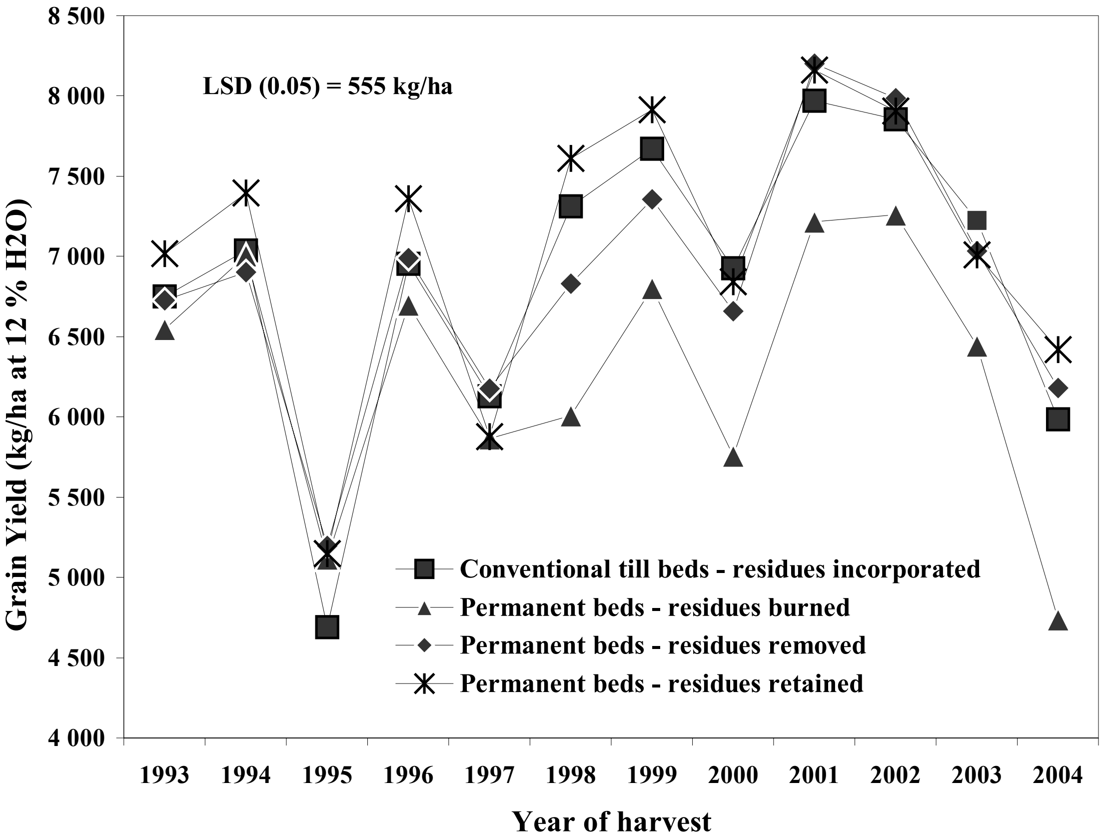
Figure 1 presents the yield trends over the twelve wheat crop cycles when 300 kg N/ha was applied at the first node stage. Only small yet significant yield differences between the tillage/residue managements occurred from 1993 to 1997. However, beginning with the 1998 wheat crop, large and significant differences between the tillage/residue management options occurred even though year-to-year yield effects were large (Figure 1). The permanent bed treatment with continuous crop residue retention demonstrated the highest average yield followed by conventional tillage with residue incorporation, then the permanent bed treatment with partial removal for fodder and lastly, with markedly reduced yields after 1997, the permanent beds with residue burning.

As has been observed for many long-term tillage experiments, major yield differences do not occur until several crop cycles have been planted. In the case of this experiment, no major grain yield differences were observed during the initial five years (10 harvested crops), especially at the higher N rates which clearly highlights the need for long-term funding and institutional commitments to such trials. If this trial had been halted before the sixth year, it could have been interpreted that there were no major wheat yield differences attributable to tillage or residue management practices for this irrigated production system.

After the 1997 wheat crop, the lowest yields have been continually observed for permanent beds with residue burning and in particular for a poor yielding crop cycle like 2004, the wheat yield for permanent beds with residue burning suffered larger, relative yield reduction as compared to the other management practices (Figure 1). It is clear that residue burning is not compatible with the permanent bed technology under these production conditions.

Permanent beds, with partial residue removal for fodder, have resulted in much smaller or no yield reductions in most years as has occurred with residue burning, especially when compared to permanent beds with full residue retention. Since at least 30-40% of the loose residues and/or standing stubbles are not removed for fodder, they appear to provide adequate ground cover to benefit soil quality-related properties. In addition, the economic value of the residue removed for fodder will likely override the associated, small grain yield reductions, at least in the short term. The yield differences between permanent beds with residue retention and conventional till beds with residue incorporation, were consistently small for most years. More importantly however, the permanent beds provided a 20-30% savings in production costs.

Figure 1. Effect of tillage and residue management over several years on wheat grain yield when 300 kg/ha N are applied at the 1st node stageat CIANO/Cd. Obregon



There was only a small interaction for year by tillage/residue management for wheat yield. There was no significant interaction between tillage/residue management by N management although the permanent beds with crop residue retention had consistently higher yields for nearly all N management treatments, especially for the 0 N rate (data not shown). It appears that the strategy of band incorporation of both basal N and first node stage N applications to minimize contact with the surface-retained crop residues may augment more efficient fertilizer N use.

A number of soil chemical, physical and biological parameters have been regularly monitored throughout the experimental period for this long-term trial. Table 1 presents a brief summary of some of these parameters that were measured during the 2001/02 wheat-growing season. Samples that were taken at the onset of the experiment in 1992 indicated uniformity for these parameters across the trial area (data not shown).

The soil chemical parameters indicate that while pH was not different for the tillage/residue management treatments, Na was significantly less for permanent beds where part or all of the crop residues had been left on the soil surface. Higher levels of Na occurred with the conventional tilled beds with residue incorporation but highest Na levels occurred for permanent beds with residue burning, This is an exceedingly important result because it indicates that for soils which may tend towards the development of salinity problems, the use of permanent beds with retention of crop residues on the soil surface may help ameliorate this trend towards saline conditions by reducing Na accumulation in the beds through minimizing evaporation from the soil surface due to the mulching effect of the retained residues and by the improvement of soil physical properties that may enhance Na removal by enhanced leaching action.

Organic matter levels were lowest for conventional tillage with residue incorporation and higher for permanent beds, especially with full of crop residue retention (Table 1). It was of interest to note that while the soil P levels were similar across the tillage/residue management treatments, the levels of the essential micronutrients, Fe and Zn were significantly higher for the permanent bed treatments, especially where some or all residues were retained on the soil surface.

Table 1 also presents the values for the wet aggregate stability. Permanent beds with residue burning showed the poorest aggregate stability followed by tilled beds. Permanent beds with partial or full residue retention (especially the latter) had the best aggregate stability.

Soil microbial biomass determinations of C and N in the biomass clearly indicated the obvious superiority of permanent beds with some or all residue retention compared to both permanent beds with residue burning or conventional tilled beds with residue incorporation (Table 1). This measure of potential soil health favors the permanent beds with residue and correlates with the observations that have been made on root disease scores and soil, pathogenic nematode levels which have been consistently higher for the permanent bed treatment with residue burning (data not shown). It seems clearly evident that the inferior grain yield performance of the permanent bed treatment with crop residue burning as shown in Figure 1 is strongly linked with the unremitting degradation associated with residue burning for most of the soil parameters that have been monitored and which are considered to be associated with the sustainability soil productivity.

Table 1. Effect of tillage and crop residue management (averaged over 4 Nitrogen treatments) on soil properties for a long-term bed planted trial initiated at CIANO, Cd. Obregon, Sonora in 1993. (Results reported here are from 0-7 cm soil samples taken during the Y2001/2002 crop cycle.

Tillage/Residue Management	PH (H_2O) 1:2	% OM	% Total N	P Olsen ppm	Na ppm	Fe ppm	Zn ppm	Wet Soil Aggregate Stability MWD[#]	Soil Microbial Biomass mg C kg^{-1}soil	Soil Microbial Biomass mg N kg^{-1}soil
Conventional Till /Incorporate Residue	8.13	1.23	0.069	10.6	564	1.66	0.29	1.26	464	4.88
Permanent/Beds Burn Residue	8.10	1.32	0.071	9.9	600	1.97	0.30	1.12	465	4.46
Permanent Beds/Remove Residue For Fodder	8.12	1.31	0.074	12.1	474	2.22	0.32	1.41	588	6.92
Permanent Beds/Retain Residue	8.06	1.43	0.079	10.3	448	2.03	0.44	1.96	600	9.06
Mean	8.10	1.32	0.073	10.7	513	1.97	0.34	1.44	529	6.33
LSD (P =0.05)	0.13	0.15	0.004	5.4	53	0.31	0.12	0.33	133	1.60

- Mean Weight Diameter

Conclusions

The bed planting system for wheat and other crops has been widely adopted by farmers in northwest Mexico where they depend on the widespread, gravity irrigation systems, however, with continued use of intensive, conventional tillage combined with considerable burning of crop residues. The research reported here indicates that the extensive tillage with its associated high costs and long turn-around- time can be dramatically reduced by the use of permanent raised beds with furrow irrigation. The results, however, also indicate that surface retention of crop residues with permanent beds may be essential to enhance chemical, physical and biological soil parameters that are crucial to insure that long-term production sustainability can be achieved. Farmers must clearly realize this before they attempt to adopt permanent bed planting systems for the primary objective to simply lower production costs inherent with the reductions in tillage while continuing to remove all crop residues for fodder or other purposes or by burning.

These results also indicate that the efficiency of N use may be enhanced because of the new opportunities offered by the bed planting system to apply N when and where the wheat plant can make more effective use, especially in the presence of retained surface residues.

Finally, as has been observed elsewhere, research to investigate potential advantages and disadvantages of contrasting tillage/residue management systems must be undertaken with a medium to long-term perspective. As was observed in the long-term trial reported here, five years involving 10 crop cycles were required to see the development of major, differential tillage/residue management effects on wheat yield.

References

Aquino, P. 1998. The adoption of bed planting of wheat in the Yaqui Valley, Sonora, Mexico. Wheat Special Report No. 17a. Mexico, D. F.: CIMMYT.

Blevins, R. L., Smith, M. S., Thomas, G. W. 1984. Changes in soil properties under no - tillage. In: Phillips, R. E., Phillips, S. H. (Ed.) No – Tillage Agriculture – Principles and Practices. pp. 190 – 230. Van Nostrand Rheinhold Company, New York.

Meisner, C. A., Acevedo, E., Flores, D., Sayre, K., Ortiz-Monasterio, I., Byerlee, D. 1992. Wheat production and grower practices in the Yaqui Valley, Sonora, Mexico. Wheat Special Report No. 6. Mexico, D. F.: CIMMYT.

Sayre, K. D., Moreno Ramos, O. H. 1997. Applications of raised-bed planting systems to wheat. Wheat Special Report No. 31. Mexico, D. F.: CIMMYT.

USE OF SYSTEM EKOTECH TO ENSURE „GOOD AGRONOMICAL PRACTICES"

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When the Law of soil protection was constructed in 1936 the President F.D. Roosevelt noted a statement -" Nation, that destroys its soil is destroying itself". The law begins with the statement "Prosperity of the nation is characterized by its care of its own land". This law helped to protect the soil and raised the soil protection standards in the states. One of the other advantages of USA is that the land owner is also the same person who is tilling the land. Ownership of the land is bringing higher awareness of its value for current production as well as its value for future generations. The law ensures that irresponsible land and soil management is strictly penalized.
In our country has the soil the same function asin the USA. It is a basic tool of production of food. But from our current land management practices it is hard to say, that we are caring for it as for irreplaceable tool for producing food. The soil erosion is one from the problems. Soil erosion rate is documented in table 1.

Table 1

Degree of threat	Arable land share	
	ha	%
Not endangered	180 655	4,2
Susceptible	1 192 676	27,9
Slightly endangered	1 106 743	25,9
Medium endangered	771 599	18,0
Strongly endangered	429 891	10,1
Most endangered	595 250	13,9

Shall we estimate the damage caused by erosion, we can calculate the yield loss about 15-20% in slightly endangered areas, on medium endangered the yield losses can be expected about 40-50% and in the most endangered areas the yield can drop down by 75%. In all these evaluations we consider technologies using the moldboard plow.

New norms were established to promote good agronomical practices that are more in the line with environment protection. Basic conditions are listed in the table 2. and possible punishments on table 3.

But there does not exist general accord of those criteria with other norms and subsidies that are now in place after the country joined EU. For example in the subsidy titled as intercrops exist three separate risks of inducing soil erosion, mechanical destruction of soil structure and loss of organic content, all with possible negative economic effect of reduced yields of main crop.

On top of that, methodology of the subsidy title establishes a language that directly forces ploughing of the land and therefore calls for breach of "good agronomic practices".
Following the title blindly leads to devastation of soil structure with consequent yield loss. On the other side it increases a risk of penaltz for the farm for breaking rules of :good agronomical practice".

Table 2

"Good agronomical practice and environment protection conditions	
Goal	**Evaluated criteria**
Soil erosion: **Soil protection by correct management**	• **Minimum soil coverage** • **Minimum rules of land management taking in account local specific conditions** • **Protection of terraces**
Organic matter in soil: **Protection of soil organic matter via correct soil management practices**	• **Cropping pattern** • **Stubble management** • **Mulch treatment**
Soil structure: **Protection of soil structure by correct use of machinery**	• **Use of suitable machinery** • **Vertical soil tillage**
Minimal level of soil management: **Ensuring minimal level of soil management and preventing the degradation of the land**	• **Minimum animal density** • **Protection of pastures** • **Protection of countryside** • **-Prevention of weed spreads**

Table 3

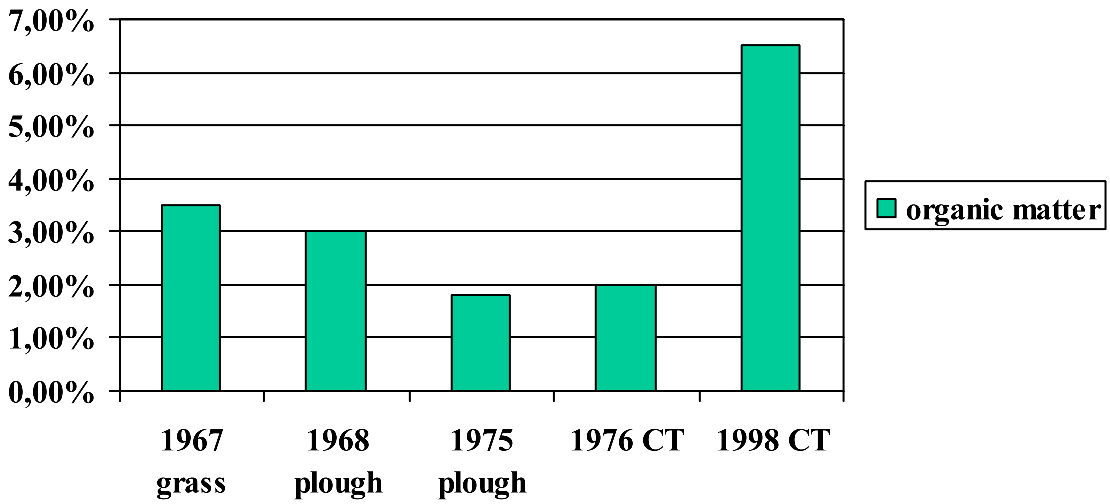
Sanctions for breaking the conditions	
Reason of the sanction	**Sabction**
Neglecting	**Decrease of payments by 5% on the area for each case**
Intended breach	**Decrease of payments by 20%**
Intended breach of all rules	**Exclusion from subsidies in the given year** **Intended breach of 50% Exclusion from subsidies in the following year**

EKOTECH means economy and ecology in technologies. Its success is based on strict technological discipline and precise agronomical practices. There is no room for neglecting or intended breach of agronomical practices. Making EKOTECH as on farm used technology

automatically prevent any chance of breaking the “Good agronomical practices” rules and effectivelz protect farm from getting any sanction imposed. The question is “ Why is that?
It is given by its nature. The stonecorner of EKOTECH is conservation tillage. This system leads to 90% decrease of soil erosion even in the most endangered areas, regardless whether we consider water or wind erosion.
EKOTECH is management of crop residues on the top of the soil and therefore it saves the soil from both types of erosion by default. We can document this by the following picture of corn growing out from the crop residues of intercrop - mustard. Corn was direct-drilled into the frozen-out intercrop and the mulch has completely protected the soil from the erosion.

Not only this practice reduces the soil erosion, but it also generates growth of organic mater content in the soil due to reduced decomposition rates as it is documented on the graph 1.

Graph 1



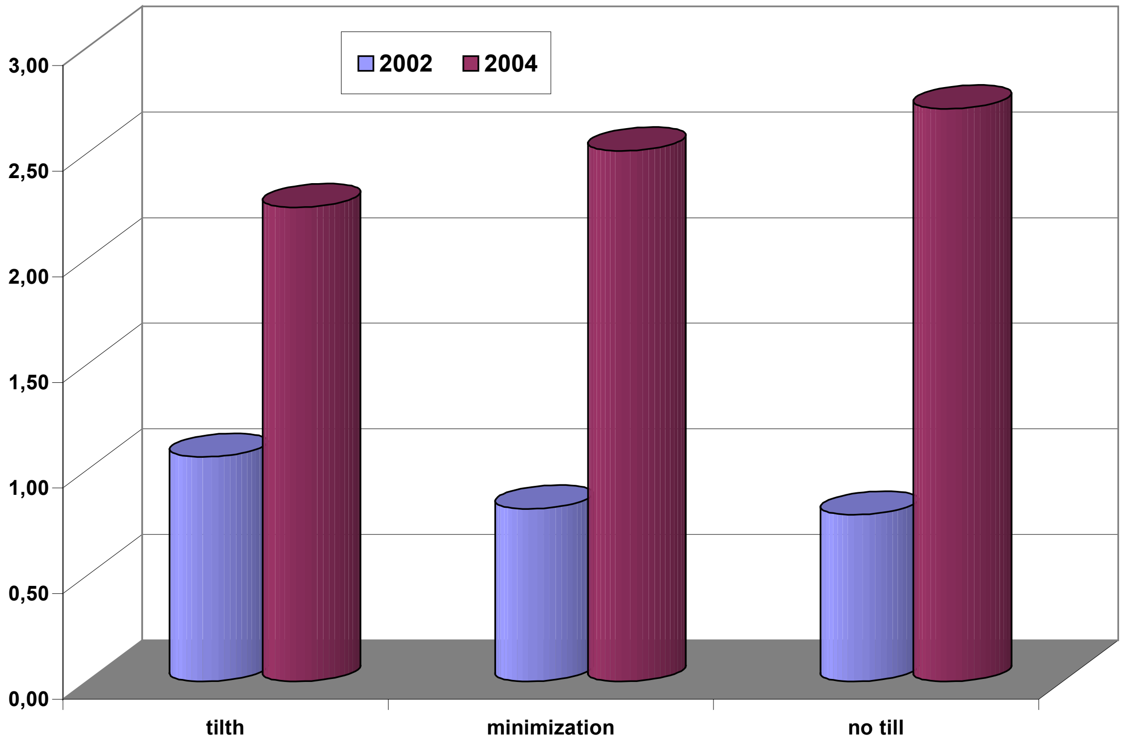
Source: No Till farmer No 11, November 2001

In Czech conditions the organic matter grows in soil by 0,3-0,5% a year, as documented by research of VÚP Troubsko done on the land under normal commercial farming.

Second pollar of EKOTECH is ROUNDUP management which reduces the number of cultivation trips over the field and has agein positive influence on the soil structure. The main

goal is of course the complex regulation of weeds and crop volunteers which are not controlled by cultivation.
Oncerning the soil structure it is important to mention that EKOTECH includes various-changing system of soil tillage where there are continually changed the depth of necessary cultivation including periodical deep soil cultivation without disturbing the top layer. This leads to continual improvement of physical and biological properties of soil.

Graph 2



(author: Badalikova et al, 2004)

Development of soil structure is characterized by the structure coefficient – share of structured vs. non-structured soil particles. Here are the results from technology center in Branišovice.
Soil structure improvement at ploughed variant is given by incorporation of straw, decrease of plowing depth and reduction of total machinery passes over the field (graph 2).

The result is structured soil in the whole profile, which is crucial for development of rich root system of crop. That allows plants to tap water and nutrients from the whole soil profile and from deeper soil and therefore better use of the yield potential of the seeds. On top of that the risk of nutrient leaching (especially nitrates) is decreased. That management leads to overall decrease of the use of industrial fertilizers without the risk of yield decrease. This way the proper management of soil leads to increase of economic gain from the land.

Following picture documents results:

This way we follow the global trend of introduction of vertical tillage, where soil is loosed only in the area of seeding and not as the whole (soil can be loosed down to the depth of seeding or if required even deeper down to 40 cm). Always the condition of not disturbing of top soil layer is obeyed and the top of the soil is protected by crop residues.
Currently we have enough experience and there exist sufficient machinery to make the technology widespread to protect all the soils of Czech Republic without any negative impact on the economy of farming. On top of that the technology protects the environment. In technology EKOTECH is the subsidies title Intercrops managed in accordance with the requirements of “Good agronomical practices” and avoids any conflicts and sanctions.

YIELD AND QUALITY OF WINTER WHEAT CORN AFTER PERENNIAL DIFFERENT SOIL TREATMENT

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Introduction

The yield formation by winter wheat and his quality is influenced on the cultivation locality, year, forecrop and variety also agrotechnical measures inclusive soil tillage and fertilization nitrogen. On the basis our perennial piece of knowledge and sighting plantations by winter wheat establishment to the reduced soil tillage mostly faster and well - balanced emergence and during autumn better shoot than plantations establishment in same term after ploughing. Follows it from better entice into and heat regime in fleet processed soil, where except higher dampness soil in the area north bed obstruct postharvest remnants to the eye soil bigger wastes soil water and on accrued warm. On the contrary in spring period unploughed soil slower soaking, are damper and mineralization nutriments from organic materials in soil is slow. Also lower nutrient reserve, especially nitrogen, in lower strata soil after reduced soil tillage requires other access to fertilization plants than after ploughing.

Material and method

In field experiments with winter wheat after peas (2001 - 2003) and after spring barley (2003 - 2004) was compared with influence different waies soil tillage (C= conventionel with ploughing to the 0,22 m, M = reduced to the 0,1 m - since 1994 without ploughing) and various intensity of plant nutrition and protection on grain yield 13 - 14 variety winter wheat and his quality. Experiments were effected on stand in Ruzyně (*sugar beet growing region of production, above sea level altitude:340 m, yearly total rainfall:450 mm, annual mean temperature air: 7,8* ^{0}C *, brown soil on loess, clayey*). After harvest preceding crop was effected in both waies soil tillage (strips about latitude 12 m in 2 renewals) stubble ploughed under disks, after followed ploughing (2001 – 7.9., 2002 – 13.9., 2003 – 16.9.) and by reduced soil tillage shallow stubble ploughed under disks (2001 – 7.9.) or claw (2002 – 24.9., 2003 – 29.9.). Resolve preparation was effected rotary recruit and sowing accurate small-plot sec machine Oyjord in the year 2001 – 10.10. (3,6 MGS), 2002 – 1.10. (3,8 MGS), 2003 – 3.10. (3,8 MGS). Coarse size plots was 18 m^2 and harvest size plots 12 m$^{2.}$ Harvest was effected small-plot harvester Wintersteiger 30.7.2002, 24.7.2003 and 10.8.2004

Intensity of cultivation:

- CI and MI: lower dues fertilization N (of regeneration 30 kg N.ha^{-1} in LAV-ammonium nitrate with calcite, produce 40 kg N. ha^{-1} in LAV, in the year 2004 late 30 kg N. ha^{-1} in LAV), without fungicides, without growth regulator.
- CII and M II: higher dues fertilization N (of regeneration 60 kg N. ha^{-1} in LAV, produce 60 kg N. ha^{-1} in LAV, in the year 2004 late 30 kg N. ha^{-1} in LAV), 2 fungicides (Duett 1 l. ha^{-1} at the stalk shooting – DC 30-31 and tango super (in the year 2004 Horizon) 1 l. ha^{-1} in phase heading – DC 59), growth regulator Retacel extra 1 l. ha^{-1} in phase DC 30-31.

Spraies herbicides and insecticides were perform on the basis occurrences weeds and pests.

From qualitative parameters were investigate with Thousand-kernel weight, volume weight, crude protein, wet gluten, Falling Number, sedimentation test – in the year 2002 in flour (Zeleny), in the year 2003 in groats (SDS test).

Results and discussion

From results in the table (1 – 3) follows, that in years 2002 and 2004 were higher yields grains by most varieties winter wheat achieved by reduced soil tillage than in ploughing.. While at lower intensity of plant nutrition and protection were especially in the year 2002 differences unconclusive, at higher intensity were yields 13 variety in the year 2002 at average about 3,4 % and in the year 2004 (14 variety) about 9,5 % higher after reduced soil tillage in comparison with ploughing. On reduced soil tillage at higher intensity of plant nutrition and protection best respond variety Banquet, Niagara, Contra, Akteur and Sarka. In both systems soil tillage were ascertained higher yields grains at higher intensity of plant nutrition and protection. In the year 2002 higher intensity disply manifest increasing decrees by single variety about 17 – 37 % ploughing and about 14 – 38 % reduced soil tillage and in the year 2004 about 5 – 20 % ploughing and about 8 – 27 % reduced soil tillage. On higher intensity of plant nutrition and protection best respond variety Banquet, Nela, Niagara, Rapsodia and at least variety Rheia. In year 2004 by reduced tillage (RT I) were achieved highest yields by varieties Bill (10,54 $t.ha^{-1}$) and Contra (11,08 $t.ha^{-1}$) compared to (RT I) average (9,57 $t.ha^{-1}$) and conventional tillage (CT I) by varieties Contra (10,44 $t.ha^{-1}$) and Windsor (10,04 $t.ha^{-1}$) in average (9,03 $t.ha^{-1}$) from all varieties (CT I). Highest yields over 12 $t.ha^{-1}$ were observed in reduced tillage (RTII) by varieties Contra, Mladka and conventional tillage (CT II) by varieties Contra (10,91 $t.ha^{-1}$) and Rapsodia (10,89 $t.ha^{-1}$). Ducsay, Ložek (2004), Capouchová, Petr (2004), Pommer (1991) show in higher yields in comparison with advances with low, or zero entrances, it acknowledges by most experiments statistically significant effect manure nitrogen. In year 2002 - 2003 had influence over achieved yields grains varieties winter wheat unfavourable course cold and above all very warm and dry month June. Critical entice into period for wheat is May and June. Limitation supply plants water in these periods raised production proteins in grains (Petr, 1987), lower Thousand-kernel weight and grain yield in comparison watered wheat. Hubík (1995), Vrkoč et al. (1995) and Delogu et al. (1998) state a strong effect of weather conditions on winter wheat grain yield formation. Damage plants winter freezing injury was from all followed varieties bigger ploughing than in reduced soil tillage. Ploughing were mostly involved variety Mladka, Nela, Contra, Windsor, Bill, Apache and by reduced soil tillage variety Mladka and Nela. The temperature measuring at a depth soil 0,05 m we are found out, that after ploughing reached temperature during cold lower values than after reduced soil tillage as well as embody bigger fluctuations. Worseness plants after ploughing could follow also bigger movements soil with owing to mechanical damage plants. It followed from our results (Tab. 2), decisive for grain yield wasn't upon this stand damage plants during cold, but their reaction to poverty of moisture and high temperature air in month June, which at the time flowerage and resulting infusion grains exceed 30 ^{0}C (along June 7 days with tropical temperatures). Unfavourable weather influences were mostly cursed with short stalk variety Rapsodia, Šárka, Bill and Clever, by which soon after from - flower he began drying leaf area. On the contrary variety Samanta and Ebi with longer stalk attained highest yields. Longitude stalk however was only one of to many factors, which could influence immunity variety in face of stress dry atmosphere and high temperatures. E.g. involved variety Rapsodia, Bill, Clever respond highly on higher intensity of plant nutrition and protection, where was applied growth regulator and get to the next truncation stalk. Researchs Palfi and Dezsi proved, that and sterile, strong stalk on plant relay out created asimilates to the fertile stalks and escalate so general sources asimilates and productivity fertile stalks, this statement confirmed in our experiments in the year 2002, when was found more strong offshoots by most varieties. Tillering is main agent autoregulation density growth thereby then and agent to partial elimination unfavourable consequences weather, pathogens and agriculturalist errors during vegetative period. Proceeds virtually from arise to the flowerage. Mortification offshoots is mannerly largely by lack of moisture and nutriments, by lack of lights in dense growths and step development (offshoots vegetative and evolutionary less advanced earlier wither away (Nielsen, Halvorsen, 1991, Sieling et al. 1994).

In year 2002 - 2003 wasn't ascertained substantial improvement yield differences among reduced soil tillage and ploughing nor among intensities of plant nutrition and protection. At the same time better state plants after cold by reduced soil tillage and better economy with soil water by those technology soil tillage create good groundwork also for achievement higher decrees grains, which disply manifest only by some variety (Banquet, Contra, Rheia, Sarka). From our nutrition experiments follows, that by reduced systems soil tillage are higher yields grains winter wheat than in ploughing above all in years, when are preferable weather conditions for slow translocation asimilates to the grains and usage leaf area liberate nitrogen and next nutriments from organic materials in soil. In the year 2003 appearance to high temperatures air during months June and carrying agent leaf area so couldn't be this potential used. On the contrary in the year 2004 were from hereof standpoint preferable weather conditions and achieved yields grains winter wheat were by reduced soil tillage higher than in ploughing.

From harvest in the year 2002 and 2003 follows, that on most followed qualitative parameters had bigger influence intensity of plant nutrition and protection than way soil tillage. Higher intensity with higher general dose nitrogen (about 50 kg $N.ha^{-1}$) by most varieties disply manifest in both years increasing crude protein, wet gluten, and higher value sedimentation test, in the year 2003 also higher Falling Number. On the contrary didn't have favourable influence over volume weight, which in the year 2002 incurred, that some high - quality wheat A (e.g . Nela, Niagara) fail to satisfy in contrast to lower intensity because of this parameters norm on food wheat. Some variety (Clever, Banquet,) registered to the high - quality wheat A fail to satisfy norm on volume weight nor at lower intensity of plant nutrition and protection, where on top fall short of nor requisite content of crude protein. Reduced soil tillage in comparison with ploughing was ascertained by most variety higher Thousand-kernel weight and volume weight, but lower Falling Number and in the year 2003 also lower crude protein and wet gluten. From our agrotechnical results follows, that more intense soil tillage with ploughing by most followed variants fertilization disply manifest in comparison with reduced soil tillage higher crude protein and wet gluten in grain winter wheat and higher value sedimentation test. Thousand-kernel weight, volume weight wasn't processing soil significant effected. The results of the studies written by Hubík (1995), Vrkoč et al. (1995) and Šíp et al. (2000) document that intensity of cultivation, particularly by the use of different doses of N fertilizers can be affected by the content of crude protein and wet gluten in grain wheat in a significant way.

Conclusions

From obtained results from field variety trial agriculturalist experiments on the cultivation locality in Ruzyně follows, that in years 2002 and 2004 were by reduced soil tillage achieved by most varieties winter wheat higher yields grains than in ploughing. In the year 2003 wasn't ascertained substantial improvement yield differences among reduced soil tillage and ploughing nor among intensities of plant nutrition and protection. In both systems soil tillage were ascertained higher yields grains at higher intensity of plant nutrition and protection. In the year 2002 higher intensity disply manifest increasing decrees by single variety about 17 – 37 % ploughing and about 14 – 38 % by reduced soil tillage and in the year 2004 about 5 – 20 % ploughing and about 8 – 27 % by reduced soil tillage. On higher intensity of plant nutrition and protection best respond variety Banquet, Nela, Niagara, Rapsodia and at least variety Rheia. On quality grains winter wheat had bigger influence intensity of plant nutrition and protection than way soil tillage.

References

CAPOUCHOVÁ, I., PETR, J.: The effect of variety and agroecological factors on the yield and quality of winter wheat. Scientia agriculturae bohemica, 35, 2004 (1): 1-11.

DELOGU, G, CATIVELLI, L, PECCHIONI, N, De FALCIS, D., MAGGIORE, T., STANCA, A. M.: Uptake and agronomic efficiency of nitrogen in winter barley and winter wheat. Eur. J. Agron., 1998, (9): 11-20.

DUCSAY, L., LOŽEK O.: Effect of topdressing with nitrogen on the yield and quality of winter wheat grain. Plant Soil Environ., 50, 2004, (7): 309-314.

HUBÍK, K.: The effect of fertilization and year on the bread wheat quality. Rostl. Výr., 1995, (41): 521-527. (In Czech).

NIELSEN; D:C:; HALVORSON; A:D:; 1991: Nitrogen fertility influence on water stress and yield of winter wheat. In: Agron. J., 1991, 83, 1065-1070.

PETR, J., et al.: Počasí a výnosy (Weather and Yields). SZN Praha 1987, 381 pp.

POMMER, G.,1991: Effect of cultivation intensity on yield, yield structure and quality of various crops. Bayerisches Landwirtschaftliches Jahrbuch, 1991: 68, č. 3, s. 380 – 388 s. 380 – 388

SIELING; K:; CHRISTEN; O:; RICHTER-HARDER, H., HANUS, H.: Effects of temporary water stress after anthesis on grain yeild and yield components in different tiller categories of two spring wheat varieties. In: J. Agron., Crop Sci., 1994, 173, 30-40

ŠÍP, V., ŠKORPÍK, M., CHRPOVÁ, J., ŠOTTNÍKOVÁ, V., BÁRTOVÁ, Š.: The effect of variety and cultivation measures on the grain yield and food quality of winter wheat. Rostl. Výr., 46, 2000: 159-167. (In Czech)

VRKOČ, F., VACH, M., SKALA, J.: The effect of cultivation measures, sites and years on the content of nutrients and baking quality of winter wheat grain. Rostl. Výr., 41, 1995: 315-319. (In Czech)

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Table 1. Yield of winter wheat corn at different soil treatment and nitrogen fertilization and plant protection (Ruzyně, 2002)

Variety	Yield (t/ha)				% difference CT vs. RT (CT =100%)		% difference of rates (Int. I = 100%)	
	RT I	CT I	RT II	CT II	I	II	RT	CT
Alka	7,90	7,64	9,38	9,29	3,4	1,0	19	21
Apache	8,44	8,86	10,70	10,61	-4,8	0,8	27	20
Banquet	7,50	7,15	10,32	9,77	5,0	5,7	38	37
Clever	9,38	9,20	11,26	10,82	2,0	4,0	20	18
Contra	9,82	9,66	12,07	11,53	1,7	4,7	23	19
Ebi	8,62	8,28	10,26	9,83	4,0	4,4	19	19
Nela	8,04	7,65	10,61	9,97	5,2	6,3	32	30
Niagara	7,59	7,65	10,02	9,39	-0,9	6,8	32	23
Rheia	9,17	8,69	10,42	10,24	5,5	1,8	14	18
Samanta	7,91	7,64	10,27	10,14	3,6	1,2	30	33
Sulamit	7,57	7,96	9,77	9,75	-4,8	0,1	29	23
Šárka	8,03	8,53	10,43	9,97	-5,8	4,6	30	17
Windsor	9,10	9,22	11,55	11,20	-1,3	3,2	27	21
Average	**8,39**	**8,32**	**10,54**	**10,19**	**0,9**	**3,4**	**26**	**23**

Table 2. Yield of winter wheat corn at different soil treatment and nitrogen fertilization and plant protection (Ruzyně, 2003)

Variety	Yield (t/ha)				% difference CT vs. RT (CT =100%)		% difference of rates (Int. I = 100%)	
	RT I	CT I	RT II	CT II	I	II	RT	CT
Apache	4,97	5,32	5,56	5,51	-6,4	0,9	12	4
Banquet	6,53	6,49	6,99	6,62	0,6	5,6	7	2
Bill	3,86	3,80	4,04	4,34	1,5	-7,0	5	14
Clever	3,74	3,95	3,91	4,46	-5,2	-12,5	4	13
Contra	6,65	6,66	6,91	6,51	0,0	6,1	4	-2
Ebi	6,61	6,61	7,03	6,83	-0,1	3,0	6	3
Mladka	5,61	5,66	6,26	6,12	-0,8	2,3	12	8
Nela	6,03	6,07	6,27	6,16	-0,7	1,8	4	2
Rapsodia	1,41	1,42	1,57	1,62	-0,1	-3,2	11	15
Rheia	5,01	4,61	5,13	4,73	8,7	8,3	2	3
Samanta	6,91	6,96	7,20	7,28	-0,7	-1,1	4	5
Sulamit	5,88	6,25	6,65	6,66	-5,9	0,0	13	6
Šárka	3,99	2,56	3,79	2,47	55,8	53,3	-5	-3
Windsor	6,44	6,39	6,83	6,54	0,8	4,4	6	2
Average	**5,26**	**5,20**	**5,58**	**5,42**	**1,3**	**3,0**	**6**	**4**

Table 3. Yield of winter wheat corn at different soil treatment and nitrogen fertilization and plant protection (Ruzyně, 2004)

Variety	Yield (t/ha)				% difference CT vs. RT (CT =100%)		% difference of rates (Int. I = 100%)	
	RT I	**CT I**	**RT II**	**CT II**	**I**	**II**	**RT**	**CT**
Apache	9,62	9,31	11,03	9,80	3,2	12,5	15	5
Banquet	7,83	7,42	9,97	8,87	5,5	12,3	27	20
Bill	10,54	9,89	11,60	10,78	6,6	7,6	10	9
Clever	10,26	9,78	11,64	10,73	5,0	8,4	13	10
Contra	11,08	10,44	12,08	10,91	6,2	10,7	9	5
Ebi	9,48	8,94	11,02	10,04	6,1	9,7	16	12
Mladka	10,26	9,71	12,07	10,86	5,7	11,1	18	12
Nela	8,29	7,80	9,87	9,16	6,2	7,7	19	17
Rapsodia	9,82	9,40	11,93	10,89	4,5	9,5	21	16
Rheia	9,15	8,37	9,89	9,42	9,4	5,0	8	13
Samanta	9,37	8,55	10,66	9,58	9,6	11,2	14	12
Sulamit	8,94	7,96	10,10	9,42	12,3	7,3	13	18
Šárka	8,89	8,81	10,61	9,35	0,8	13,4	19	6
Windsor	10,41	10,04	11,59	10,83	3,7	7,0	11	8
Average	**9,57**	**9,03**	**11,00**	**10,05**	**6,0**	**9,5**	**15**	**11**

Tab. 4 Sums of precipitation and average temperatures (Ruzyně 2002-2004)

	2002	2003	2004	2002	2003	2004	2002	2003	2004
Month	t °C	t °C	t °C	mm	mm	mm	precipitation from % norm		
III.	4,9	5,1	3,9	30	6,2	37,2	107,1	22,1	132,9
IV.	8,5	8,5	10,1	27,7	31,4	16,2	72,9	82,6	42,6
V.	19,4	15,8	12,3	8,5	72	40	11	93,5	51,95
VI.	17,6	20,4	16,3	53,4	28,2	110,4	73,2	38,6	151,2
VII.	18,6	19,5	18,3	93,2	73,8	52,2	141,2	111,8	79,1
Sums of precipitation: III. - VII. Month				212,8	211,6	256			

	2002	2003	2004
temperature interval from norm			
	1,6	1,6	0,6
	0,6	0,6	2,2
	6,7	3,1	-0,4
	1,7	4,5	0,4
	1,1	2	0,8

EFFECT OF SUSTAINABLE TILLAGE AND EXTENSION OF WINTER CROP PART IN ROTATIONS ON SOIL PHYSICAL PROPERTIES

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Abstract
Complex investigations with a view to reducing soil physical degradation were carried out over the period 1998-2002 at the Lithuanian Institute of Agriculture's Joniskelis Research Station on a glacial lacustrine clay loam on silty clay *(Gleyic Cambisol)*. The study compared the effects of: A. Crop rotations with different area of winter and spring crops (1.Without winter crops; 2. 25% of winter crops; 3. 50% of winter crops; 4. 75% of winter crops; 5. 100% of winter crops), growing annual and perennial grasses, spring and winter wheat, triticale, and barley. B. Soil tillage systems: 1. Conventional (primary soil tillage was performed by ploughing); 2. Sustainable (after grasses the soil was ploughed, after other preceding crops the soil was loosened without inverting of the topsoil).
The results of investigations suggests that increasing of winter crops area in the crop rotation enabled us to decline compaction of the topsoil from high to moderate, maintain up to 37,3% higher productive moisture reserves, improve water to air ratio, and increase the crop rotation productivity up to 44,7%. The application of reduced primary tillage in sustainable system determined persistence of high soil compaction and 8,0% lower air-filled porosity at the bottom of the topsoil, but the whole topsoil had reached physical maturity more evenly in spring, however, the grain yield of cereals was 6,4% lower compared with their growing after the conventional soil tillage. On clay loam spring cereals responded more sensitively to reduced soil tillage compared with winter cereals.

Key words: clay loam, crop rotations, soil tillage, physical properties, crop yield

Introduction

The application of new technological principles in soil tillage, the use of economically more efficient but heavier tractors and agricultural machinery raise higher requirements for soil physical properties. Consequently, in contemporary agriculture the soil must be resistant to all degradation factors, and the soil properties must meet the requirements of input-saving crop cultivation technologies (Bondarev, 1990; Horn et al., 2000; Boizard et al., 2002; Schafer-Landefeld, et al., 2004).
Compaction as the form of soil physical degradation is especially typical on heavy soils, because they are mostly in the state of not resistant to compaction. The means intended for the elimination of the negative effects of soil compaction (deep loosening, cultivation of deep-rooted crops etc.) are not always sufficiently effective. Clay loam and clay soils, noted for higher susceptibility to compaction, tend to densify more when spring sown and especially row crops are grown (Maiksteniene, 1997; Horn et al., 2000; Kladivko, 2001).
Great compaction of heavy soils results in a considerable worsening of their physical and technological properties. With increased soil cohesion, hardness, plasticity, and stickiness soil resistance to tillage as well as energy input increase. Therefore it is vital to improve clayey soils' physical properties, apply the proper primary and pre-sowing soil tillage methods, choose the best-suited crops and their preceding crops and other soil and crop management

practices that determine cultivation conditions for the crops grown (Maiksteniene, 1997; Etana *et al.*, 1999; Mueller et al., 2003).
Physical degradation of heavy soil increases its a high resistance to mechanical tillage and much energy input is required for this. Energy input for soil tillage is markedly declined by replacement of ploughing by ploughless tillage. In Sweden it was found out that on heavy soils replacement of ploughing by ploughless tillage is more effective for winter crops than for spring crops. Most authors maintain that tillage without inversion of the ploughlayer results in improved agrophysical, agrochemical and biological properties of the upper topsoil layer and, however the soil properties tend to deteriorate at the bottom of the topsoil (Aura, 1999; Rasmussen, 1999; Tebrugge and During, 1999; Boizard et al., 2002).
In the soils susceptible to compaction it is recommended to grow more winter crops whose soil preparation, sowing and harvesting operations are usually performed in the dry period, since dry soils are more resistant to compaction. When a field is covered by plants for a longer period, the soil properties are less deteriorated by climatic factors (Yamoah et al., 1998; Etana et al., 1999; Dabney et al., 2001; Palojarvi and Nuutinen, 2002).
The aim of this study was to analyse the impacts of reduced soil tillage and feasibility extension of winter crops area in the crop rotation and to assess the investigated means from the viewpoint of heavy soil protection and crop productivity.

Materials and methods

Site and soil description. The study on soil tillage systems and feasibility of extension of winter crops area in the crop rotation was conducted at the Lithuanian Institute of Agriculture's Joniskelis Research Station situated on the soils of the northern part of Central Lithuania's lowland (56^{o}21' N, 24^{o}10' E) during the period 1998-2002. The experiments were carried out on drained, clay loam on silty clay with deeper lying sandy loam *Endocalcari-Endohypogleyic Cambisol* (FAO classification), whose parental rock is glacial lacustrine clay. Clay particles < 0,002 mm in A_a horizon (0-30 cm) made up 27,0%, in B_1 horizon (52-76 cm) – 51,6%, in C_1 horizon (77-105 cm) -10,7%, in C_2 horizon (106-135 cm) – 11,0%. The soil in the ploughlayer (0-25 cm) according to pH_{KCl} is neutral, humus content 2,20%.
Experimental design. The experiments were done according to the scheme: **Factor A. Crop rotations with different area of winter and spring crops:** 1. Without winter crops (1.Annual grasses; 2. Spring wheat; 3. Spring triticale; 4. Spring barley). 2. 25% winter crops (1. Perennial grasses; 2. Spring wheat; 3. Spring triticale; 4. Spring barley, undersown crop). 3. 50% winter crops (1. Perennial grasses; 2. Winter wheat; 3. Spring triticale; 4. Spring barley, undersown crop). 4. 75% winter crops (1. Perennial grasses; 2. Winter wheat; 3. Winter triticale; 4. Spring barley, undersown crop). 5. 100% winter crops (1. Perennial grasses; 2. Winter wheat; 3. Winter triticale; 4. Winter barley, undersown crop). **Factor B. Soil tillage systems:** 1. Conventional (primary soil tillage is performed by ploughing by a mouldboard plough). 2. Sustainable (after grasses the soil for wheat is ploughed by a mouldboard plough; after cereals ploughless soil tillage is applied for all crops). The experiment was established using the fully expanded crop rotation method. Plots were 5 m wide and 18 m long. Replications 4.
Crops and field operations. In the experiment we grew vetch (*Vicia sativa L.*) 'Kurshiai' and oats (*Avena sativa L.*) 'Jaugila' mixture, as annual grasses, red clover (*Trifolium pratense L.*) 'Vyliai' and timothy (*Phleum pratense L.*) 'Gintaras II' mixture, as perennial grases, spring wheat (*Triticum aestivum L.*) 'Munk', winter wheat (*Triticum aestivum Host.*) 'Shirvinta', spring triticale (*Triticosecale Wittm.*) 'Gabo', winter triticale (*Trticosecale Wittm.*) 'Tewo', spring barley (*Hordeum vulgare L.*) 'Ula', winter barley (*Hordeum vulgare L.*) 'Moldavskyj-16'.

While performing the primary soil tillage (factor B) in the conventional soil tillage system the soil was ploughed with a mouldboard plough with skimmers at 23-25 cm depth. In the sustainable soil tillage system the soil was ploughed by a mouldboard plough at the same depth only for wheat after grasses, and after all the other preceding crops the soil was loosened by a ploughless method at the same depth as ploughing, using for this purpose a combined stubble breaker. The other operations were carried out following the Lithuania's conventional soil and crop management practices.

Measurements and assessments. In the year of trial establishment the soil was tested for humus content (Tiurin method); pH_{KCl} (potentiometrical method). Each experimental year the following was estimated: a) soil agrophysical properties at 0-15, 15-25 cm topsoil layers in the second half of the growing season of crops: 1) soil bulk density (Kachinski method); 2) air-filled porosity (according to Dolgov); b) soil hydrophysical properties during the course of crops growing season: 1) moisture content at 0-15, 15-25 cm layers (weighing method); 2) total and productive moisture reserves (according to Dolgov) (Rastvorova, 1983), c) the yield of primary production of all crops.

The effects of the tested means on the compaction of topsoil of clay loam soil were assessed according to the following gradation: 1) low compaction when topsoil equilibrium bulk density - <1,3 Mg m^{-3}, 2) moderate compaction - 1,3-1,5 Mg m^{-3}, 3) high compaction - >1,5 Mg m^{-3} (Bondarev, 1990). Critical topsoil compaction limit of clay loam will be considered soil bulk density 1,35 Mg m^{-3} (Muller, 1986; Lechtveer and Nugis, 1992). Physical maturity of clay loam soil -17,5% (w/w) of moisture /Maiksteniene, 1997/.

Statistics. The experimental data were processed by ANOVA and STATENG (* - 95%, ** - 99% probability level) (Tarakanovas, 1999). Significant differences are presented at 95% probability level.

Environmental conditions. The growing seasons in 1998 and 2001 were characterised by a moisture excess, whereas the years 1999, 2000 and 2002 were droughty.

Results and discussion

Assessments of soil compaction. Soil bulk density as a major indicator of soil physical state and effect of all investigated factors on it was estimated in the second half of crops growing season. In the first year of the investigated crop rotations (1999) the soil bulk density in the upper (0-15 cm) topsoil layer tended to increase with an increase in the winter crops area in the crop rotation. In the crop rotations with 75 and 100% winter crops this indicator was higher by 6.9 and 5.6%, respectively than in the crop rotation grown with only spring crops, corresponded to a high compaction (soil bulk density >1,5 Mg m^{-3}) and by 14,1 and 12,6% exceeded the critical compaction limit (soil bulk density 1,35 Mg m^{-3}) (Table 1).

A longer effect of the tested means determined the fact that when increasing of winter crops area in the crop rotations soil bulk density at the end of the rotation consistently declined at the bottom (15-25 cm) of the topsoil. Here the soil bulk density in the crop rotations with 100, 75 and 50% winter crops was lower by 5,8, 4,5 and 4,5%, respectively compared with solely spring crops rotation, furthermore it corresponded to moderate compaction (soil bulk density 1,3-1,5 Mg m^{-3}) and exceeded the critical compaction limit by only 8,9, 10,4 and 10,4%.

Our experimental evidence indicates that increasing of winter crops area in the crop rotations allows to decline the harmful technological effect on heavy soils and to reduce physical degradation of soils. While comparing the data of topsoil bulk density and its correspondence to compaction level and critical limit at the end and beginning of the crop rotation, we can see that in the crop rotations without winter crops and with 25% winter crops these indicators were very similar, and when increasing winter crops area to 50, 75 and 100% the soil bulk density tended to decline in the upper topsoil layer by 5,3, 7,1 and 5,3% and in the bottom layer by 4,5, 5,1 and 6,4%, respectively, the level of compaction declined from high to moderate, and exceeding of critical limit declined on average twice (Table 1).

Table1. Effect of tillage and winter crops on indices of soil compaction at the beginning (1999) and end (2002) of crop rotation

Treatment	Depth cm	Soil bulk density Mg m^{-3} at the beginning of rotation	exceeding of critical compaction limit %	at the end of rotation	exceeding of critical compaction limit %
		Area of winter crops % (factor A)			
0	0-15	1,44	6,7	1,42	5,2
	15-25	1,57	16,3	1,56	15,6
25	0-15	1,46	8,1	1,44	6,7
	15-25	1,58	17,0	1,54	14,1
50	0-15	1,50	11,1	1,42	5,2
	15-25	1,56	15,6	1,49	10,4
75	0-15	1,54	14,1	1,43	5,9
	15-25	1,57	16,3	1,49	10,4
100	0-15	1,52	12,6	1,44	6,7
	15-25	1,57	16,3	1,47	8,9
		Soil tillage systems (factor B)			
1.Conventional	0-15	1,49	10,4	1,42	5,2
	15-25	1,56	15,6	1,50	11,1
2. Sustainable	0-15	1,49	10,4	1,44	6,7
	15-25	1,58	17,0	1,52	12,6
LSD_{05}		A	B		
At the beginning of rotation	0-15	0,062	0,050		
	15-25	0,073	0,059		
At the end of rotation	0-15	0,062	0,051		
	15-25	0,068	0,056		

Through the application of conventional ploughing soil bulk density per rotation declined and at the end of the crop rotation corresponded to moderate compaction in both layers of the topsoil. In the sustainable soil tillage system due to the application of reduced primary tillage a high compaction still persisted at the bottom of the topsoil.

Soil moisture and water storage. Soil water storage plays a critical role in crop production. Possibilities to maintain adequate moisture parameters in heavy soils are of special relevance both for crops emergence and establishment and technological measures – soil tillage and performance of other agricultural practices.

It is noteworthy that prior to soil tillage in spring the moisture content at the bottom of the topsoil, unlike that of the upper layer, on clay loam soil exceeded by 7,1-9,4% physical maturity (17,5% w/w). Therefore the threat of overcompacting this layer during the pre-sowing soil tillage and sowing remains as long as soil protection requirements are disregarded in the technologies.

In the sustainable soil tillage system the application of reduced ploughless soil tillage for spring cereals after winter triticale or spring wheat revealed a more uniform drying of both layers of the topsoil resulting from the better capillary regime. Therefore this system has better chances to compact less the bottom of the topsoil during the period of spring operations compared with mouldboard ploughing.

Droughty years predominated during the period (1999-2002) of conducted research. Increasing of winter crops area determined a better persistence of soil moisture (Table 2) and more abundant reserves of total and especially productive moisture (Fig.) in the second half of crops growing season. In the crop rotation with 100% winter crops the reserves of productive moisture in the topsoil were 37,3% higher, compared with solely spring crops rotation (18,4 mm).

Table 2. Effect of soil tillage and winter crops on soil moisture and air-filled porosity in the second half of growing season. Average of 1999-2002.

Area of winter crops % (factor A)	Depth cm	Soil tillage systems (factor B) 1. conventional moisture % (w/w)	1. conventional air-filled porosity % (v/v)	2. sustainable moisture % (w/w)	2. sustainable air-filled porosity % (v/v)	Average of factor A moisture %)w/w)	Average of factor A air-filled porosity % (v/v)
0	0-15	14,5	24,0	14,5	23,8	14,5	23,9
	15-25	14,7	21,1	14,7	19,2	14,7	20,2
25	0-15	14,4	25,5	14,5	23,8	14,5	24,7
	15-25	14,8	20,1	14,6	18,9	14,7	19,5
50	0-15	14,8	23,2	15,0	22,1	14,9	22,7
	15-25	15,1	20,2	15,4	18,6	15,3	19,4
75	0-15	15,4	22,2	15,3	21,3	15,4	21,8
	15-25	15,6	19,7	15,9	17,8	15,8	18,8
100	0-15	16,0	20,6	15,5	21,4	15,8	21,0
	15-25	16,1	19,4	16,1	18,2	16,1	18,8
Average of factor B	0-15	15,0	23,1	15,0	22,5	-	-
	15-25	15,3	20,1	15,4	18,5	-	-
			moisture			air-filled porosity	
LSD_{05}		A	B	AB	A	B	AB
	0-15	1,55	1,36	1,64	1,73	1,69	1,51
	15-25	1,27	1,11	1,34	1,42	1,51	1,25

The relationship between the productive moisture reserves at the bottom of the topsoil during the second half of crops growing season and soil bulk density ($r = -0,516^{*}$, $y = 47,475 - 26,506x$) was moderate and inverse.

Soil* air-filled *porosity. While applying reduced soil tillage we observed a reduction in soil air-filled porosity in the topsoil in the second half of crops growing season. In the upper topsoil layer this phenomenon exhibited a slight declining, and in the bottom layer it declined by 8,0%, compared with conventional soil tillage (Table 2).

When increasing the area of winter crops in the crop rotations, air-filled porosity in the second half of crops growing season in all topsoil layers in most cases declined or maintained such trend. This was determined by an increase in moisture content and longer period after the primary and pre-sowing soil tillage for winter crops, compared with spring crops.

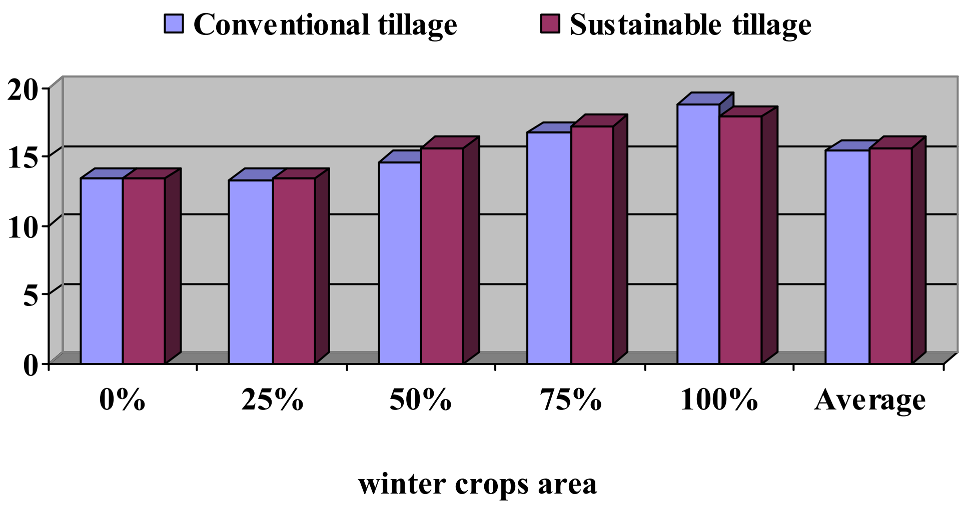

Fig. Effect of tillage and winter crops on productive moisture reserves (mm) in topsoil (0-25 cm). Average of 1999-2002 m.

Moisture to air ratio in the soil. On clayey soils it is vital to maintain a proper moisture to air ratio in order to achieve satisfactory plant growth. Lithuanian experimental evidence suggests that on clay loam soil the best conditions are created when moisture occupies 60%, and air 40% of pores. Therefore for the estimation of the tested means according to this indicator, optimal moisture to air ratio was considered to be 1,5:1. When increasing the area of winter crops in the crop rotations, moisture to air ratio consistently improved in both layers of the topsoil. Reduced soil tillage in sustainable system determined a slightly more favourable moisture to air ratio at the bottom of topsoil, compared with the conventional soil tillage system (Table 3).

Table 3. Effect of soil tillage and winter crops on soil moisture to air ratio in the second half of growing season. Average of 1999-2002.

Area of winter crops % (factor A)	Depth cm	Soil tillage systems (factor B)				Average of factor A	
		1. conventional		2. sustainable			
		moisture to air ratio	accordance to optimal ratio %	moisture to air ratio	accordance to optimal ratio %	moisture to air ratio	accordance to optimal ratio %
0	0-15	0,88:1	58,7	0,89:1	59,3	0,89:1	59,3
	15-25	1,02:1	68,0	1,18:1	78,7	1,10:1	73,3
25	0-15	0,78:1	52,0	0,89:1	59,3	0,84:1	56,0
	15-25	1,13:1	75,3	1,21:1	80,7	1,17:1	78,0
50	0-15	0,93:1	62,0	1,02:1	68,0	0,98:1	65,3
	15-25	1,14:1	76,0	1,28:1	85,3	1,21:1	80,7
75	0-15	1,02:1	68,0	1,07:1	71,3	1,05:1	70,0
	15-25	1,15:1	76,7	1,38:1	92,0	1,27:1	84,7
100	0-15	1,20:1	80,0	1,07:1	71,3	1,14:1	76,0
	15-25	1,25:1	83,3	1,36:1	90,7	1,31:1	87,3
Average of factor B	0-15	0,96:1	64,0	0,99:1	66,0		
	15-25	1,14:1	76,0	1,28:1	85,3		

Total productivity of crop rotations. When increasing winter crops area in the crop rotation, the total average productivity of all crops increased, and in the crop rotation with 100% winter crops the increase was by 44,7% higher than in the crop rotation composed of solely spring crops (Table 4). Expansion of the area of winter crops gave a higher increase in grass yield compared with cereals. Moreover, when increasing winter crops area the differences in the crop productivity between sustainable and conventional soil tillage systems declined, and in the crop rotations with 100% winter crops it was as low as 2,4%.
Cereal grain yield. The application of reduced soil tillage in sustainable system had a marked effect on grain yield reduction in the crop rotations with prevalent spring crops area. Spring cereals on clay loam soils were more susceptible to the reduction of primary soil tillage compared with winter cereals. When growing cereals according to sustainable soil tillage system, the total average grain yield per rotation was 6,4% lower, compared with the conventional technology (4,09 t ha^{-1}). With increasing winter crops area in the crop rotations the total average cereal grain yield consistently increased.
Interrelationship between crop yield and soil properties. Averaged experimental data revealed a strong direct correlation between the total average yield of crop rotation crops and productive moisture reserves in the topsoil layer (r = 0,753*, y = 1,174 + 0,215x) and subsoil layer (r = 0,703*, y = 0,791+ 0,556x) and medium direct correlation between the average yield of crop rotation crops and total moisture reserves in the topsoil (r = 0,694*, y = -6,591 + 0,196x) and in subsoil (r = 0,647*, y = -10,057 + 0,559x).

Table 4. Effect of soil tillage systems and winter crops area on productivity of rotations according to dry matter yield of crop primary production. Average data of 1999-2002.

Area of winter crops % (factor A)	Soil tillage systems (factor B) 1. conventional		2. sustainable		Average of factor A	
	t ha^{-1}	relative values	t ha^{-1}	relative values	t ha^{-1}	relative values
0	3,66	100	3,28	89,6	3,47	100
25	4,62	100	4,21	91,1	4,42	127,4
50	4,76	100	4,50	94,5	4,63	133,4
75	4,98	100	4,81	96,6	4,90	141,2
100	5,08	100	4,96	97,6	5,02	144,7
Average of factor B	4,62	100	4,35	94,2	-	-

LSD_{05}A 0,493 LSD_{05}B 0,312 LSD_{05}AB 0,697

Conclusions

1. The effects of increasing of winter crops area in the crop rotations during the four-year rotation determined a consistent reduction in clay loam soil bulk density in the bottom layer of the topsoil. When growing in the crop rotations from 50 to 100% of winter cereals during a four-year rotation it is possible to reduce topsoil compaction from high to medium, and the exceeding of critical compaction limit by on average twice. When in the sustainable soil tillage system we applied reduced ploughless soil tillage, a higher soil bulk density remained at the bottom of the topsoil layer, which corresponded to high compaction.
2. When applying non-ploughing soil tillage, the topsoil of clay loam soil dried more evenly in spring before sowing, while after the conventional mouldboard ploughing the bottom layer of the topsoil remained wetter than the upper layer for a longer period. Increasing of winter

crops area in the crop rotation secured a better preservation of the total and productive moisture reserves in droughty years.
3. Reduced primary soil tillage resulted in the reduction of air-filled porosity in the topsoil, compared with mouldboard ploughing, however, moisture to air ratio remained favourable.
4. Increasing of winter crops area enabled to increase the productivity of crop rotations. Winter crops were 44,7% more productive than spring crops. As a result, the area of winter crops on clay loam soils can be expanded up to 75-100%.
5. On heavy soils it was better to apply sustainable primary soil tillage system (after grasses – ploughing, after cereals – reduced non-ploughing soil tillage without ploughing) to winter cereals (wheat, triticale, barley) grown in the crop rotation. For spring cereals it was better to use the conventional mouldboard ploughing.

References

Aura, E. 1999. Effects of shallow tillage on physical properties of clay soil and growth of spring cereals in dry and moist summers in southern Finland // Soil & Tillage Research, 50, 169-176.

Boizard H., Richard G. et al. Cumulative effects of cropping systems on the structure of the tilled layer in northern France // Soil & Tillage Research, 64, 149-164.

Bondarev, A. G. 1990. Problem of soil compaction by field technique and ways to solve it // Pochvovedenie, 5, 31-37. (in Russian).

Dabney, S. M., Delgado, J. A. and Rieves D.W. 2001. Using winter cover crops to improve soil and water quality // Communication in Soil Science and Plant Analysis, 32, 1221-1250.

Etana, A., Hakansson, I. et al. 1999. Effects of tillage depth on organic carbon content and physical properties in five Swedish soils // Soil& Tillage Research, 52, 129-139.

Horn, R., Van den Akker, J. and Arvidsson, J. 2000. Subsoil compaction. Catena Verlag, Reiskirchen, Germany; 462 pp.

Yamoah, C. F., Varvel, G. E. et al. 1998. Weather and management impact on crop yield variability in rotations // Journal of Production Agriculture, 11, 219-225.

Kladivko, E.J. 2001. Tillage systems and soil ecology // Soil & Tillage Research, 61, 61-76.

Lechtveer, R. and Nugis, E. 1992. Field soils and their trampling. In: Soil Compaction & Soil Management; Tallin, 26-48.

Maiksteniene, S. 1997. Investigation of cultivation practices on heavy-textured soils. Jonishkelis; 180 pp. (in Lithuanian)

Mueller, L., Schindler, U. et al. 2003. Comparison of methods for estimating maximum soil water content for optimum workability // Soil & Tillage Research, 72, 9-20.

Muller, P. 1986. Ackerbau. Berlin: VEB Deutscher Landwirtschaftsverlag, 240 pp.

Palojarvi, A. and Nuutinen, V. 2002. The soil quality concept and its importance in the study of Finnish arable soils // Agricultural & Food Science in Finland, 11, 329-342.

Rasmussen, K. J. 1999. Impact of ploughless soil tillage on yield and soil quality: A Scandinavian review // Soil & Tillage Research, 53, 3-14.

Rastvorova, O.G. 1983. Soil Physics. Leningrad; 196 pp. (in Russian)

Schafer-Landefeld, L. et al. 2004. Effects of agricultural machinery with high axle load on soil properties of normally managed fields // Soil & Tillage Research, 75, 75-86.

Tarakanovas, P. 1999. The programs package ‘Selekcija‘ for processing statistical data. Vilnius; 56 pp. (in Lithuanian).

Tebrugge, F. and During, R. A. 1999. Reducing tillage intensity – a review of results from a long-term study in Germany // Soil & Tillage Research, 53, 15-28.

EFFECT OF DIFFERENT SOIL TILLAGE ON THE CHANGE OF THE SOIL PHYSICAL PROPERTIES

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Abstract

On the plots of the Plant Breeding Station at Branišovice in a maize growing region, studies were made of changes in the physical properties of soil under different winter wheat tillage systems. In winter wheat soil bulk density red., as the fundamental soil property, was impacted by soil tillage in the years of study. Soil bulk density was the highest on average with minimum tillage and no-till systems in all years. The actual water content was always higher in treatments with higher bulk density and this was reverse-correlated with values of soil porosity and aeration.

Keywords: soil tillage, soil physical properties, soil water, winter wheat

Introduction

From assessing the importance of tillage as part of agronomy measures it is evident that tillage influences yield formation less than any other factors such as the previous crop, rate and method of fertilizer application, species and variety composition, protection from harmful agents, etc.

Minimum tillage, which reduces the level and depth of tillage, enables to combine operations or possibly no-till planting, is intended predominantly for cereal crops, though it may also be used for other crops (maize, rape). At present, minimum tillage systems are mostly used as soil conservation technologies in which the organic matter left on the surface of the plot after crop harvest plays an important role. Soil conservation technologies considerably influence the soil environment from the viewpoint of physical properties of soil and water management and are favourable especially in areas affected by water erosion. Changes induced by soil tillage greatly affect bulk density which consequently influences the entire system of physical properties of soil, i. e. porosity, air and soil water capacity, thermal conductivity, etc. Soil water content, availability and movement are changing and soil water is beneficial especially in technologies, which are the least affected.

Methodology of the experiment

Soil and climatic conditions

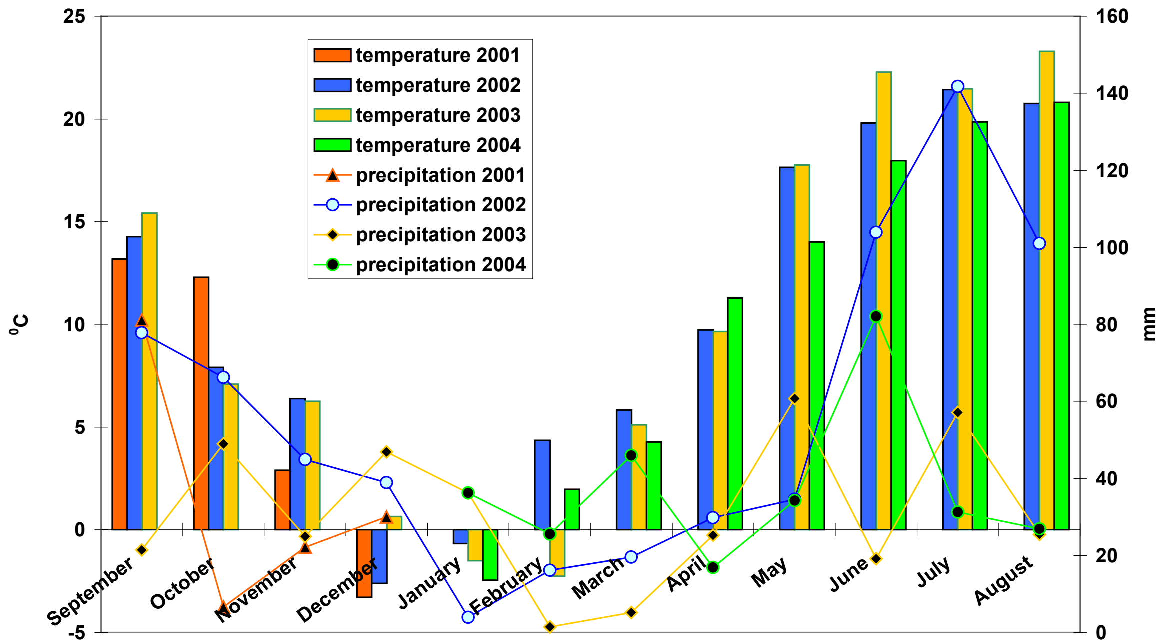
The experiment was established on the plots of the Monsanto ČR, s.r.o company at Branišovice in a maize-producing area. The plots are located at an altitude of 210 m. The mean annual temperature is 8.9^0 C, the mean temperature in the growing season is 15.3^o C and the mean annual precipitation sum is 461 mm, and with 302.3 mm during vegetation. The soils are medium heavy, clayey loam, degraded Chernozem on loess. According to the last soil survey the average content of humus in the topsoil horizon is 1.7 %, pH is 6.4, which is a slightly acid reaction. The content of available P is medium, the content of total N is medium, the content of available K is good and the content of available Mg is high.

A five-field crop rotation – maize, spring barley, winter wheat, winter rape winter rape – was established to study physical properties of soil in winter wheat after winter rape grown with three soil tillage and planting systems:

1. – conventional system, i.e. stubble ploughing, medium ploughing
2. – minimum tillage
3. – no-till

The results are for the years 2001 – 2004. The climatic conditions during the period of 2001 – 2004 are presented in Graph 1.
The experiment also included the study of the physical state of soil at the start of vegetation and before harvest using the method of Kopecky cylinders and focused on reduced bulk density, total porosity, actual soil water and air content, maximum capillary water capacity and minimum air capacity.
The samples were taken from three depths of soil: 0-0.10, 0.10-0.20 and 0.20-0.30 m.

Graph 1: Climatic conditions during period 2001 - 2004



Results and Discussion

Soil tillage is one of fundamental agronomy practices, which have a direct impact on soil fertility (Suškevič, 1992). It contributes to favourable soil structure, good soil and subsoil permeability for roots and good capacity to conduct water and air in the active soil profile (Kováč, 1991). As Husnjak *et al.* observed (2002) the smallest changes in the physical properties of soil were associated with reduced tillage system. To express changes in the physical properties of soil reduced bulk density (OH) is often used. In the experiment the highest OH values were recorded in the no-till treatment with direct planting. They changed only a little during the 4-year period, in contrast to the tillage treatment when the average bulk density was 1.39 g.cm^{-3} at the start of study (2001) and 1.58 g.cm^{-3} at the end of study (2004). This is the highest increase of all the soil tillage treatments (Tables 1- 4). In all the three soil tillage treatments bulk density (OH) was always higher at the sampling prior to crop harvest.

As for depth, it was found that with increasing depth bulk density increased in all soil tillage systems. Moreno *et al.* (1997) confirmed that bulk density at the 0-0.2 m layer was significantly higher with reduced tillage than conventional tillage. In the last two years of study (2003, 2004) the bulk density limit of 1.45 $g.cm^{-3}$ was exceeded in the bottom horizon of 0.2-0.3 m in all tillage systems.
A positive effect of higher bulk density on the increase in soil water content was also confirmed.
Graphs 2-5 show a relationship between bulk density and actual soil water content in the years of study, including the assessment of the regression equation and the value of reliability. It was found that higher bulk density promoted water retention in soil, which might be beneficial in drier soils, especially during drought. The effect of soil tillage and a season on the changes in soil water content and bulk density changes was studied by Kováč *et al.* (1999). Soil water is a dynamic factor, which changes in the course of the year, but it may also be markedly affected just by soil tillage. The highest soil water variability is in the topsoil, it is relatively stable in the bottom layer and almost equal in all soil tillage systems. The same results were also obtained in similar experiments in a sugarbeet-growing region (Badalíková, Hrubý, 2001), (Badalíková, Kňákal, 2000).
Reduced tillage can be used without a marked deterioration in physical properties of soil if the technology is strictly applied. Ledvina *et al.* (2004) pointed to the seasonal dynamics of physical properties and relatively homogeneous values of soil properties at the depths of 0.05 and 0.15 m with tillage in contrast to no-till systems. This conclusion was also confirmed by our experiment. As evident from Tables 1 – 4, the variation of values of physical characteristics decreased in the bottom soil layer. An important factor which characterizes reduced soil tillage is the relationship between soil environment, tillage and plant production (Birkás, 2004).
As the other physical properties of soil, such as maximum capillary water capacity and minimum air capacity, have not markedly changed during the last 4 years, reduced or minimum tillage systems can be used in these climatic and soil conditions without deteriorating soil fertility.

Conclusions

The soil tillage and planting system influenced the physical properties of soil and soil water content. Minimum tillage including no-till systems increased bulk density and reduced porosity (non-capillary pores) in comparison with conventional tillage. However, four years later the situation was less differentiated.
Soil water content was higher with shallow cultivation or no-till, especially in the top layer. The effect of a season was considerable, no-till treatments created more favourable moisture conditions in drier periods.

Literature

Badalíková B., Hrubý J.: Fyzikální stav půdy u různých systémů jejího zpracování k jarnímu ječmeni. Farmář, 7, č. 3 , 2001, p.18- 19

Badalíková B., Kňákal Z.: Effect of different tillage systems for winter wheat on physical properties of soil In CD: ISTRO-Conference 2000, Tillage at the Threshold of the 21st Century: Looking Ahead, Texas, USA, 2000 (angl.)

Birkás M., Jolankai M., Gyuricza C., Pereze A.: Results and Considerations in Conservation Tillage in Hungary. In CD: International Soil Tillage Research Organisation Conference. Australia, 2004, p. 159-164

Husnjak S., Filipovi S., Košutić S.: Influence of different tillage systems on soil physical properties and crop yield. In Rostlinná výroba, 48, 2002 (6): 249-254

Kováč K.: Novšie poznatky v oblasti obrábania pody. Úroda, 3, 1991, p. 52

Kováč K., Žák Š.: The effect of different types of soil cultivation on its physical and hydrophysical properties. Rostlinná výroba, 45, 1999, (8): 359-364

Ledvina R., Horáček J., Čechová V., Hřebečková J.: Soil protective technologies for arable crop farming. Collection of Scientific Papers, faculty of Agriculture in České Budějovice, Series for Crop Sciences, 21, 2004 (2): 61-66

Moreno F., Pelegrin F., Fernandez JE., Murillo JM.: Soil physical properties, water depletion and crop development under traditional and conservation tillage in southern Spain. Soil and Tillage Research, 1997, 41: 1-2, 25-42, 35 ref.

Suškevič M.: Vliv zpracování půdy na její biologické a chemické vlastnosti. Úroda, 8, 1992, p. 1-2, příloha

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Table 1 Physical soil properties by different soil tillage by winter wheat - Branišovice 2001

Soil tillage	Soil depth (m)	Bulk density ($g.cm^{-3}$)	Total porosity (%)	Momentary content of		Maximum capilary capacity %vol.	Minimum air capacity %vol.
				water %vol.	air %vol.		
1 Ploughing	0 - 0,1	1,34	48,33	22,90	25,43	42,34	5,99
	0,1 - 0,2	1,37	47,28	28,66	18,62	42,79	4,49
	0,2 - 0,3	1,47	43,51	29,09	14,42	39,93	3,58
	0 - 0,3	1,39	46,38	26,88	19,49	41,69	4,69
2 Minimum till	0 - 0,1	1,40	46,21	27,42	18,79	41,12	5,09
	0,1 - 0,2	1,46	43,85	30,00	13,85	39,25	4,60
	0,2 - 0,3	1,48	43,22	26,19	17,03	38,30	4,92
	0 - 0,3	1,44	44,43	27,87	16,56	39,56	4,87
3 No till	0 - 0,1	1,42	45,35	28,73	16,62	39,86	5,49
	0,1 - 0,2	1,50	42,42	31,13	11,29	38,28	4,14
	0,2 - 0,3	1,51	42,04	32,07	9,97	37,40	4,64
	0 - 0,3	1,47	43,27	30,64	12,63	38,51	4,76

Table 2 Physical soil properties by different soil tillage by winter wheat - Branišovice 2002

Soil tillage	Soil depth (m)	Bulk density ($g.cm^{-3}$)	Total porosity (%)	Momentary content of		Maximum capilary capacity %vol.	Minimum air capacity %vol.
				water %vol.	air %vol.		
1 Ploughing	0 - 0,1	1,37	51,16	26,51	24,65	41,18	9,98
	0,1 - 0,2	1,41	46,91	25,97	20,94	41,69	5,22
	0,2 - 0,3	1,61	39,13	24,44	14,69	34,78	4,35
	0 - 0,3	1,46	45,73	25,64	20,09	39,22	6,52
2 Minimum till	0 - 0,1	1,33	49,80	22,49	27,31	41,78	8,02
	0,1 - 0,2	1,56	41,26	28,77	12,49	37,52	3,74
	0,2 - 0,3	1,57	40,72	27,59	13,13	37,13	3,59
	0 - 0,3	1,49	43,93	26,28	17,64	38,81	5,12
3 No till	0 - 0,1	1,49	43,61	28,23	15,38	39,79	3,82
	0,1 - 0,2	1,54	41,81	29,58	12,23	38,96	2,85
	0,2 - 0,3	1,57	40,84	26,35	14,49	38,41	2,43
	0 - 0,3	1,53	42,09	28,05	14,04	39,05	3,04

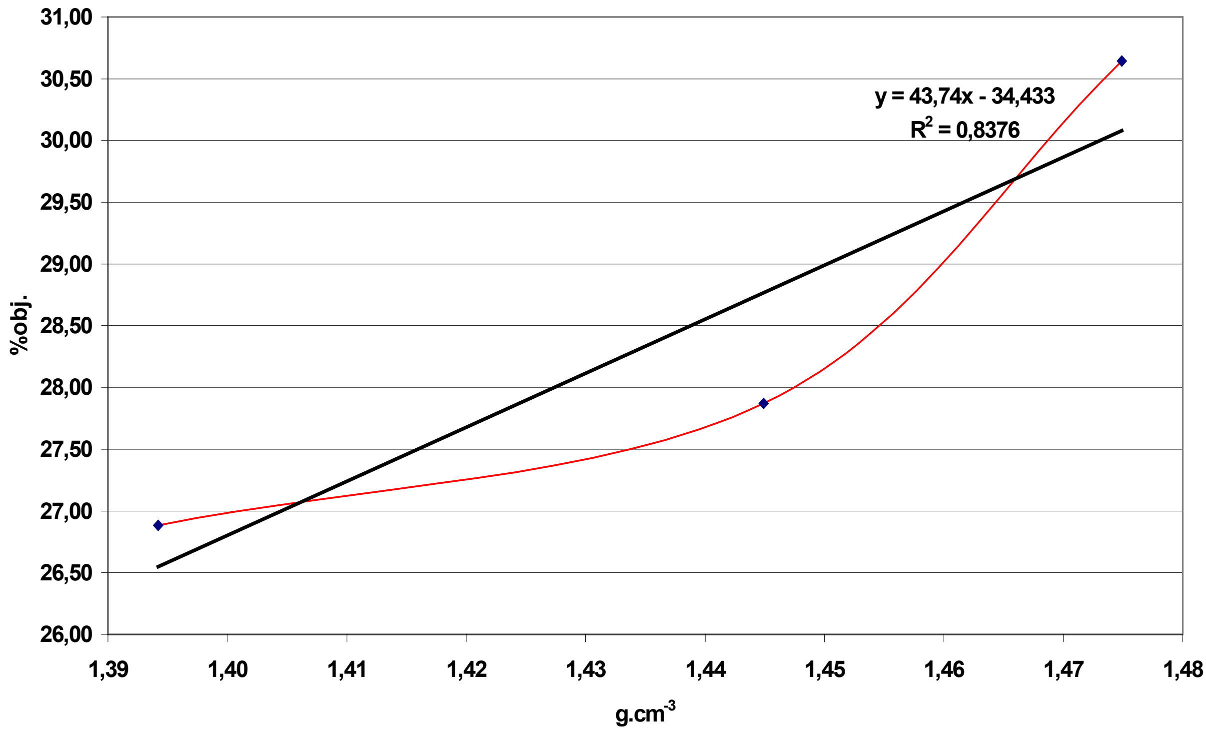
Table 3 Physical soil properties by different soil tillage by winter wheat - Branišovice 2003

Soil tillage	Soil depth (m)	Bulk density ($g.cm^{-3}$)	Total porosity (%)	Momentary content of		Maximum capilary capacity %vol.	Minimum air capacity %vol.
				water %vol.	air %vol.		
1 Ploughing	0 - 0,1	1,44	44,45	15,34	29,11	40,12	4,33
	0,1 - 0,2	1,52	41,68	20,24	21,44	38,84	2,84
	0,2 - 0,3	1,59	38,76	19,66	19,10	35,35	3,41
	0 - 0,3	1,52	41,63	18,41	23,22	38,10	3,53
2 Minimum till	0 - 0,1	1,47	43,32	18,90	24,42	38,25	5,07
	0,1 - 0,2	1,60	38,62	19,92	18,70	34,17	4,45
	0,2 - 0,3	1,57	39,43	20,17	19,26	36,11	3,32
	0 - 0,3	1,55	40,45	19,66	20,79	36,18	4,28
3 No till	0 - 0,1	1,47	43,30	16,59	26,71	36,64	6,66
	0,1 - 0,2	1,55	40,53	21,90	18,63	35,05	5,48
	0,2 - 0,3	1,56	40,02	23,32	16,70	34,64	5,38
	0 - 0,3	1,53	41,29	20,60	20,68	35,44	5,84

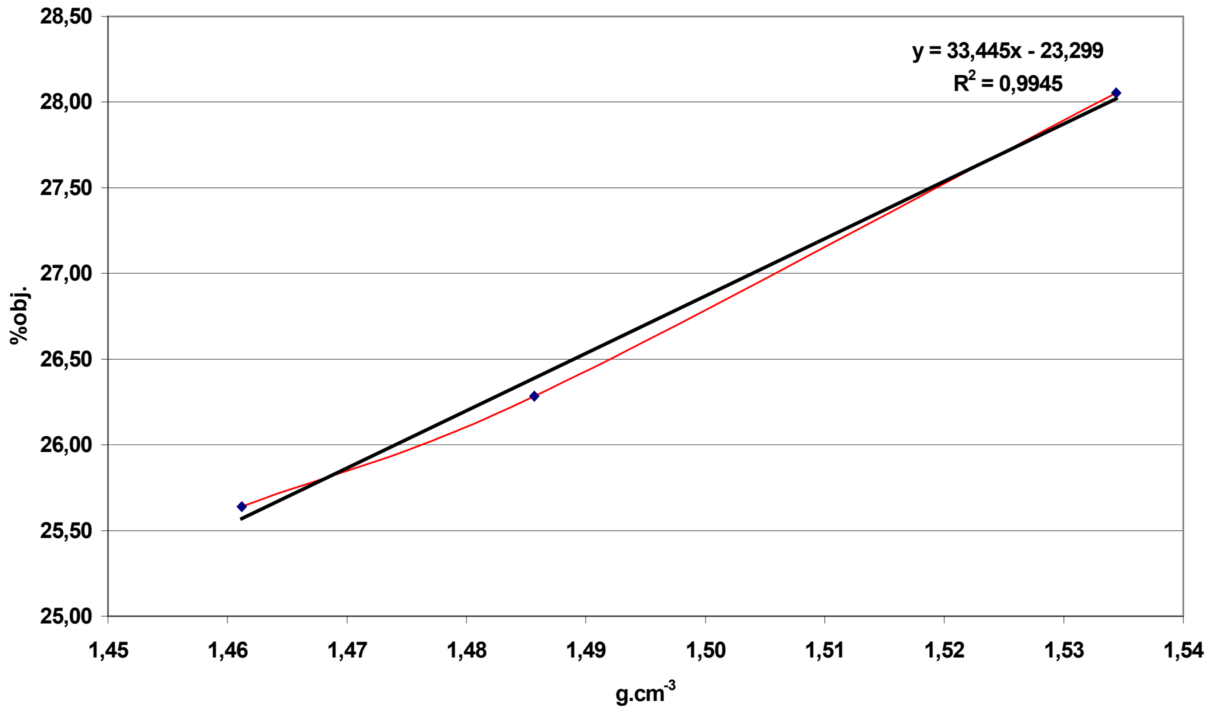
Table 4 Physical soil properties by different soil tillage by winter wheat - Branišovice 2004

Soil tillage	Soil depth (m)	Bulk density ($g.cm^{-3}$)	Total porosity (%)	Momentary content of water %vol.	Momentary content of air %vol.	Maximum capilary capacity %vol.	Minimum air capacity %vol.
1 Ploughing	0 - 0,1	1,49	42,86	13,25	29,61	37,00	5,86
	0,1 - 0,2	1,56	40,07	14,45	25,62	34,86	5,21
	0,2 - 0,3	1,71	34,21	16,66	17,55	30,41	3,80
	0 - 0,3	1,58	39,04	14,79	24,26	34,09	4,95
2 Minimum till	0 - 0,1	1,50	42,46	13,93	28,53	35,18	7,28
	0,1 - 0,2	1,72	33,83	15,23	18,60	27,46	6,37
	0,2 - 0,3	1,73	33,51	17,83	15,68	27,66	5,85
	0 - 0,3	1,65	36,60	15,66	20,93	30,10	6,50
3 No till	0 - 0,1	1,59	38,87	16,01	22,86	33,76	5,11
	0,1 - 0,2	1,69	34,85	16,93	17,92	30,13	4,71
	0,2 - 0,3	1,67	35,80	15,03	20,77	31,17	4,63
	0 - 0,3	1,65	36,51	15,99	20,52	31,69	4,82

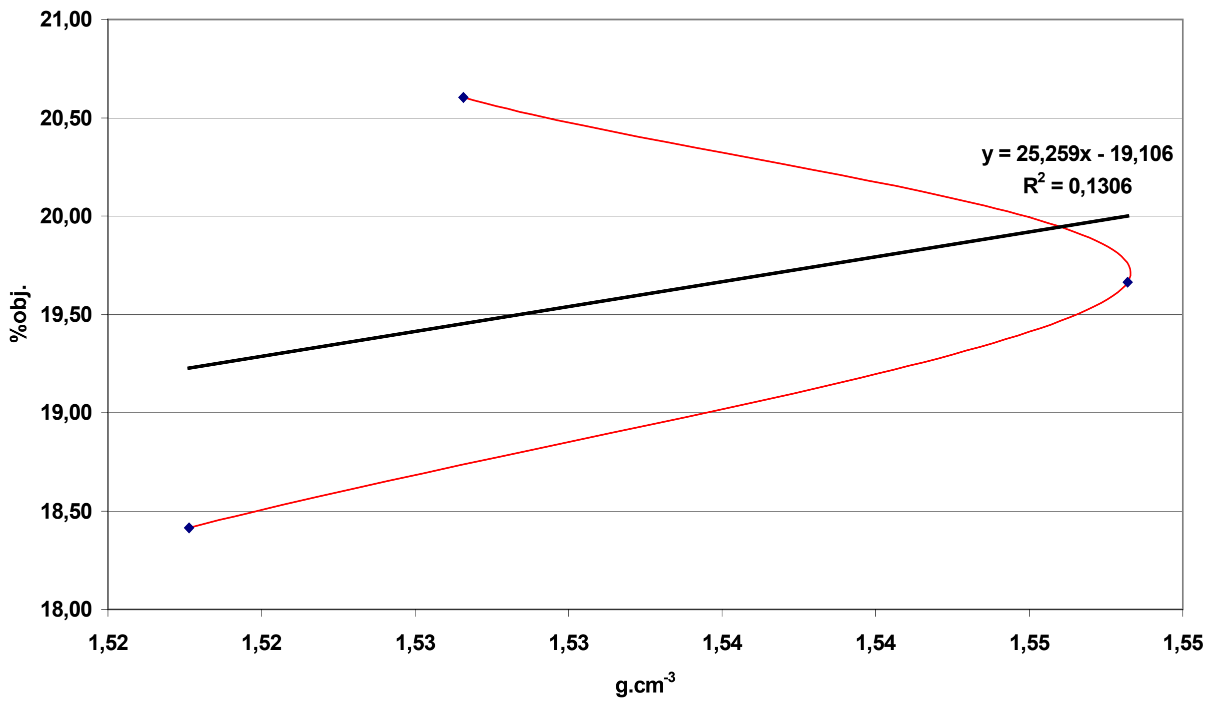
Graph 2: Relationship between bulk density and actual soil water content in year 2001



Graph 3: Relationship between bulk density and actual soil water content in year 2002

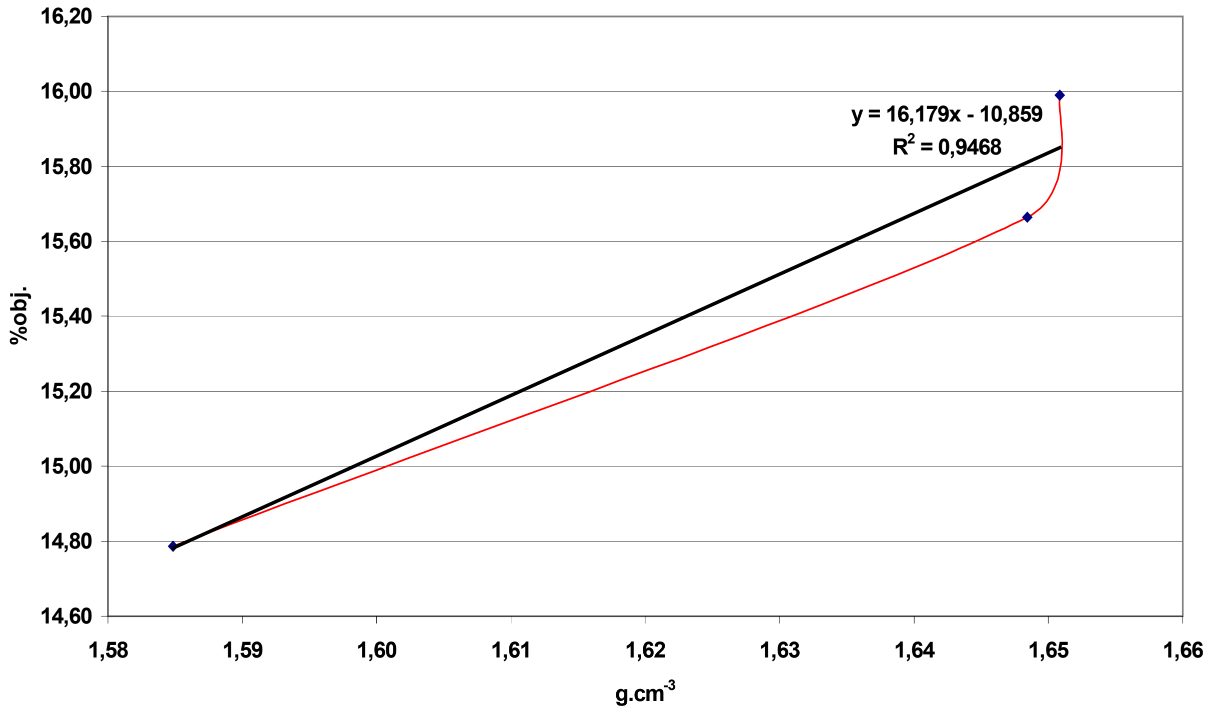


Graph 4: Relationship between bulk density and actual soil water content in year 2003



CONTENTS

Graph 5: Relationship between bulk density and actual soil water content in year 2004



EFFECT OF HUMUS CONTENT IN SOIL ON THE UPTAKE OF HEAVY METALS BY PLANTS

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Abstract

In an experimental locality of an ash storage space in Orlová (Northern Moravia) a plot trial with three levels of anthropogenic soil contamination with heavy metals was established in the year 2002. Studies were conducted in the years 2003 and 2004. The experimental plants were selected clones of fast-growing woody species – osier (*Salix L.*) and (*Populus L*). The experimental locality was actually a rehabilitated area based on the utilisation of waste with a high proportion of organic matter (wastewater sludge), inherent ashes in the upper layers and earth with a high proportion of clay fractions. The following are the basic treatments: 1) application of sludge and heavy metals, 2) application of inorganic salts with heavy metals, and 3) control. During the two-year studies of the effect of humus content on the uptake of heavy metals by plants it was found that reduced humus content in the year 2004 in the treatment with applied salts may have increased the uptake of Cd, Pb and even Zn, predominantly in osier. Further, it was reported that pH in the year 2004 increased, compared with the year 2003, and that the neutral reaction changed into the strongly alkaline reaction, which might be one of the reasons for the reduced uptake of heavy metals by plants. The highest accumulation of heavy metals was detected in osier and poplar, in their leaves and roots.

Keywords: heavy metals, humus content, soil reaction, osier, poplar

Introduction

As it is known, the plant takes up hazardous elements from the soil as well as from the atmosphere. The uptake from soil is dependent on soil properties, plant species and properties of particular contaminants. Facek (1986) showed that 60 % of Pb and 10 % of Cd in oats are due to direct effects of atmospheric deposition. Sáňka (1989) revealed that Pb uptake in maize is more than 4 times higher and in permanent grasslands almost twice as high from the atmosphere as from the soil. Cd uptake in maize is more than 3 times higher from the atmosphere and in permanent grasslands it is approximately the same. It is supposed that plants take up metals in the chelate form only to some extent. Their concentration in plants is significantly affected by the concentration of the free, i. e. non-chelate element (Cd^{2+}, Pb^{2+}, Zn^{2+}, Cu^{2+}, etc.) in soil solution, or possibly by the concentration of elements in the form of soluble compounds and bonds with organic matter. According to Greger, Lindberg (1986) and Domažlická, Opatrný (1989), under experimental conditions cadmium uptake by plant roots is directly dependent on the concentration of free Cd^{2+} ion in the nutrient medium.

Material and methods

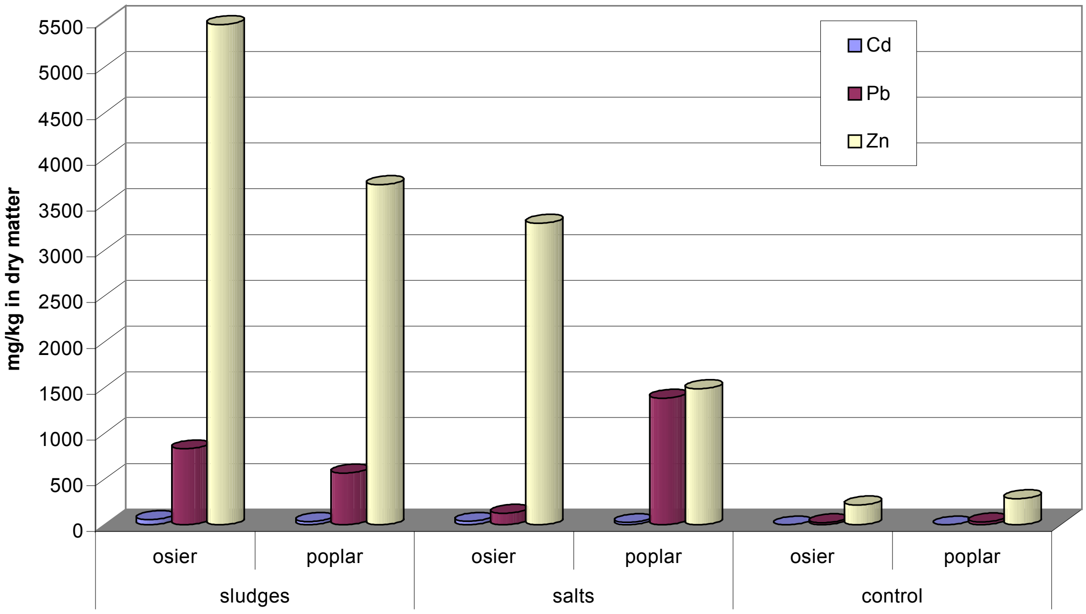
On the experimental locality of storage space in Orlová in North Moravia a plot trial was established in the year 2002 with 3 levels of soil contamination with heavy metals. The experimental plants were clones of fast-growing woody species – osier (*Salix L.*) and poplar (*Populus L.*), (poplar – clone J 104, osier – clone S 4156). A total of 250 cuttings of each species were planted. The cuttings were planted in two rows with spacing of 0.70 m between individual trees. Between the clones there a shelter belt 1.50 m wide.
The experimental locality was actually a rehabilitated area. It was based on utilisation of waste with a high organic proportion (wastewater sludge) accounting for ca 30 %, inherent ashes from the coal-burning plant in the upper layers and earth with a high proportion of a clay fraction (boulder clays from the anaglacial stage of Salic glaciation). As for grain size distribution of the original average sample, fine and medium sand fractions prevail. The soil sample can be characterized as sandy. Higher contents of some contaminants (e.g. non-polar extractable substances) were eliminated in the course of soil rehabilitation measures in such a way that the resulting rehabilitation material fully complied with standards and codes. The long-term mean annual temperature in this locality is 8.3^0C. The long-term annual precipitation sum is about 717 mm.

The basic experimental treatments were 1) application of sludge with heavy metals, 2) application of inorganic salts with heavy metal contents, and 3) control.
A model of topsoil contamination to a depth of 0.20 m with heavy metals to reach the values of total contents in treatments 1 and 2 of Cd = 20.2 ppm, Pb = 280 ppm, Zn = 1500 ppm was designed.
According to the values mentioned above, a rate of fresh sludge was applied per l m^{-2} = 21,1 $kg.m^{-2}$ (treatment 1). On the basis of the contents and a ratio of hazardous elements a rate was determined, being applied in the form of inorganic and organic salts per woody species (treatment 2). To determine the relationship between soil organic matter and metal contents in the soil and the plant, on the experimental site, the evaluation was made of soil reaction, humus contents in the soil, heavy metal contents in the soil and the plant. For this purpose soil samples were taken from depths of 0-0.15 and 0.15-0.30 m and entire plants were sampled to determine the contents of heavy metals in the roots, leaves and wood with the aim of finding which part of the plant accumulates the highest content of heavy metals. All samplings were made at three replications.

Results and Discussion

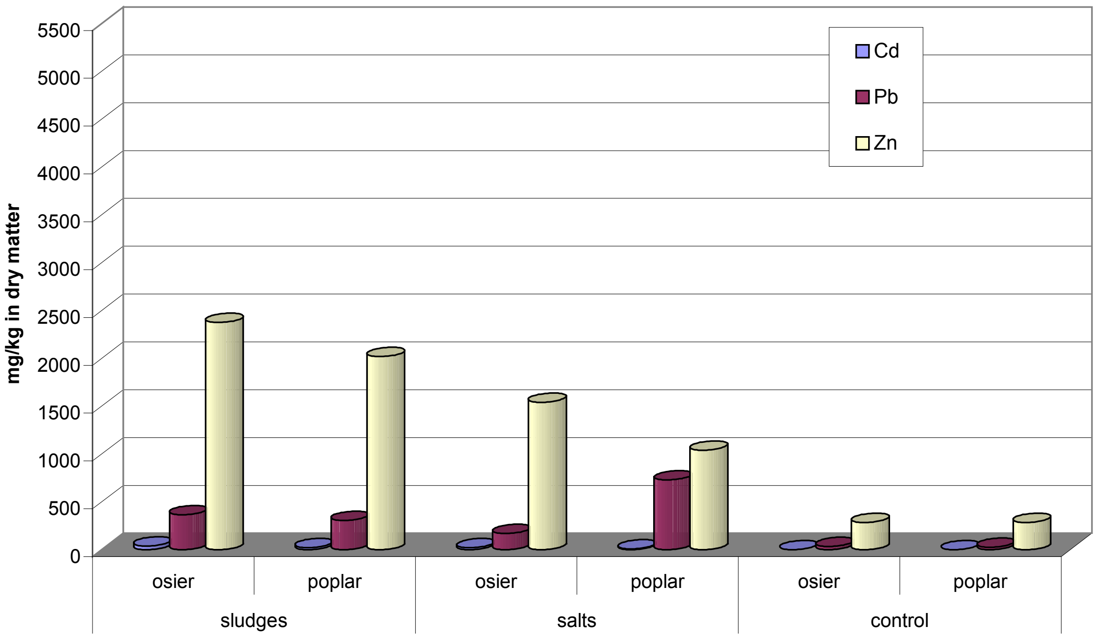
The initial contents of heavy metals in the soil corresponded to the composition of the anthropogenic soil on the site and the amount of salts supplied. In the year 2003 (Graph 1) the highest proportion of zinc in treatment 1 was evident (sludge) under osier and poplar, in treatment 2 (salts) the values were rather lower. Lead content slightly increased only in treatment 2 under poplar, other values remained on the same level. Of the metals studied, the lowest content was found in cadmium, in both treatments of heavy metal application.

Graph 1: The average content of heavy metals in soil by different variants Orlová 2003



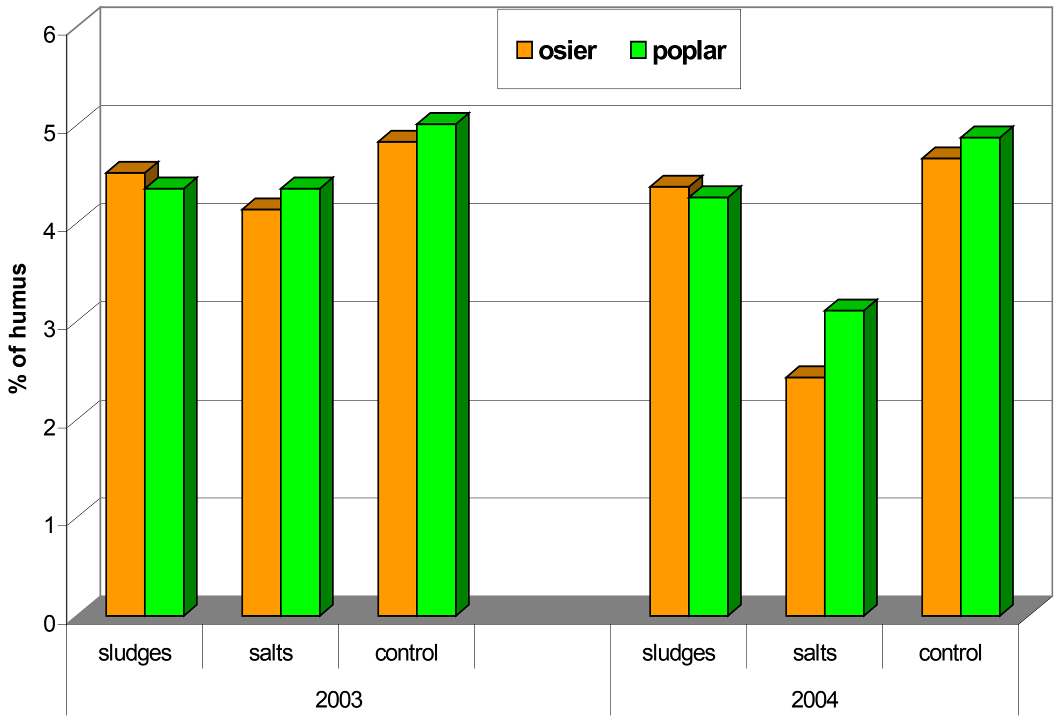
In the year 2004 (Graph 2) zinc and lead contents were roughly half the contents of the year 2003. In treatment 3 (control) the values of all three metals corresponded to the initial situation and their levels did not change throughout the two years of observation.

Graph 2: The average content of heavy metals in soil by different variants Orlová 2004



Graph 3 shows humus content in the soil under different heavy metal treatments over the two years of study, comparing the values reported for osier to those reported for poplar. It was found that changes in humus content or rather Cox occurred during the two years only in the treatment with heavy metals. Under osier the content decreased from 4.14 % in the year 2003 to 2.43 % in the year 2004. Under poplar there was a similar reduction. The values changed from 4.35 % in the year 2003 to 3.11 % in the year 2004.

Graph 3: The humus content by variants with different content heavy metals years 2003, 2004



A number of authors indicated that the content of organic matter in the soil affects the bioavailability of hazardous elements through a wide range of soil properties such as physical properties of soil, microbial soil activity, cation and anion exchange, etc. It was also stated that with increasing content of organic matter the uptake of hazardous elements by plants decreased and *vice versa*. For example, Tyler and McBride (1982) found that adding humic acid decreased Cd activity in the solution and subsequently Cd uptake by plants.
The uptake of heavy metals by plants from soil is given in Tables 1 and 2.

Table 1 The content of chosen heavy metals in separate part of plant Orlová 2003 (mg/kg in dry matter)

Woody plants	Variants	Part of plant	Cd	Pb	Zn
Osier	1	A	6,60	6,37	253
		B	2,39	5,71	95
		C	3,37	19,43	148
	2	A	4,45	8,28	334
		B	3,21	7,47	132
		C	6,13	27,4	432
	3	A	1,82	7,17	273
		B	0,75	5,04	84
		C	1,64	16,6	157
Poplar	1	A	20,94	6,72	305
		B	50,20	9,06	105
		C	9,59	77,67	399
	2	A	4,04	16,64	229
		B	5,40	20,13	218
		C	5,27	53,37	282
	3	A	1,49	5,45	136
		B	1,41	8,27	85
		C	1,51	17,63	110

Table 2 The content of chosen heavy metals in separate part of plant Orlová 2004 (mg/kg in dry matter)

Woody plants	Variants	Part of plant	Cd	Pb	Zn
Osier	1	A	1,53	5,26	120
		B	0,82	0,00	56
		C	3,20	21,83	143
	2	A	4,40	4,29	245
		B	2,60	0,00	86
		C	13,01	39,67	373
	3	A	0,74	4,57	148
		B	0,55	0,00	74
		C	0,44	5,06	72
Poplar	1	A	2,10	3,45	151
		B	1,07	0,96	58
		C	3,90	19,03	177
	2	A	2,15	3,27	110
		B	1,18	2,48	56
		C	1,08	5,53	72
	3	A	0,66	2,21	131
		B	0,52	2,97	64
		C	0,21	1,69	45

Legend:
1 - sludges
2 - salts
3 - control
A - foil
B - wood
C - radix

The tables present values of heavy metals accumulated in leaves, in stems (wood) and roots. The highest content of Cd, Pb and Zn in the year 2003 was mostly found in both woody species in their leaves and roots. In poplar (treatment with sludge) the highest content of Cd was detected in the wood and the leaves, whereas, Pb and Zn contents were highest in the roots. In the year 2004 the values of heavy metals in both woody species were much lower, which corresponds to the lower content of these elements in the soil in that year. The highest Cd, Pb and Zn contents were again in the leaves and the roots. Of the heavy metals studied, the highest uptake was found in Zn in both woody species under all the treatments. The

reduced content of humus in treatment 2 in the year 2004 might have affected the uptake of heavy metals by plants. In this treatment with osier there was the highest uptake of Cd, Pb and Zn, in the leaves and the roots, which might confirm a relationship between the content of organic matter and the uptake of heavy metals by plants (see findings of Tyler and McBride, 1982). The highest uptake of zinc in the roots of poplar was also confirmed by Di Baccio *et al*. (2003). A similar problem was also studied by Vysloužilová *et al*. (2003) and Rosselli *et al*. (2003).
The uptake of heavy metals from the soil is also influenced by soil reaction. On rehabilitated areas, where the experiment was established, pH values in the year 2003 in all the treatments and both woody species were reported as neutral. However, in the year 2004 the soil reaction in treatment 3 (control) was alkaline and in treatments 1 and 2 it was strongly alkaline. The increase in soil reaction was caused by the composition of the dump material, which was mostly made up of fly ash with high pH. It is generally known that with identical concentrations of Cd, Pb, but also Mn, Zn, Co and some other elements in the soil their contents in plant tissues decreases with the increasing pH value (Lagerwerff, 1979; Mahler *et al*., 1980 and others). Alloway (1990) reported pH of the soil as the second most important factor affecting Cd uptake by the plant. He also concluded that with reduced pH, Cd contents in the plant increased 2 – 3.9 times. In our experiment this fact might also have caused the reduced uptake of this element by the plant, as there was an increase in pH. As for Pb, pH influences the uptake by plants only to some extent. As for Zn, its uptake by plants is influenced by soil properties in the following order: total content of the element in soil – pH – organic matter content – soil texture – microbial properties of soil.

Conclusions

During the two-year study of the effect of humus content on the uptake of heavy metals by plants it was found that reduced humus content in the year 2004 in the treatment with salts may have an effect on increased uptake of Cd, Pb and Zn, mainly in osier. An increase in pH in the year 2004, compared to the year 2003, (the neutral reaction changed into the strongly alkaline reaction) might be one of the reasons for the reduced uptake of some heavy metals by plants. The total contents of Cd, Pb and Zn in the soil halved in the year 2004, which correlated with the uptake of the elements by the plants. The highest accumulation of heavy metals was found in osier and poplar, in their leaves and roots.

Literature

Alloway, B. J.: Heavy metals in soils. Blackie, John Wiley & Sons, Inc. New York, 1990, 339 p.

Di Baccio, D., Tognetti, R., Sebastiani, L., Vitagliano, C.: Response of *Populus deltoids x Populus nigra* (*Populus x euramerica*) clone I-214 to high zinc concentrations. New Phytologist, 2003, 159: 443-452

Domažlická, E., Opatrný, Z.: The effect of cadmium on potato (*Solanum tuberosum L.*) shoot culture growth. Biol. Plant, 31, 1989, 5, pp. 408-412

Facek, Z.: Hodnocení intoxikace půd v Severočeské hnědouhelné pánvi. Rostlinná výroba, 32 (LIX), 6, 1986, pp. 649-654

Greger, M., Lindberg, S.: Effects of Cd^{2+} and EDTA on zouny sugar beets (*Beta vulgaris*). I. Cd^{2+} uptake and sugar accumulation. Physiol.Plant, 1986, 66, pp. 69-74

Lagerwerff, J., V.: Uptake of Cd, Pb and Zn by radish from soil and air. SoilSci., 111, 1979, No. 2, pp. 129-133

Mahler, R. J., Bingham, F.T., Sposito, G., Page, A. L.: Cadmium – enriched sewage sludge application to acid and calcareous soils: Relation between fragment, cadmium in saturation extracts and cadmium uptake. Journal of Environmental Duality, 1980, 9, pp. 359-364

Rosselli, W., Keller, C., Bosch, K.: Phytoextraction capacity of trees growing on a metal contaminated soil. Plant and Soil, 2003, 256: 265-272

Sáňka, M.: Kontaminace zemědělské produkce některými těžkými kovy vlivem atmosférické depozice. In: Sborník referátů z celostátní konference „Cizorodé látky v zemědělství". VŠZ Brno, 1989, p.64

Tyler, L. D., Mc Bride, M. B.: Influence of Ca, pH and humic acid on Cd uptake. Plant Soil, 64, 1982, pp. 259-262

Vysloužilová, M., Tlustoš, P., Száková, J., Pavlíková D.: As, Cd, Pb and Zn uptake by *Salix* spp. clones grown in soils enriched by high loads of these elements. Plant Soil Environ., 49, 2003 (5): 191-196

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BIOLOGICAL ACTIVITY AND CERTAIN PHYSICO-CHEMICAL PROPERTIES OF RECLAMATION LAYERS AND BROWN COAL BLANKET CLAYSTONES OF "STRYMICKA VYSYPKA" OBJECT (CHOMUTOV, CZECH REPUBLIC)

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Introduction

The brown coal deposits occur under thick layers of sedimentary rocks which in the opencast mines have to be removed prior the mining process and are heaped as mounds. Those dump areas are subject to a scarce natural vegetation succession and therefore demand a reclamation. The characteristics of the post-mining wastes from Chomutov region in Czech Republic is presented in Meller et al. (2004), and Tomaszewicz et al. (2004).

The investigated object "Strymická vysypká" (50° 32'12"N, 13° 48'44"E) was reclaimed with the carbonate claystone and the mixture of the claystone with the municipal sludge compost. The blanket rocks from the brown coal pit deposited in the vicinity are characterized by a compact granulation, generally high content of available macroelements, alkaline reaction, and a low quantity of heavy metals.

It is evident from the prior works that the post-mining grounds are characterized by a defective energetic system (Bender, 1995). The individual components of this system occur in wrong quantities and proportions, which limits, and even destroys the biomass production. All the biogene transformations in the soil are stimulated by the enzymes which condition their transformation in the forms available for plants and microorganisms. The pedosphere monitoring by means of the methods based on the enzymatic tests allows the estimation of the evolutionary stage of the industrial soils, as well as the evaluation of the effectiveness of the reclamation methods (Bielińska et al., 2004). The basic merits of the biological methods of the estimation of the soil environment, based on the enzymatic designation, mean not only the possibility of performing series analyses, but among all the ability of the total expression of multiple factors effect and the estimation of the parameters impossible to be designated otherwise, eg. the elements of the cell metabolism (Bielińska, Domżał, 2004).

In the search and goal for a continuous verification of the indicators of diagnostic soil processes as well as the indicators of the post-industrial barrens transformations, the enzymatic activity was investigated and the selected physico-chemical properties of the anthropogenic soils of "Strymická vysypká" object due to the applied reclamation method.

Investigation Methods

The mound of the brown coal blanket rocks of "Strymická vysypká" object was reclaimed by two methods. The experimental plot C was covered with a sole layer of the carbonate claystone of 25-30 cm. depth. The blanket claystone on the second comparable plot D was directly covered with 25 - 30 cm deep layer of the carbonate claystone which was additionally covered with the 25 cm thick mixture of the municipal sludge compost and the carbonate claystone. Thus reclaimed area of the mound was planted with the seedlings of *Sorbus aucuparia*, *Acer pseudoplatanus, and Alnus glutinosa*.
For the estimation of the physico-chemical properties, the bulk samples were taken in 2003 and 2004. The samples of the carbonate claystone (0 - 30 cm) and the blanket rocks (30 - 80 cm) were taken from the C object, whereas those taken from D object comprised the carbonate claystone with compost (0 - 25 cm), the carbonate claystone (25 - 50 cm) and the blanket rocks (50 - 80 cm).
The sampled material was denoted for the granulation, reaction, organic C content, total N, and the available macroelements (P, K, Mg) with the commonly applied methods in the pedology.
For the enzymatic analyses the samples were taken from the active layer of the soil profile in 2004. They were the samples of the carbonate claystone and the blanket rocks (to 60 cm) from the C object, and of the carbonate claystone with compost and the carbonate claystone from the D object. The activity of dehydrogenases (Thalmann 1968), phosphatases (Tabatabai, Bremner 1969), urease (Zantua, Bremner 1975) and protease (Ladd, Butler 1972) was designated. The content of the mineral forms of nitrogen $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ (ISO 14255) was additionally designated in the soil samples.

Results and Discussion

The soils formed by the reclamation can be classified as initial anthropogenic pararendzinas of an AinCcaan-Ccaan-IICcaan profile. The soils of the investigated object originated from the fine-grained formation qualified as silty clay loam - clay loam granulometric groups characterized by an alkaline reaction which results from the contents of calcium carbonate (tab. 1). The bilayer formation is found in the anthropogenic soil profile of the C object. The surface layer - the carbonate claystone is a weakly weathered, compact, very fine-grained material. At the time of sample collection the soil material was strongly dried despite a potentially high water capacity. The soil moisture range is subject to the relief - the mound with a considerable slope. The other layer consists of the fine-grained, plastic brown coal blanket rocks of the actual moisture more favorable than the above one.
A significant difference between the C and D objects consisted in the addition of the compost in the layer of the carbonate claystone at the depth of 0-25 cm. Comparing the chemical properties of the differently reclaimed objects it can be stated that the addition of the compost resulted in a considerable increase of the organic C and the total N contents in the soil. The blanket rock is characterized by a higher content of the available forms of magnesium and potassium than the reclamation material. The blanket rocks are characterized by a considerably wide relation C:N, as the dump-heaps of these rocks contain a various admixture of brown coal (Gilewska, Wójcik 1984).

In total, the resources of the available nitrogen ($N\text{-}NH_4^+$ and $N\text{-}NO_3^-$) in the soil of the investigated experimental objects were high. The content of N min. ($N\text{-}NH_4^+ + N\text{-}NO_3^-$) ranged from about 52 to 118 $mg \cdot kg^{-1}$ of the soil, what amounts to about 156-354 kg N·ha-1. The applied reclamation methods did not affect the content of the ammonium form of nitrogen in the soil. However, a significant increase in the content of the nitrate nitrogen was observed in the soil of the D object. (tab. 2). A relatively high content of the nitrates (V) in the soil with the addition of compost could be caused by the N transformations, and most of all by the nitrification. With the increased inlet of N (compost addition) into the soil the net mineralization of N increases (Tietema, van Dam 1996). The nitrification (microbiological oxidation of NH_4^+ to NO_3^-) is a succession of the intensive mineralization of nitrogen. The content of the mineral forms of nitrogen in the soil is the resultant of the mineralization and immobilization as well as the oxidation and reduction. These transformations depend on such factors as: the biological activity of the soil, moisture, temperature and fertilization (Bielińska, Głowacka 2004).

The activity of all enzymes in the top layer of the carbonate claystone with compost of the D object was several times higher as compared to the carbonate claystone without compost of the C object (tab. 2). That stimulation was bound to the enrichment of the soil environment with the organic substance introduced with the compost, what resulted in the contents of the organic carbon (tab. 1). The presence of the carbon substrates induces a biosynthesis of the enzymes by the soil microorganisms (Kieliszewska-Rokicka 2001). Numerous data from the subject literature inform about close positive correlations between the contents of humus in the soil and the enzyme activity (Dick 1984, Kucharski 1997, Bieliñska et al. 2004). The activity of the investigated enzymes in the soil of the D object assumed the level characteristic for the soils of an uninterrupted course of the biological processes. In the case of the slope of the D object a high enzymatic activity was noted in the layer of the claystone without compost (tab. 2), which might have resulted from the relocation of a part of organic substance from the object with compost due to a considerable declivity. This suggestion is confirmed in a relatively high content of Corg in the layer of the claystone without compost admixture. The content of Corg was at about 25 % higher in the samples from the D object without the compost addition than in the claystone layer on the C object (tab. 1). The observed stimulation of the urease activity in the soil with the compost also resulted from the introduction of the urea - the urease substrate into the environment. This enzyme perfectly adapts itself to every environment independent of its temperature, humidity, and/or reaction, and the main factor limiting its activity is the availability of the substrate - urea, since as an extracellular enzyme it is solely synthesized in its presence (Carbrera et al. 1994). The changes of the enzymatic activity within the reclaimed layers of the soil profile corresponded to the changes of the quantity of the biogenic constituents, ie. a higher activity of the investigated enzymes was noted in the soil samples with a higher content of the total N and the available forms of P, K, and Mg. It also proves the incorporation of the nutritional constituents into the biological cycle. According to Kobus (1995) the biological processes responsible for the soil fertility in the land ecosystems are connected with the microbes and the enzymes excreted by them and the rate of the biogeochemical transformations conducted by them in the circulation of elements.

Observed depression of the dehydrogenases activity in the soil of the C object proves the decreased Total Microbiological Activity (TMA). The dehydrogenases, contrary to other enzymes, are active inside the live cells exclusively, and after the cell death they degrade very fast. Due to that the activity of dehydrogenases indicates the presence of physiologically active microorganisms (Kieliszewska-Rokicka 2001). During unfavorable conditions for the living activity of microorganisms, such as drought or shortage of carbon substrates, the extracellular enzymes can maintain their catalytic activity and supply mineral nutrients for the soil microorganisms and plant roots. Furthermore, the extracellular soil enzymes, which

constitute a part of a total enzymatic activity of the soil, when bound with the soil colloids can be less sensitive to the stress factors than the microbiological activity. The most recent data from the subject literature indicate that the most reliable estimation of the soil quality can be obtained from the simultaneous investigations of the activity of several enzymes which enable to record the changes of specific capabilities of the soil complex influenced by the natural and anthropogenic factors (Kucharski 1997, Kieliszewska-Rokicka 2001).
Summing up the estimation of the effects of the applied reclamation methods to the mound of the blanket rocks on “Strymická vysypká” it should be stated that the addition of the compost positively affected the enzymatic activity of the soil. These results constitute another evidence of an important role of the organic matter in the formation of the biological activity of the reclaimed anthropogenic soils.

Conclusions

1. Conducted reclamation measures did not change the accessibility of the available forms of macroelements (P, K, Mg), whereas the addition of compost to the carbonate claystone resulted in a beneficial narrowing of the carbon to nitrogen relation.
2. Applied reclamation methods did not affect the differentiation in the content of the ammonium form of nitrogen in the soil which occurs at a high level. A considerable increase of the content of the nitrate nitrogen was noted within the object reclaimed with the mixture of the carbonate claystone and compost.
3. The observed depression of the dehydrogenases activity in the soil of the object reclaimed merely with the carbonate claystone proves the decreased total microbiological activity.
4. The activity of the investigated enzymes in the soil of the object reclaimed with the mixture of the carbonate claystone and compost, assumed the level characteristic for the soils of an uninterrupted course of the biological processes.

Table 1. The chemical properties of blanket rock and reclamation layers.

Soil substance	Granulometric Group	pH KCl	Corg.	N	$CaCO_3$	Mg	K	P
			$(g \cdot kg^{-1})$		(%)	$(mg \cdot 100^{-1}$ of soil)		
Object C								
Carbonate mudstone	silty clay loam	7,7	4,9	0,43	54,2	10,0	12,1	1,00
Blanket rock of brown coal	clay loam	7,8	16,9	0,71	1,6	39,9	15,9	0,88
Object D								
Mixture of compost and carbonate mudstone	clay loam	7,6	29,3	2,26	12,1	15,9	14,4	1,14
Carbonate mudstone	clay loam	8,0	6,5	0,61	52,8	19,4	14,1	1,22
Blanket rock of brown coal	clay loam	7,9	19,1	0,74	0,7	45,3	19,2	1,04

Table 2. The biological activity and content of nitrogen mineral forms ($N\text{-}NH_4^+$ and $N\text{-}NO_3^-$)

Soil substance	Dehydrogenases $(cm^3\ H_2 \cdot kg^{-1} \cdot d^{-1})$	Phosphatases $(mmol\ PNP \cdot kg^{-1} \cdot h^{-1})$	Ureases $(mg\ N\text{-}NH_4^+ \cdot kg^{-1} \cdot h^{-1})$	Proteases $(mg\ tyrozyny \cdot kg^{-1} \cdot h^{-1})$	$N\text{-}NH_4^+$ $(mg \cdot kg^{-1})$	$N\text{-}NO_3^-$ $(mg \cdot kg^{-1})$
Object C top						
Carbonate mudstone	0,7	44,7	2,5	8,1	28,3	48,2
Blanket rock of brown coal	0,9	38,2	2,9	9,5	31,8	49,4
Object C slope						
Carbonate mudstone	0,9	50,4	2,4	10,8	31,5	35,4
Blanket rock of brown coal	0,6	39,4	2,3	4,9	27,6	24,9
Object D top						
Mixture of compost and carbonate mudstone	2,6	205,4	12,1	15,1	26,5	69,1
Carbonate mudstone	1,1	68,6	4,8	4,7	29,5	83,6
Object D slope						
Mixture of compost and carbonate mudstone	3,7	202,1	26,1	15,4	27,2	91,1
Carbonate mudstone	1,6	198,7	22,2	13,2	27,7	77,2

References

1. Bender J. 1995. Rekultywacja terenów pogórniczych w Polsce. Zesz. Probl. Post. Nauk Roln., z. 418,
2. Bielińska E.J. Domżał H. 2004. Zastosowanie testów enzymatycznych do oceny antropogenicznych przekształceń gleb leśnych na terenie Nadleśnictwa Puławy. Rocz. Glebozn. 55, 2, 61-68.
3. Bielińska E.J., Głowacka A. 2004. Zawartość mineralnych form azotu w glebie sadu jabłoniowego w zależności od metody jej pielęgnacji. Acta Sci. Pol., Hortorum Cultus 3(2), 131-145.
4. Bielińska E.J., Domżał H., Węgorek T. 2004. Aktywność enzymatyczna industrioziemów wytworzonych z piasków na zalesionym zwałowisku kopalni siarki w zależności od gatunku drzew. Zesz. Probl. Post. Nauk Roln., 501, 23-32.
5. Carbrera M.L., Kissel D.L., Bock B.R. 1994. Urea hydrolysis in soil. Effect of urea concentration and soil pH. Soil Biol. Biochem. 23, 1121-1124.
6. Dick W.W. 1984. Influence of long-term tillage and crop rotation combination on soil enzyme activities. Soil Sci. Soc. Am. J. 48, 3, 569-574.
7. Gilewska M., Wójcik A. 1984. Aktywność enzymatyczna gruntów pogórniczych pod pionierskimi nasadzeniami leśnymi. Arch. Ochr. Środow. 3-4, 141-156.
8. Kieliszewska-Rokicka B. 2001. Enzymy glebowe i ich znaczenie w badaniach aktywności mikrobiologicznej gleby. Drobnoustroje środowiska glebowego. Red. H. Dahm, A. Pokojska-Burdziej, UMK Toruń: 37-47.
9. Kobus J. 1995. Biologiczne procesy a kształtowanie żyzności gleby. Zesz. Probl. Post. Nauk Roln., 421a, 209-219.
10. Kucharski J. 1997. Relacje między aktywnością enzymów a żyznością gleby. (W:) Drobnoustroje w środowisku, występowanie, aktywność i znaczenie. AR Kraków. Red. W. Barabasz: 327-348.
11. Ladd N., Butler J.H.A. 1972. Short-term assays of soil proteolytic enzyme activities using proteins and dipeptide derivatives as substrates. Soil Biol. Biochem. 4, 19-30.
12. Meller E., Tomaszewicz T., Stankowski Sł., Maciorowski R., Honzik R., Ustiak S., preliminary comparison of two kinds of forestel reclamation of brown coal post-mining waste within “Strzymicka Vysypka” (Chomutov, Czech) In: New agrochemicals and their safe use for health and environment "Chemicals in sustainable agriculture IV", Ed.: H. Górecki, Z. Dobrzański, P. Kafarski, Wyd. Pol-Czech-Trade, s. 652-659.
13. Tabatabai M.A., Bremner J.M. 1969. Use of p-nitrophenyl phosphate for assay of soil phosphatase activity. Soil Biol. Biochem. 1, 301-307.
14. Thalmann A. 1968. Zur Methodik der Bestimmung der Dehydrogenase Aktivität in Boden mittels Triphenyltetrazoliumchlorid (TTC). Landwirtsch. Forsch. 21, 249-258.
15. Tietema A., van Dam D. 1996. Calculating microbial carbon and nitrogen transformation in acid forest litter with 15N enrichment and dynamic simulation modelling. Soil. Biol. Biochem. 28, 953-965.
16. Tomaszewicz T., Meller E., Stankowski Sł., Maciorowski R., Honzik R., Ustiak S. „Indicators of Zea mays plants growth and development against the physical-chemical traits of the humic industrial soil made of the brown coal post mining waste layers and the natural brown soil. In: New agrochemicals and their safe use for health and environment "Chemicals in sustainable agriculture IV", Ed.: H. Górecki, Z. Dobrzański, P. Kafarski, Wyd. Pol-Czech-Trade, s. s. 673-682.
17. Zantua M.I., Bremner J.M. 1975. Comparison of methods of assaying urease activity in soils. Soil Biol. Biochem. 7, 291-295.

EFFECT OF TILLAGE AND NITROGEN ON DURUM WHEAT IN A MEDITERRANEAN CLIMATE

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Abstract
Consciousness of reducing production costs and environmental impact induces farmers to revise the use of traditional techniques. This study was aimed at determining the effect of different tillage methods and N fertilization rates on soil strength and wheat yield under Mediterranean conditions in south Italy. The experiments were conducted from 1990 to 1993 in silty clay soil (Typic Chromoxerert). The treatments consisted of four tillage systems: conventional, two-layer, surface and minimum combined with three nitrogen (N) rates : 0, 50, 100 kg ha^{-1}. In all treatments a continuous cropping of durum wheat (Triticum durum Desf.) was grown in every trial crop season. The experimental design was split-plot with three replications for the grain yield trial. Once a year also measurements of penetration resistance in the soil 0-50 cm layer were carried out, but only in the plots fertilized with 100 kg ha^{-1}. So, the experimental design for soil penetration resistance was a randomized block with missing observations. As soil resistance varies with water content, the penetration measurements were standardized to a common water content and log-transformed. To examine the relationships within the set of 15 variables corresponding to penetration measurements at different depths and reduce the number of variables, the measurements were submitted to Principal Component Analysis and the first two principal components (PC) were retained and separately processed according to multivariate analysis of variance. The first PC was associated to soil penetration measurements in the 27-50 cm depth and the second PC was associated to the measurements in the top layer. The first PC was significantly influenced by the effect of SEASON, whereas the second PC by the three-way interaction SEASON * block * tillage", revealing the influence of soil variability at the surface on penetration measurement.
As regards wheat yield, the effect of TILLAGE was significant only in the second season, whereas N was always significant. These results demonstrated that a good combination of soil tillage management and N fertilization may reduce production costs and environmental impact under semi-arid mediterranean conditions.

Key words: tillage system, soil resistance, nitrogen, durum wheat

Introduction

Global grain price competition has forced growers to increase production and decrease cost. This has often entailed the use of agronomic techniques that are not always environmentally sound. However, the recent and growing awareness of a more appropriate use of natural factors and the need to achieve a sustainable agriculture, together with availability of advanced know-how and technical means, induced the agricultural world to revise the use of traditional techniques. These include primarily soil tillage and the application of nitrogen fertilizers, which have direct and indirect implications both on production costs and on soil fertility.
Soil tillage problems have been historically studied for their complexity. The current trend is

to reduce both the number and the depth of tillage. To be generalised this trend needs to be supported by experimental data since it involves many soil-related issues such as the change in soil air, aggregate stability, weed control, incorporation of plant residues, structure, specific weight, organic matter, temperature, moisture, roots' resistance to penetration and nutrient uptake. This makes the scenery particularly complicated and not easy to be interpreted due to synergetic and complementary relations that are often established between them. Previous research has been conducted on this subject in both Italy (Ferri et al., 1988; De Giorgio et al., 1994) and abroad (Mendera and Feyen, 1994; Pierce et al., 1994). However, the dependence of tillage on soil and climatic conditions makes the study of its effects on soil physical properties and crop production necessary for different areas of the world. In semi-arid areas, such as southern Italy, continuous cropping of durum wheat (Triticum durum Desf.) is widespread and water availability is the most important limiting factor in agriculture under rainfed conditions. Traditional cultivation systems include ploughing, disking and harrowing before sowing. The fallow practices and the minimum tillage system are practised only in few locations, whereas these techniques might help to make the system more sustainable, by reducing the inputs and evaporation loss of accumulated soil water.
The objectives of this study were to evaluate how tillage sistems can affect a continuous winter wheat grown under mediterranean conditions, at high risk of desertification.

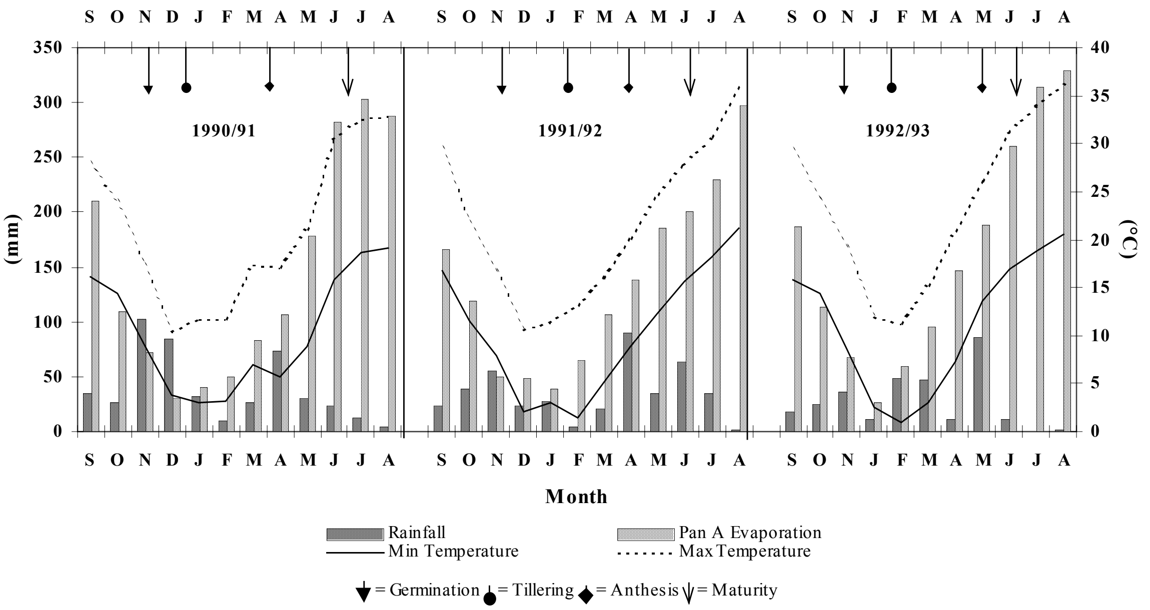

Figure 1. Monthly variation of some meteorological the parameters at Foggia site during the three seasons.

Materials and Methods

Site location and climate

The study was conducted at the Experimental Agronomic Institute's research farm, Foggia, southern Italy (altitude 90 m a.s.l. ; latitude 41° 27' N, longitude 15° 36' E) during three crop seasons (1990/91; 1991/92; 1992/93). The area has a climate characterized by hot, dry summers and cold, rainy winters although mild winter and low rainfall have been increasingly recorded over the last few years. Rainfall was high early in the season 1990- 1991(186 mm in November-December 1990), which caused a good moisture storage in soil, helping plant development (Fig. 1) On the contrary, the second season was characterized by rainfall which remained low until February. Therefore, the crops suffered owing to moisture stress during the long dry spell untill April. Rainfall pattern was more favourable to crop growth in the third season, with rains distributed more evenly during the crop cycle. However, early-season rainfall was not sufficient to create a soil water reserve fulfilling crop water requirements for potential yield. In the second and third seasons May mean temperature was 3° C greater than the one of the first season (Tab. 1).

Table 1. Cumulative evaporation (mm) of the main growth stages for the three seasons.

Growth Stage	1990/91	1991/92	1992/93
Germination-Tillering	98	127	106
Tillering-Anthesis	165	266	309
Anthesis-Maturity	456	434	318
Total	**719**	**827**	**733**

Soil

The soil is a silty clay, classified as fine, mixed, thermic, Typic Chromoxerert (Soil Survey Staff, 1992), with evident Vertic characteristics, with several cracks, 4-5 cm wide in surface and 1 cm wide in depth up toabout 50 cm, especially during dry season. It has a good structure in surface, which facilitates root penetration and water drainage, while its texture, rich in clay, enhances moisture and nutrient holding capacity.

Experimental layout

The experimental field design of the grain yield trial was a split-plot design with three retangular blocks. The treatments consisted of four tillage systems : CT - conventional (double-share ploughing at 45 cm depth, two rotary tillage applications at 20 cm depth with disc plough + 10 cm rotary tillage); TT - two-layer (combined equipment - 60 cm subsoiling + 10-cm rotary tillage); ST - surface (25 cm five-share ploughing + 10 cm rotary tillage); MT - minimum (10 cm rotary tillage), combined with three nitrogen (N) fertilization rates: 0, 50, 100 kg ha^{-1}. The tillage treatments were randomly assigned to the whole 900-m^2 plots, whereas the split-plots were assigned to N fertilization. The treatments were applied to the same plots in each crop season. Durum wheat (cv. Simeto) was grown in every trial season. Nitrogen was applied as top dressing, half at the start of tillering and half at the time when the first node became visible (stem extension stage). The rate of phosphorus fertilization was 100 kg ha^{-1} of P_2O_5 before sowing.

Penetration resistance

Penetration resistance (cone index) was measured using a Bush Recording soil penetrometer with a 30 degree and 12.83-mm diameter cone, corresponding to the American Society of Agricultural Engineering standard. Penetrations were made by recording cone resistance at 3.5 cm increments from the surface to a maximum depth of 52 cm. (P1-P15). The first depth of measurement (0-3.5 cm) (P1) was excluded from the analyses because it usually showed values near 0 MPa, owing to an incomplete contact of the penetrometer base plate on the uneven soil surface. Ten random penetration profiles were made only in the plots fertilized with 100 kg ha^{-1} N once a year when the first node of stem became visible. Due to the presence of missing observations, the experimental field design for cone index was a unbalanced randomised block with four treatments for soil tillage and three replications. At the same time of penetration resistance recording soil samples were collected at 20 cm deep increments in each treatment plot, to determine gravimetric water content.

Statistical Analysis

Correction of cone index for soil water content

Since even small differences in soil moisture may cause large changes in penetrometer resistance, this might mask the effects on penetration resistance imposed by tillage treatment. Correcting strengths for significant differences in water contents among the various treatments permits examination of soil strength aspects other than those caused by water Campbell and O'Sullivan (1991) showed that cone index could be predicted as a function of moisture content and bulk density by:

$$\mathbf{PR = Am^B (\rho_b)^C} \qquad \mathbf{[1],}$$

where PR is cone index (MPa), ρ_b is bulk density (g cm^{-3}), m is gravimetric water content (g g^{-1}) and A, B and C are empirical soil dependent parameters. To correct cone indices for differences in water content and then make them comparable, the correction model takes the form:

$$\mathbf{PR1/PR2 = (m_1/m_2)^B} \qquad \mathbf{[2],}$$

where the indices 1 and 2 are corrected and uncorrected values. The [1] had been previously determined for different combinations of cone index, water content and bulk density, measured on the same site in an independent trial. The empirical coefficients of [1] were estimated by non-linear least-squares regression for the two depths 0-25 cm and 25-50 cm separately . All penetrometer values were then corrected using the [2], by standardisation to a common water content, set equal to the maximum soil water content recorded over the three study years (m_1).

Principal Component Analysis

As measurements made at different depths in one penetration are not independent (O'Sullivan et al, 1987), to examine the relationships within the set of 14 variables (P2-P15), corresponding to the penetration measurements at each soil depth increment, Principal Component Analysis (PCA) (Rao, 1964) was applied, pooling all penetration data recorded during the three crop seasons (Stelluti et al., 1998). That allowed to derive a smaller number of linear combinations (Principal Components, PC) of the original variables, which retained most of information. To aid their interpretation a Varimax rotation was applied to PCs. Because the distributions were approximately lognormal, data were transformed to logarithms and all means and variances were computed in the logarithms. Finally, to obtain unbiased estimates of the means, the logarithms were transformed back using the standard formula:

$$\mathbf{PR = exp (<y> +1/2\, \sigma^2{}_y)} \qquad \mathbf{[3],}$$

where $<y>$ is the mean of the transformed values of PR (y) and $\sigma^2{}_y$ is the estimated variance of y (Aitchison and Brown, 1957).

Univariate and Multivariate Variance Analysis

Each retained PC was submitted to univariate variance analysis in order to test the effect of tillage management on soil penetration resistance on any recording date. Tillage effect was considered fixed. However, as penetration values represented a repeated-measures design, so the observations on the same plot might be correlated, a multivariate analysis of variance (Castrignanò, 1990) was performed to test hypotheses about the significance of the measurement factor (SEASON, also called within-subject factor) as well as the one of the main factor (TILLAGE, also called between-subject factor) and of the two-way interaction of within-subject factor with between-subject factor. To test the null hypothesis, the following tests were used: Wilks' Lambda ; Pilai's Trace ; Hotelling-Lowely Trace and Roy's Greatest Root. To analyse temporal trend, orthogonal polynomial single-degree-of-freedom contrasts were generated for the within-subject factor. The same approach was followed to analyse crop production data, with the only difference that in this case the experimental design was split-plot with two between-subject factors: TILLAGE (main factor) and N (secondary factor). Both the effects were considered fixed. Multiple comparisons among means were made using Student-Newman-Keuls test. All statistical procedures were made by using the statistical software package of SAS\STAT (SAS\STAT, SAS Institute, 1998).

Results

Results of soil penetration resistance measurements in the four tillage systems on the sampling dates of each crop season are shown in figure 2a. There were no significant

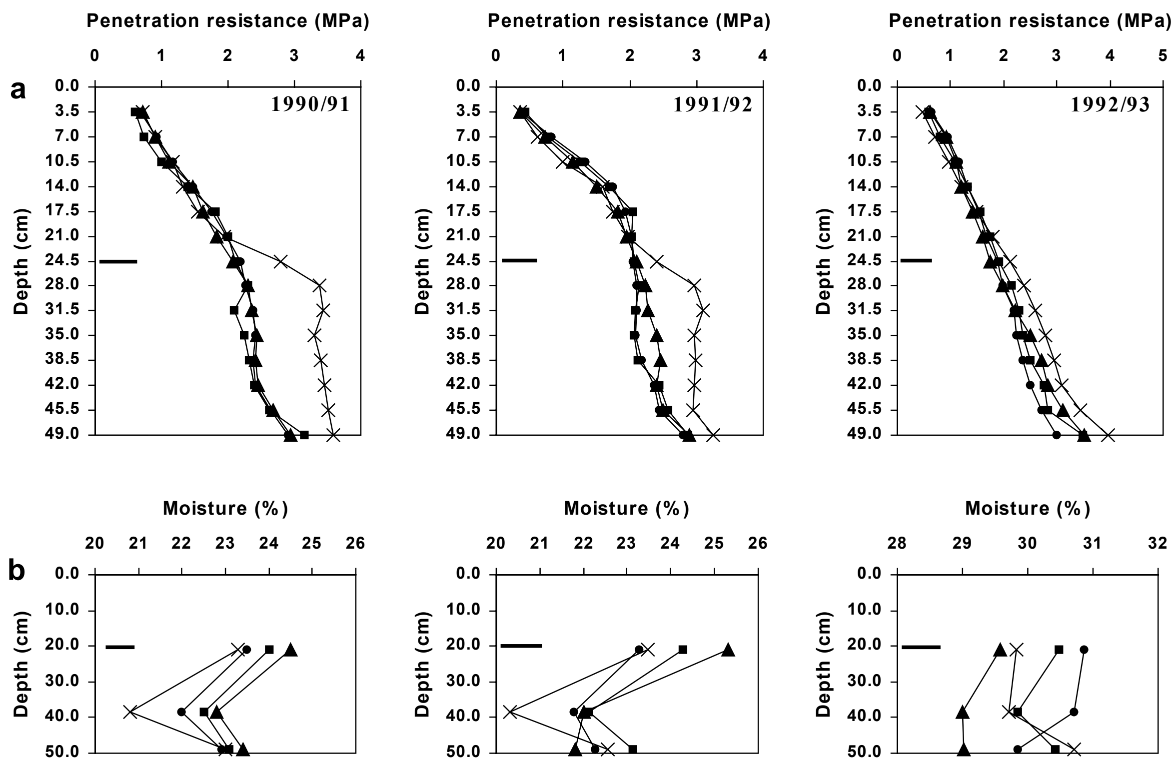

Figure 2. Penetration resistance (**a**) and soil water content (**b**) on the selected dates of the seasons 1990/91, 1991/92 and 1992/93 for the four tillage systems (—♦— **CT** = conventional, —■— **TT** = two-layer, —▲— **ST**= surface, —x— **MT** = minimum), with the relative mean standard deviations (——).

differences among all the four tillage treatments in the top layer (0-20 cm). However the 0-20 cm depth had lower penetration resistance than the one at deeper depth. It then was clear that a strong compact layer had developed below the depth of conventional tillage in all tillage systems. The existence of a layer, also termed as hoe pan or plough pan is actually a common feature in cultivated soils and is thought to be caused by annual tillage to the same depth. Using the generally accepted criteria (Threadgill, 1982) that cone index values greater than 2MPa frequently reduce crop yields and values above 1.5 MPa frequently reduce root growth, it is evident that below approximately 25 cm depth root growth might be hindered. Compaction of soil below this depth was persistent in all tillage systems and in any crop season.

At deeper depth minimum tillage was different from the other treatments in the first two

seasons, recording the greatest soil resistance. However, the pattern in changes of soil penetration resistance mirrored the changes in water content of soil. Actually, soil was drier at the 20-40 cm depth in the minimum tillage system in the first two seasons, whereas in the third season there were no significant differences in soil resistance among the all tillage treatments, because of more similar water contents (Fig. 2b)
The Principal Component Analysis (PCA) applied to the cone index measurements, standardised to a common water (the maximum value recorded in the three seasons) according to the [2] and then transformed to natural logarithms resulted in a first PC explaining 73% of total variance, and in a second PC, explaining 16 %. As the cumulative percentage of variance explained by both components being more than 88%, only the first two PCs were retained. The pattern of the rotated PCs is reported in table 2.

Table 2. Pattern of the first two rotated Principal Components.

Depth	1	2
P12	0.91*	0.26
P13	0.90*	0.18
P14	0.90*	0.16
P11	0.87*	0.31
P10	0.85*	0.30
P15	0.83*	0.20
P9	0.78*	0.38
P8	0.67*	0.51
P2	0.60	0.33
P5	0.13	0.88*
P6	0.16	0.86*
P4	0.25	0.80*
P7	0.38	0.74*
P3	0.43	0.62*

Values greater than 0.61 have been flagged by an (*).

It is clear from the table that the first PC can be associated to soil penetration measurements in the soil layer below approximately the 27 cm depth, whereas the second PC is related to measurements in the top layer. Therefore, also PCA displays a discontinuity in soil profile at 27 cm depth.
Orthogonality between the two principal components authorizes us to submit each PC to distinct variance analyses of both univariate and multivariate type. As regards the first PC, tillage management caused no significant effect on cone index measurements either in each season or averaged over time. In the multivariate analysis only SEASON was highly significant, as proved unambiguously by all the four multivariate tests at the probability level of p<0.0001. The temporal trend analysis shows that the linear component was significant but not different among the tillage systems (Tab. 3). We can then conclude that soil strength showed a continuous trend in changing over time.

Table 3. Variance analysis results for the linear component of the temporal trend of the Principal Component **1**.

Source	Degrees of Freedom	Mean Square	F Value	Pr>F
Linear component				
Mean	1	18.834	84.05	0.0001
Block	1	0.052	0.23	0.6380
Tillage	2	0.034	0.15	0.8605
Block*Tillage	2	0.114	0.51	0.6106
Error	15	0.224		

All the above results were confirmed for the second PC as regards the main factor. On the contrary, as regards the repeated factor, the only significant term was the three-way interaction SEASONxBLOCKxTILLAGE at the probability level of p<=0.01, revealing the influence of position on soil resistance measurement at top layer. Indeed, the existence of probable horizontal gradient in soil structure seems to affect soil resistance variability as well as weather pattern. Therefore, soil resistance was a function not only of meteorological variability but also of the position on soil surface. Moreover, such spatial-temporal variability may have masked the actual effect of tillage on soil resistance. The approach followed in this study did not allow to deeply investigate spatial variation and then estimate the influence of soil structure on penetrability. An alternative approach , when observations are autocorrelated, is the use of geostatistics (Matheron, 1965), which might better identify physical factors, such as tillage, contributing to the soil resistance variability and examine the extent of spatial autocorrelation. The results of the univariate variance analysis for grain yield relative to the main factors (TILLAGE and N), separately for each season, are reported in table 4.

Table 4. Variance analysis of grain yield for each of the three sasons.

Season	Source	Degrees of Freedom	Mean Square	F Value	Pr>F
1990/91	Block	2	1358.93	47.11	0.0001
	Tillage	3	328.39	3.50	0.0894
	First Error	6	93.69		
	N	2	1841.76	63.85	0.0001
	Tillage*N	6	40.75	1.41	0.2284
	Residual Error	50	28.85		
1991/92	Block	2	13.20	1.09	0.3443
	Tillage	3	146.24	6.03	0.0305
	First Error	6	24.25		
	N	2	247.23	20.41	0.0001
	Tillage*N	6	23.24	1.92	0.0961
	Residual Error	50	12.11		
1992/93	Block	2	248.74	19.06	0.0001
	Tillage	3	13.00	0.20	0.8896
	First Error	6	63.55		
	N	2	196.29	15.04	0.0001
	Tillage*N	6	15.29	1.17	0.3365
	Residual Error	50	13.05		

At this point it needs to emphasise that also N was considered a fixed effect, because the aim of the trial was comparing the local standard of fertilization (100 kg ha^{-1}) with other more ecologically sounded treatments (50 kg ha^{-1} and unfertilized). Tillage was significant ($p<=0.05$) only in the second season, whereas N was always highly significant. But, when the effects were averaged over the years, tillage was not significant.

As regards the effect within subjects in the multivariate analysis, SEASON was highly significant, as all the four multivariate tests agree at the probability level of $p<0.0001$. Yields were significantly higher ($p<=0.05$) in 1990/91 season compared with the other seasons, which was very probably caused by early-season rainfall ensuring enough water supply to crops during the growth.

Table 5. Effect of nitrogen uptake on durum wheat grain yield for each season.

Season	Nitrogen rates	Grain yield (t ha^{-1})	SNK Grouping [1]
1990/91	100	4.88	A
	50	4.15	B
	0	3.11	C
1991/92	0	2.39	A
	50	2.18	B
	100	1.72	C
1992/93	50	1.92	A
	100	1.85	A
	0	1.40	B

[1] Means with the same letter are not significantly different for P≤0.05.

Variation in grain yield was also associated with N treatments in each season (Tab 5). N fertilization increased production only in the first season, whereas a large decrease in grain yield occurred with the highest N level in 1991/92 and in 1992/93, as a consequence of rainfall pattern and then reflecting the negative effect of N fertilization under drought conditions. This effect was partly compensated by the wetter meteorological pattern in 1992/93 compared with the one in 1991/92, so N fertilization increased grain yield in the third year. The results then confirm that available soil water is the principal factor that limits yield potential of wheat and its response to nitrogen fertilization under Mediterranean climatic conditions. Therefore, yield response of wheat was reduced during the seasons 1991/92 and 1992/93 owing to the low rainfall, especially during early crop season. As nitrogen fertilization constitutes a large portion of production costs, it often represents a risky strategy in low-rainfall seasons. Therefore a better understanding of the interactive effects of N and water on wheat yield would be desirable in order to produce economically sound yield increases. Multivariate analysis showed that the two-way interactions SEASON*N (p<0.0001) and the three-way interaction of SEASON*BLOCK*TILLAGE produced significant effects on grain yield. That means several interacting factors had varying influence on yield obtained in each season: undoubtedly, low rainfall contributed to the low yields in the seasons 1991/92 and 1992/93, but also tillage management in interaction with local soil properties caused yield variation in the three seasons. The results of temporal analysis (Tab.6) prove that wheat yield pattern showed a continuous trend, significantly affected by N fertilization and also by many contingent factors related to soil microvariability, resulting from natural processes and management practices.

Table 6. Variance analysis of the linear component of the grain yield temporal trend.

Source	Degrees of Freedom	Mean Square	F Value	Pr>F
Linear component				
Mean	1	18404.028	1273.72	0.0001
Block	2	222.723	15.41	0.0001
Tillage	3	168.167	2.19	0.1903
First Error	6	76.831		
N	2	504.992	34.95	0.0001
Tillage*N	6	21.930	1.52	0.1917
Residual Error	50	14.449		

Conclusions

This study has demonstrated the importance of water supply, in turn depending on rainfall pattern, during the growth season of wheat under Mediterranean climatic conditions on both soil resistance to penetration and grain yield. Soil mechanical resistance can influence the distributions of roots in the profile. The existence of a compact layer (soil resistance greater than 2MPa) below the 25-27 cm layer may slow downward growth of roots, restricting the root system to the upper part of the profile. As regards wheat response to N fertilization, high N levels adversely affected grain yields in the two drier seasons. A probable explanation was the over-stimulation of vegetative growth early in the season, which reduced soil water availability during grain filling. Therefore, in a dry season supplemental irrigation is very crucial for increasing crop production in the semi-arid Mediterranean conditions, but this solution should be tested in farms with different water availability. Fertilizer N, applied at stem elongation, may not have been sufficient for crop demand, because it was not fully available owing to soil dryness. Thus, appreciable amounts of N may have been immobilized or lost before rain. It then is advisable to apply N fertilization only when soil moisture status appears favourable. Water and N availability should be matched together in order to ensure better utilization of resources according to sustainable agriculture.

Under these particular experimental conditions tillage management seems to have produced no relevant effect on soil strength and wheat grain yield. These results, if appropriately confirmed by further research findings, provide interesting indications about the possibility to reduce energy input at the moment of land preparation for seeding, without jeopardising yields. An alternative to traditional soil tillage might then be minimum tillage. However, since age-hardening processes might occur in field soils, it is recommended to alternate years of more intensive tillage with others of reduced tillage. A good combination between soil tillage and nitrogen fertilization may then reduce production costs and lay the basis for a sustainable agriculture with beneficial economic and environmental effects.

References

Aitchinson, J., Brown, J.A.C., 1957. The lognormal distribution. The University Press, Cambridge.

Campbell, D.J., O'Sullivan, M.F., 1991. The cone penetrometer in relation to trafficability, compaction, and tillage. In: K.A. Smith and C.E. Mullins (Editors), Soil Analysis, Physical Methods. Marcel Dekker Inc. New York, NY, pp. 399-429.

Castrignanò, A., 1990. Applicazione dell'analisi multivariata della varianza ad esperimenti con misure ripetute nel tempo (Multivariate variance analysis application to repeated measurement experiments). Ann. Ist. Sper. Agron. Bari, XXI, (Suppl. 2), 183-195.

De Giorgio, D., Castrignanò, A., Rizzo, V., 1994. A multivariate approach to assess the effects of different tillage systems on biometric parameters and weeds in durum wheat continuous cropping. Proc. of 13th Int. Conf. ISTRO, 2, 983-989.

Ferri D., De Giorgio, D., Rizzo, V., 1988. Efficienza di utilizzazione ed esportazione dell'azoto in frumento duro coltivato con diverse modalità di lavorazione del terreno. Risultati preliminari (Nitrogen use and uptake efficiency in durum wheat cropped with different soil tillage management. Preliminary results). Ann. Ist. Sper. Agron., 19, 85-99.

Matheron, G., 1965. Les variables regionalisées et leur estimation. Masson, Paris.

Mendera, E., J., Feyen, J., 1994. Effects of tillage and evaporative demand on the drying characteristics of a silty loam: an experimental study. Soil Till. Res., 32, 61-69.

O'Sullivan, M.F., Dickson, J.W. and Campbell, D.J., 1987. Interpretation and presentation of cone resistance data in tillage and traffic studies. J. Soil Sci., 38, 137-148.

Pierce, F., J., Fortin, M., C., Staton, M. J., 1994. Periodic plowing effects on soil properties in a No-Till farming system. Soil Sci. Soc. Am. J., 58, 1782-1787.

Rao, C.R., 1964. The use and interpretation of principal component analysis in applied research. Sankhya A (26), 329-358.

SAS Institute Inc. SAS STAT User's Guide, Version 6.12. Cary, NC: SAS Institute Inc., 1998.

Soil Survey Staff, 1992. Keys of Soil Taxonomy Fifth ed. SMSS. Technical monograph n° 19. Blacksburg, Virginia (USA).

Stelluti, M., Maiorana, M., De Giorgio D., 1998. Multivariate approach to evaluate the penetrometer resistance in different tillage systems. Soil Tillage Res. 46, 145-151.

Threadgill, D.E., 1982. Residual tillage effects as determined by cone index. Transcactions of the ASAE, 859-863.

SOIL TILLAGE AND ROOT GROWTH OF BROAD BEAN (*Vicia faba* L. *major*) ON A SILTY CLAY SOIL IN SOUTHERN ITALY

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Abstract

The broad bean is a very interesting crop because of its nitrogen-fixing capacity, but it usually demands a good soil preparation for the seedbed. In this research the possibility of using low environmental impact techniques on broad bean crop was evalued.
The "Istituto Sperimentale Agronomico" of Bari, located in Southern Italy, in 1995 and 1997 a was conducted a study to determine the effects of different soil tillage on root growth, yield and biometric parameters of broad bean in rotation with durum wheat.
The experiment was conducted in the Apulian region (southern Italy) on a clay-silty soil. In the randomized block design four tillage systems were compared: conventional, two-layer, surface and minimum tillage. Sowing was done in the first week of November.
The root study was conducted with mini-rhizotrons methods. At flowering and pod formation stages the root development was determined. The soil moisture was determined at sowing, flowering, pod formation and harvest.
No significant effect of different tillage systems were observed on the RLD (Root Length Density), yield and on soil moisture. These results may contribute in extending the minimum tillage on crops like the broad bean that, through its action as on improving crop, can contribute to preserving soil fertility.

Key words: soil tillage, broad bean, roots growth, soil water

Introduction

An improper and intensive use of the soil in the last ten years, the over-use of depth tillage technique, chemicals product, the shortage of irrigation water, the increase in groundwater salinity, poor organic matter supply, etc. contributed to soil fertility degradation (Lal R., 1991; Lewandowski et al. 1999; Balesdent et. al. 2000; Young and Ritz, 2000). The harmful effect of some of these factors may be reduced through the use of more appropriate and less destructive cultivation techniques. In some regions in Southern Italy, such as Apulia, an intensive agriculture agronomic technique was more common. These areas urgently require preventive action involving the use of low environmental impact cultivation techniques such as the reduction of both the number and depth of soil tillage operations (Hernanz et. al. 1995; Castrignanò et al. 1997) to prevent soil fertility deterioration.
Knowing how the rooting system interact with the soil, more or less ploughed along the profile, may be very helpful to check the adaptability of these crops to reduced tillage, and to recommend low environmental impact cultivation techniques (Bottomley et. al., 1993; Ball-Coelho B.R. et al., 1998; De Giorgio et al. 1998; Pietola and Tanni, 2003).
With regard to these considerations the "Istituto Sperimentale Agronomico", Bari (Southern Italy), has conducted research on the influence of different tillage methods on the rooting system of broad bean, a typical crop of the Mediterranean region, grown in two-year rotation with durum wheat.

Material and methods

The research was conducted in 1995 and 1997 in Foggia (Southern Italy) at the experimental farm of the Institute. The soil is clay-silty, classified as typic Chromoxerert (Soil Survey Staff, 1992). The climate, classified as accentuated thermomediterranean" by the FAO-UNESCO Bioclimatic Maps, is characterized by hot and dry summer with maximum temperature around 40 °C, cool winter (below zero °C), and moderate rainfall concentrated in autumn and spring. In the two year the climate (Figure 1) was characterized by an annual rainfall from September to August, of 501 mm and 469 mm respectively for 1994-'95 and 1996-'97, slightly above the 45-year average (556.47 mm). In the period from November to May, which is particularly important for the crop, the recorded rainfall was 315.8 and 262.8 mm, respectively for the first and second year.

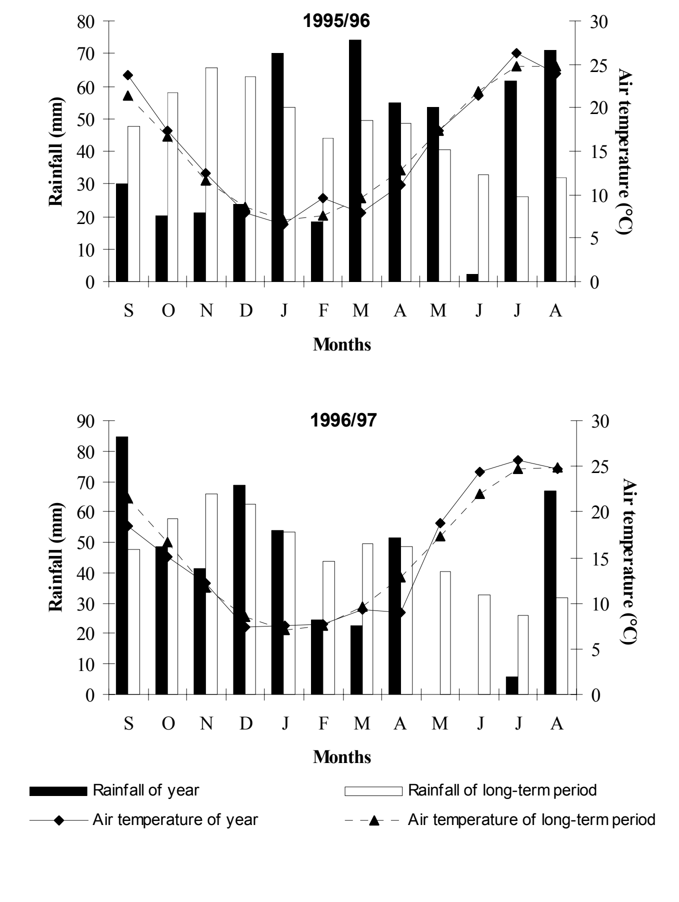

Figure 1. Monthly averages of air temperature and rainfall.

In the randomized block design with three replicates, broad bean (Cv. Supersimonia) grown in rotation with durum wheat, was submitted to four different tillage systems: CT - conventional (double-share ploughing at 35-40 cm depth, one surface ploughing at 15-20 cm with disc plough, 10 cm rotary tillage); TT - two-layer (combined equipment 50 - 55 cm sub-soiling and 10 cm rotary tillage); ST - surface (20 cm five-share ploughing, 10 cm rotary tillage); MT - minimum (rotary tillage). Tillage operations were effected between September and October. Seeding was performed in the first week of November. The sowing was made on 3.11.'94 and on 19.11.1996, respectively in the two years, with a density of 12 plants m^{-2}. One week before sowing the mini-rhizotrons (transparent plexiglas tubes 0,05 x 1m in length) were inserted at 45° degree angle into the soil surface and located parallel to the crop row. The section of the tube left above the ground and wrapped with black plastic was closed to exclude light. The study was conducted on the plots, which in the previous years were to wheat used as control plots, without nitrogen fertilization. During the cropping cycle, two measurements were run at flowering and at pod formation, in 1995 on the 135th and 208th and '97 on the 128th and 193rd days after sowing. The roots intersecting the mini-rhizotrons were observed using the microvideo camera and the video recorder. The number of roots crossing the tube was counted on the monitor and transferred to the statistical and graphical package SAS/STAT and SAS/GRAPH (SAS/STAT, SAS Institute 1998). Root counts were converted to root length density (RLD) cm cm^{-3} (Upcharch and Ritchie, 1983; Upchurch, 1985). Throughout the cropping cycle the soil moisture was determined at sowing, flowering, pod formation and harvest.

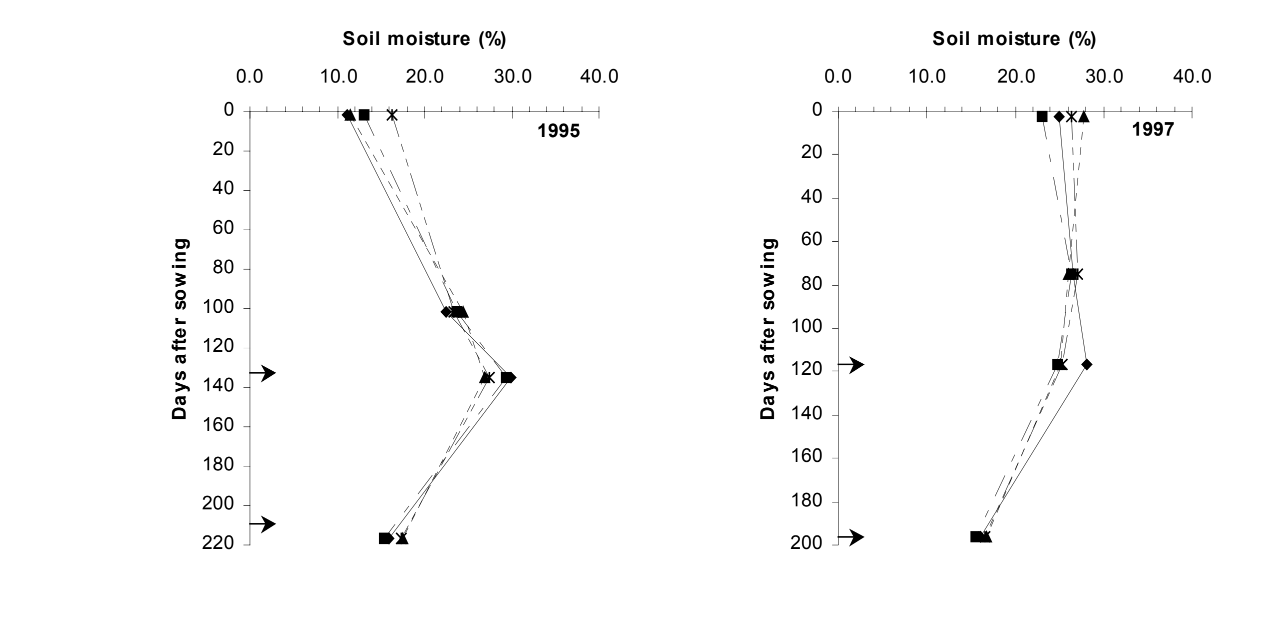

Figure 2. Moisture content from sowing to harvest in the 4 tillage systems (CT ♦——♦; TT ▲--------▲; ST ■-—-■; MT *- -— - -*; ↑ root observation).

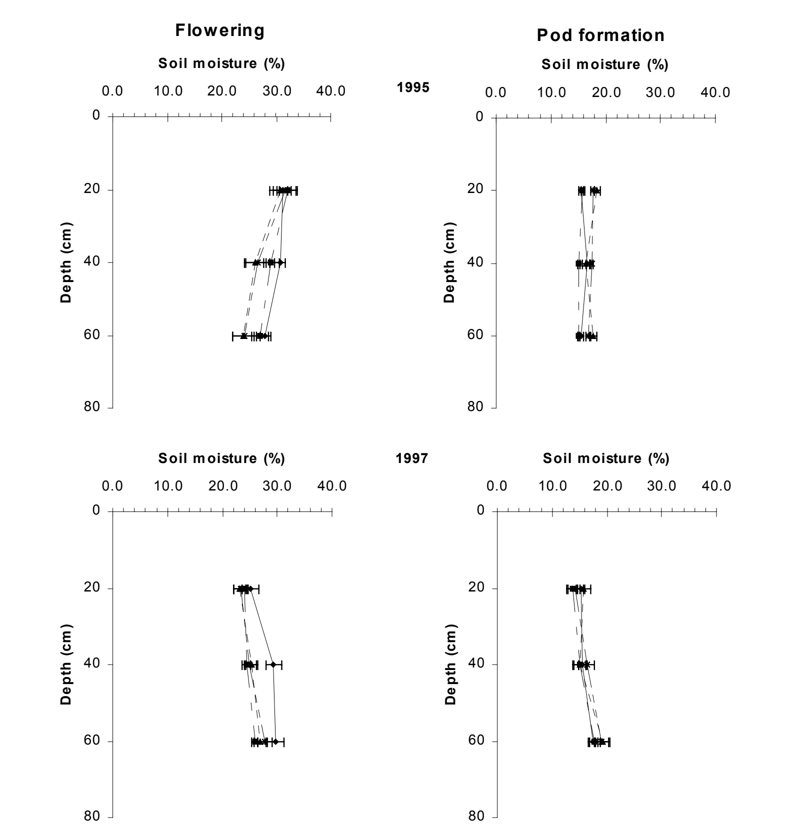

Figure 3. Soil moisture content in the 0-60 cm profile in 1995 and '97 measured at the same time as the root length density in the 4 tillage systems (CT ♦——♦; TT ▲--------▲; ST ■-—-■; MT *- -— - -*).

Results and discussion

The variations of the soil moisture content (Figure 2), throughout the whole cropping cycle, in both years, were not statistically significant with the variation of the tillage system. It is worthwhile, however, to make few considerations on the trend during the two-year period.

At sowing, in both years, the tillage systems with less and more surface operations (ST and MT) had higher moisture content. In winter (2^{nd} measurement) and with a higher rainfall, the differences become null. Afterwards with the rise in temperature and a greater vegetative growth, the conventional tillage showed higher moisture values as compared to the other systems (135 and 117 days after sowing, respectively for 1995 and '97) At the end of the cycle the differences disappeared. Hence the moisture content increased from sowing till flowering, winter period characterized by higher rainfall; later on, with the temperature rise and the rainfall reduction, it decreased

similarly in the four tillage systems being compared.
The moisture distribution in the 0-60 cm soil profile, for the two measurements made at the same time as the observations on the root development, in both years, varied significantly between the conventional tillage (with the highest value) and the two- layer system (with the lowest value) only in the 1st measurement, at flowering, in the 21-40 cm layer (Figure 3).
The same pattern, although without statistical differences, was also observed in the deepest layer (41-60 cm). These differences disappeared shifting from flowering in late winter, that is usually rainy, to pod formation in late spring, characterized by a severe rainfall scarcity and high temperatures.

Table 1. Root lenght density of broad bean for year.

Year	**RLD ($cm\ cm^{-3}$)**	**SNK Grouping (§)**
1997	3.55	A
1995	2.06	A

(§) Means with the same letter are not significantly different for P≤0.05.

The differences of the mean annual values of RLD (Root Length Density) between the 2 years were not significant, although a higher value was observed in '97 as compared to '95 (Table 1). The RLD was statistically different between the 1st measurement, made at flowering (Table 2), when plants were in full vegetative growth, with a double root concentration as compared to the 2nd measurement, (pod formation) when plants had reached the maximum development and concentrated their activity in the accumulation of protein substances in seeds.

Table 2. Root lenght density of broad bean during the growing stage.

Growing stage	**RLD ($cm\ cm^{-3}$)**	**SD**	**SNK Grouping (§)**
Flowering	3.75	2.64	A
Pod Formation	1.87	1.55	B

(§) Means with the same letter are not significantly different for P≤0.05.

Tillage systems, although varying between each other in terms of number and depth of operations, have not affected the RLD significantly (Table 3). The trend was, however, decreasing shifting from the conventional tillage, with the highest value, to the surface, minimum and two-layer tillage.
Although the study on broad bean root development concerned the 0-60 cm profile, the

Table 3. Effect by tillage sistems on root lenght density of broad bean.

Tillage methods	**RLD ($cm\ cm^{-3}$)**	**SD**	**SNK Grouping (§)**
CT	3.28	2.72	A
ST	2.93	2.43	A
MT	2.52	2.22	A
TT	2.42	1.81	A

(§) Means with the same letter are not significantly different for P≤0.05.

highest root concentration was found between 0 and 30 cm (Tab. 4), therefore the analysis of results will be referred to this layer. The highest RLD concentration was observed in the two top layers 0-10 and 11-20 cm, with values similar to each other but statistically different from the 21-30 layer with the lowest value.

Table 4. Root lenght density of broad bean affected by depth.

Depth	**RLD ($cm\ cm^{-3}$)**	**SD**	**SNK Grouping** (§)
0-10	2.97	2.09	A
10-20	3.02	2.50	A
20-30	2.44	2.43	B

(§) Means with the same letter are not significantly different for P≤0.05.

As for tillage systems (Table 5), although in both vegetative stages a higher value was recorded in the conventional tillage, no significant differences were observed on root development. The same response was recorded along the profile in the interaction between tillage and the two vegetative stages (Table 6). Analysing the RLD distribution for each measurement in the two-year period (Figure 4), it may be observed that in 1995 at flowering the variability ranged from 2 to 4 $cm\ cm^{-3}$ along the whole profile. In the top layer it is the two-layer tillage that showed the lowest values as compared to the three other systems. In the 11-20 layer the minimum tillage showed an inverse trend with a reduction of RLD, similar to the TT that showed along the profile the lowest root density. The two other systems showed in all cases a greater and similar root development .

Table 5. Soil tillage and root lenght density of broad bean in each growing stage.

Tillage methods	**RLD ($cm\ cm^{-3}$)**	**SNK Grouping** (§)	**Growing stage**
CT	4.46	A	Flowering
ST	4.22	A	
MT	3.26	A	
TT	2.93	A	
CT	2.10	A	Pod Formation
TT	1.93	A	
MT	1.82	A	
ST	1.64	A	

(§) Means with the same letter are not significantly different for P≤0.05.

The same RLD pattern was also confirmed in the 21-30 layer for the four systems. Such differences disappeared when the plant had already completed the vegetative development; indeed at pod formation the values in the two deeper layers tended to overlap. In the first measurement of '97, at flowering, the root development was very similar in the four systems, with a similar trends as in '95, except a greater root density in the 11-20 layer in conventional tillage. During pod formation, in general, a decrease in RLD and a further reduction of the differences between different systems were observed. The conventional tillage kept the highest root density in the 11-20 layer.

Table 6. Manova test criteria and exact F statistics for the hypothesis of no growing stage * depth * tillage methods effect on root lenght density of broad bean.

Statistic	Value	F	Pr>F
Wilks' Lambda	0.6616	2.8291	0.0156
Pillai's Trace	0.3629	2.8085	0.0160
Hotelling-Lawley Trace	0.4741	2.8452	0.0153
Roy's Greatest Root	0.3750	4.7502	0.0066

In short, it possible to assert that with the conventional tillage there is a slight increase of the RLD, with small differences that do not justify more expensive and less environmentally sound tillage systems. Broad bean can develop a good rooting system also with a single surface tillage operation.

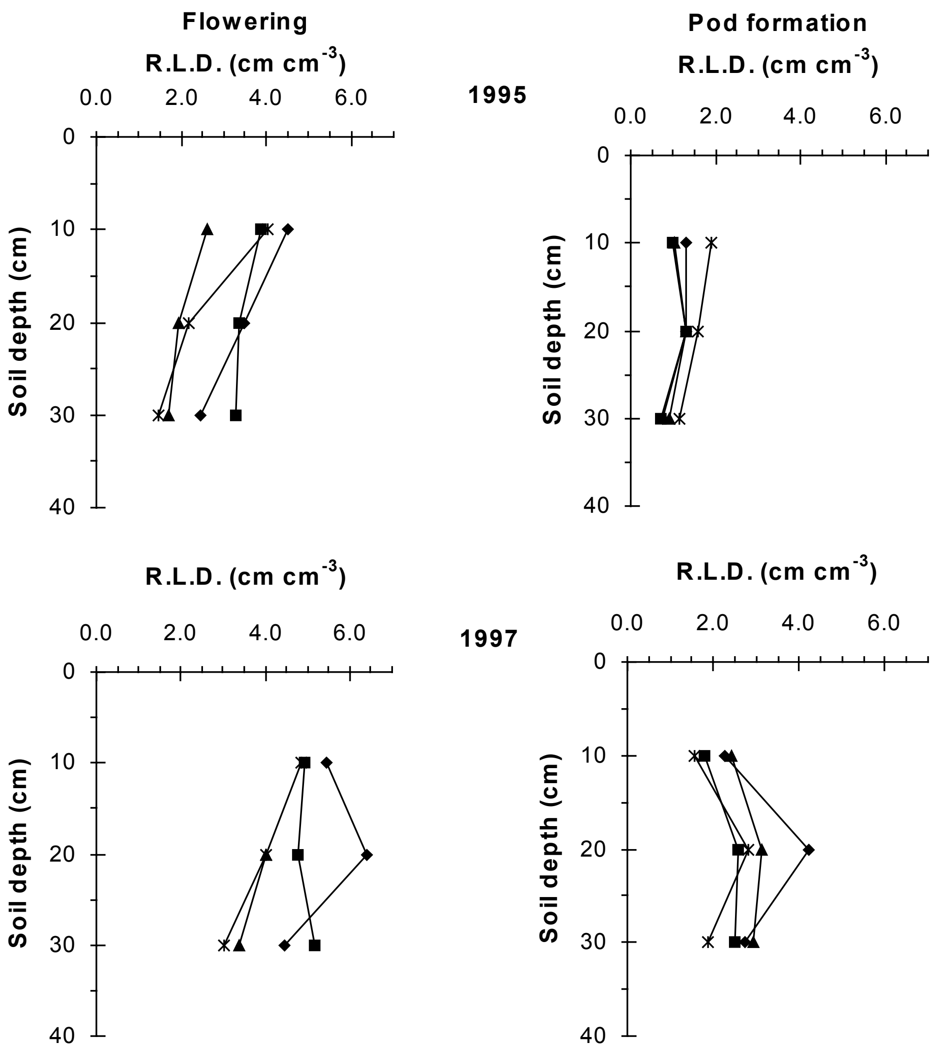

Figure 4. Root length density in the four tillage systems in relation to soil depth and growth stage (CT ♦——♦; TT ▲--------▲; ST ■- — -■; MT *- - — - -*).

Conclusions

These results, although showing some differences of root development, between tillage systems, are very important, because they point out that even when reducing the number and depth of operations, the broad bean rooting system can also adapt in minimum tillage soil, contrary to common agronomic belief, which holds that the broad bean requires seedbed preparation. Working the soil very deeply, even if only with a vertical cuts as per the two layer system, leads to a reduced level of in the soil and therefore less available water for the roots.

Therefore, using the broad bean more frequently in rotations, thanks to its well-known properties as a nitrogen nitrogen-fixing plant, may contribute to naturally enriching the soil with available nitrogen to the subsequent crop, such as soil depleting crops, like grasses.

The study of interaction between root development, agronomic techniques and the processes occurring in the rhizosphere in close contact with roots, can contribute, on one hand, to increasing our knowledge of root-soil interaction in different crops, submitted to less intensive cultivation techniques and on the other hand, to increasing natural fertility and reducing production costs.

References

Balesdent J., Chenu C., Balabane M., 2000. Relationship of soil organic matter dynamics to physical protection and tillage. Soil Till. Res., 53, 215-230.

Ball-Coelho B.R., Roy R.C.; Swanton C. J., 1998. Tillage alters corn root distribution in coarse-textured soil. Soil Till. Res., 45, 237-249.

Bottomley P.A., Rogers H.H. and Prior S.A., 1993. NMR imaging of root water distribution in intact *Vicia faba* L., plants in elevated atmospheric CO_2. Plant Cell Environ., 16, 335-338.

Castrignanò, A. Colucci, R., De Giorgio, D., Rizzo, V., 1997. Tillage Effects on plant extractable soil water in a silty clay vertisol in Southern Italy. Soil & Tillage Research, 40, 227-237.

De Giorgio D., Convertini G., Ferri D., Giglio L., La Cava P., 1998. Roots distribution, yield and protein content of broadbean (*Vicia faba* L. *maior*) treated with different tillage methods in Southern Italy. Proc. Improved Crop Quality by Nutrient Management. Bornova, Izmir (Turkey), 293-296.

Hernanz J. L., Giron V.S., Cerisola C., 1995. Long-term energy use and economic evaluation of three tillage systems for cereal and legume production in central Spain. Soil Til. Res., 35, 183-198.

Lal R., 1991. Soil structure and sustainability. J. Sustainable Agric., 1, 67-92.

Lewandowski I, Hardtlein M., Kaltschmitt, 1999. Sustainable crop production: definition and methodological approach for assessing and implementing sustainability. Crop Science, Vol. 39, 184-193.

Pietola L.M., Tanni R., 2003. Response of seedbed physical properties, soil N and cereal growth to peat apèplication during transition to conservation tillage. Soil Tillage Res. 74, 65-79.

SAS Institute Inc. SAS STAT User's Guide, Version 6.12. Cary, NC: SAS Institute Inc., 1998.

Soil Survey Staff, 1992. Keys of Soil Taxonomy Fifth ed. SMSS. Technical monograph n° 19. Blacksburg, Virginia (USA).

Upchurch, D.R., Ritchie, J.T., 1984. Root observation using to video recording system in mini-rhizotrons. Agron., J., 75, 1009-1015.

Upchurch, D.R., 1985. Relationship between observations minirhizotrons and the true root lenght density. PH.D. diss. Texsas Tsch Univ. (Diss. Abstr. 85-28594).

Young I. M., Ritz K., 2000. Tillage, habitat space and function of soil microbes. Soil Till. Res., 53, 201-213.

COMPARISON AMONG DIFFERENT AGRONOMIC TECHNIQUES IN A LONG TIME TRIAL ON ALMOND TREES CARRIED OUT IN A MEDITERRANEAN AREA

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Abstract

This paper report results obtained in a long-term experimental trial on the comparison among agronomical practices (soil tillages, weed control and green manure). In 1976 a study on almond trees (cv. "*Filippo Ceo*") was started with the aim of comparing three "no tillage" treatments with different weeds control methods (chemical control on sprouting weeds; weeds cutting and green mulching; chemical drying and mulching of weeds) ploughing under of broad bean plant (*Vicia Faba,* L. *minor* Beck.) and conventional soil tillage with plough and harrow. The trial was made, without irrigation, in an area near Bari (southern Italy).
Every year in experimental plots with chemical and mechanical weeds control an average of 3.4 t ha^{-1} (as d.m.) of crop residues were left on the surface, while 4.0 t ha^{-1} (as d.m.) of crop residues were incorporated in the soil in green manured plots.
After 25 years of repeated treatments, soil layers from between 0 and 30 cm were sampled. The chemical composition of the soil was determined as mineral N composition ($N\text{-}NO_3$ and $N\text{-}NH_4$), organic C (total, extracted and humidified), $NaHCO_3$–P (Olsen method), NH_4Ac–K, pH, lime, E.C.C. Different treatment modified the chemical properties showing of the soil, the incorporation of broad bean in the soil improved N mineralization because microbial biomass activity increased, in comparison to other "conservative" treatments. On the other hand, the green manured and mulched plots showed the highest contents of total C in the soil, C/N ratio, rate and degree of humidification.

Key words: soil tillage, weeds control, almond, soil chemical characteristics

Introduction

In southern Italy, particularly in the Apulia region, the almond tree (*Prunus amygdalus* Batsch) is one of the oldest and most traditional crops.
The recent UE guidelines to valorize typical products of the mediterranean areas characterized by low income seem to modify the agricultural activities concerning almond tree crops; a better typification of Apulian almond trees (De Giorgio and Stelluti, 1995; De Giorgio et. al., 1996a, 1996b; Ferri et al., 1996) can be obtained through agronomical interventions wich can reduce productive on costs and contemporarily conserve soil fertility.
Even if the selection of agronomical interventions is not easy, because there are numerous interacting factors that interact, like those of economic, environmental and edaphyc nature, the "no-tillage" method determines the best compromise between productivity and conservation of soil fertility because it is less invasive than traditional soil tillages (Carter, 1991).
Some problems result from the necessity of controlling weeds that subtract water and nutrients from the soil in minimum-tilled plots and lead to negative variations in soil fertility.

In fact, the presence, the amount and the typology of crop biomass and the various treatments used (chemical control on sprouting weeds; weeds cutting and green mulching; chemical drying and mulching of weeds) are the main factors that determine variations in biochemical transformations of many elements biogenics like C, N, P, S (Dommergues and Mangenot, 1970; Nannipieri, 1984; Streeter, 1987). The carbon cycle, that includes processes of synthesis of organic molecules and mineralization, can be modified in function of the chemical nature of the organic matter of the soil. The nitrogen cycle, is strictly related to the carbon one; in fact the processes of N_2 fixation, ammonification and nitrification (Nuti and Lepidi, 1985, Haynes, 1986) depend on the transformations of soil organic matter. Moreover, when a layer of vegetable material is accumulated on the surface, it can cause shapes of immobilization of mineral N with reduction of nitrification, denitrification and leaching (Gosz and Fischer, 1984). As a consequence of soil tillage and weeds control practices on soil fertility variations, almond yields and productivity can vary (De Giorgio and Macchia, 1989). In this study the effects of soil tillage and weed control were examined, observed after twelve years on almond yields, productivity and soil fertility in experimental crop field of almond trees in southern Italy (Apulia region).

Materials and methods

Experimental site

The research was carried out in the experimental field of almond tree germplasm of the Institute, that comprises 205 cv of various origin (domestic, new constitutions and foreign) located in Bitetto (BA) southern Italy, 126 m above sea level.

The climate is “mesothermomediterranean accentuated” with a xerothermic index of 75–100 days. The monthly averages of air temperatures vary from 7–8°C in winter to 20–30°C (with peaks of 35–40°C) during the summer. In Figure 1 the average monthly precipitation, potential evapotranspiration and half potential evapotranspiration of the experimental farm are presented. The site is classified as semiarid by the aridity index (0.20 < P/ETP < 0.50) and by the FAO growing period classification (the average monthly precipitation exceeds 0.5 ETP for 100 days). The last 24-year period has been characterized by an yearly average precipitation of 446 mm.

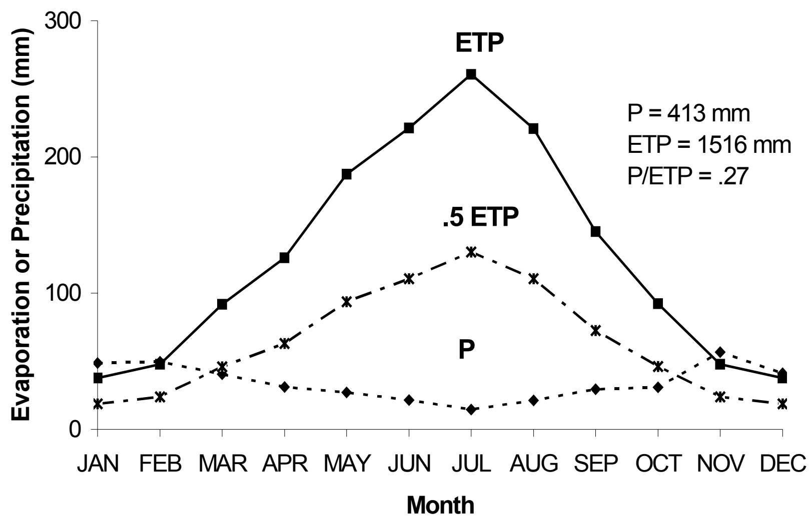

Figure 1. Average monthly precipitacion, potential and halh potential evapotranspiration of experimental farm.

The experimental field consists of a predominantly flat surface with an arable layer of 30 cm of red, mainly loamy, soil on the compact calcareous rock of the Cretaceous period ("rupthyc-lithic" soil, denominated Rodoxeralf according to the USDA Soil Taxonomy classification).

Material and methods

In 1976 a study was started on experimental design arranged as randomized blocks with 5 replications, (elementary plots of 3 "Filippo Ceo" almond trees with distance of 7x7m), with the following treatments: A) no tillage with chemical control (pre-emergence weeding) at sprouting stage; B) no tillage with weeds cutting and green mulching; C) no tillage with chemical drying and mulching of weeds; D) ploughing under of broadbean (*Vicia Faba,* L. *minor* Beck.); E) conventional soil tillage with plough and harrow.
In plot A, treated with 4 different active principles were used in the early years have been used, until 1990, changing product every 4 years (Bromacile, Propyzamide + Simazina, 2.6 Dichlorenil tiobezamide, Chlorprophandiuron). Afterwards due to the withdrawl from the marchet of commerce of some of these products a pre-emergence weeding with gliphosphate (10%) + oxadyazyon (20%) was carried out.
In treatments B and C the plots were left with spontaneous herbaceous species and hal-fway trough spring the weeds were cutt and mulched (B), or chemically dried (C).Treatment D mean while broadbean was sowed in autumn and at the moment of the flowering in spring was ploughed under. The plots with conventional tillage ("E"–treatment) were plowhed 3 to 4 times every year depth of 20–25 cm to ensure good weed control. In the treatments B, C and D, before carrying out green manuring or mulching treatments, some plants were removed from 2 m^2 area in order to determine biomass production as d.m., respectively of 3.4 and 3.2 t ha^{-1} as averages of the fifteen years of three treatments.
Starting from the tenth year after grafting, the phenological, bioagronomic and productive characteristics were observed and some of these were reported: kernel yield (kg $tree^{-1}$), shelling percentage (%), nut and kernel weights (g), double kernels (%). Shelling percentage, double kernels, nuts and kernel weight were evaluated on a sample of one kilogram of in-shell almonds for each plot.
The depth of sampling comprised between 0 and 40 cm is relative to the arable land layer.
On soil samples the total organic carbon -TOC, and extracted-TEC, N-NO_3, N-NH_4, C/N, $NaHCO_3$-P , NH_4Ac-K, pH, active limestone and C.S.C. were determined.
From the determinations of TOC, TEC and humified matter the following coefficients were calculated: 1) Degree of humification =DH% = C[HA + FA]/TEC*100; 2) Rate of humification = HR% =C[HA + FA]/TOC*100; 3) Organic Carbon extracted and not humified = NH= TEC - C[HA+FA C]; 4) Index of humification = HI = NH / C[HA +FA].
In order to estimate the significance of the differences between the averages it has been used the Duncan Multiple Range Tes has been usedt.
The principal methods of soil analysis were: **1**–Moisture content: Dry overnight at 105 °C. **2**–Total Nitrogen: Kjeldahl procedure modified. **3**–Available Nitrogen: Determination of soil N-NO_3, N-NH_4 by automatic colorimetric method after the extraction through 1 M KCl. **4**–Phosphorus soluble in sodium bicarbonate: According to Olsen et al., 1982. Phosphate in the extract is determined colorimetrically (at 640 nm). **5**–Exchangeable bases: Ammonium acetate (pH=7) method. **6**–Total organic Carbon: a) Walkley Black; b)Springer Klee. **7**–Organic carbon extracted and humified: According to Sequi et al., 1986.

Result and discussion

Among the treatments (Table 1), maximum kernel yield was observed in the A-treated plots. On the contrary, least kernel yields were recorded in B-treated plots, while the plots chemically dried (C), ploughed under with broadbean (D) and conventional tilled (Control - E), statistically undifferentiated, presented intermediated values of kernel yield. The shelling percentage observed (as average) on A - treated plots seems higher than the shelling

Table 1. **Effects of the treatments on yield and carpological characteristics of the almonds in trial period (fifteen years).**

Treatments	Kernel yield (kg tree^{-1})	Shelling percent. (%)	Weight (g) Nut	Weight (g) Kernel	Double kernels (%)
A	**2.67 a**$^{(*)}$	**36.96 a**	**4.21 a**	**1.51 a**	**18.45 a**
B	**1.49 c**	**35.80 ab**	**4.04 a**	**1.43 a**	**17.08 a**
C	**2.13 b**	**35.35 b**	**4.01 a**	**1.41 a**	**16.91 a**
D	**2.05 b**	**35.97 bc**	**3.97 a**	**1.42 a**	**14.03 a**
E	**2.25 b**	**36.02 ab**	**4.04 a**	**1.45 a**	**15.97 a**

$^{(*)}$ The values with different letters are significantly different per P<0.05 (DMRT test).

percentage obtained only on C - and D-treated plots.
The interpretation of the best response (as kernel yield) at "A" treatment (no-tillage with sprouting weeds) is not very easy because two experimental treatments could interact (i.e.: no-tillage and weeding at sprouting stage) and where is a best utilization of available water, that is very low. In mulched (B) or chemically dried (C) treated plots doesn't observe significant differences in comparison to conventional tilled plots (E): for consequence also the best agronomical response observed in "A" treated plots probably could be independent from tillage treatment. On the other hand appears very significant the influence of weeding at sprouting stage; in fact, in the plots where the weeds were cutted and mulched (B) or chemically dried (C) or green manured with broadbean (D) there is a competition among the weeds or leguminous species and almond trees on plant uptake of soil water and nutrients (very poor in this environment).

Table 2. Effects of the treatments on total organic, extracted, humified and not organic Carbon after the trial period .

Treatments	TOC (g kg^{-1} soil)	TEC (g kg^{-1} soil)	C (HA+FA) (g kg^{-1} soil)	NH (g kg^{-1} soil)	C/N
A	12.67 c$^{(*)}$	8.78 c	3.18 b	5.71 b	8.5
B	18.89 a	14.04 a	4.87 a	9.36 a	26.2
C	17.31 b	10.36 b	3.71 b	6.68 b	18.9
D	19.20 a	10.19 b	5.12 a	5.12 b	22.3
E	12.97 c	13.24 ab	2.72 b	9.84 a	68.3

$^{(*)}$ The values with different letters are significantly different per P<0.05 (DMRT test) in each column.

The main chemical characteristics of the experimental plots are reported in Table 2. In the green manured plots (D) the contents of total and organic N (difference between total and mineral N) are lowest in front of C/N ratios (Table 3). In these plots, the mineralization of organic N prevailed on N-immobilization process in that was incorporated in the soil fresh crop biomass constituted from easy decomposable organic fractions with low contents of lignin. Soil total and mineral N contents is almost the half compared to the control (E); this is probably due to the nitrifiers activity on N contained in the fresh biomass introduced and soil N native.

Table 3. Effects of the treatments on degree, rate and index of humification after the trial period.

Treatments	DH	HR	HI
	%		
A	38.31	26.51	1.80
B	34.00	29.82	2.10
C	36.80	28.40	1.89
D	58.00	29.30	1.09
E	23.68	23.04	3.74

In the chemically dried (C) plots intermediate N contents values were observed. The green mulched plots (B) and early weeding treated (A) show the same contents in organic N, but a great significant difference on total and mineral N. This last one in fact is much more elevated in A- than in B-treated plots probably because the selective action of the weeding at sprouting stage on some plants reduces the absorption of nitrates and ammonium from the soil, that accumulated in the soil arable layer in greater measure that in B-plots, in which the plants are cutted after a longer period of activity of root apparatus.

The soil content of $NaHCO_3$-P (Olsen) is more elevated in the control plots. With all the other treatments a greater plant uptake of phosphate and consequently, a lower P content in the soil.

K and Mg contents of D-treated plots are significantly lower than the control for a better nutrients uptake efficiency from the plants determined by the green manuring in “D”-plots.

In Tables 3 and 4 are reported the results for organic C and humification parameters. The total organic carbon (TOC) is maximum in “B” and “D” plots, intermediate in “C”; minimum in “A” and “E”, because TOC is influenced from the addition to the soil of organic substances through broadbean green manuring (D) or green mulching (B).

The extractable organic carbon (TEC) results more elevated only in the plots treated with “B”, similar values were recorded also for “C” and “D”. Finally, it must be remarked minimal value found in “A”. Such results seem to confirm that the TEC is essentially conditioned by the organic material incorporated in the soil (B = green mulching) that it is different from A (early weeding). B and D plots show C(HA+FA) contents statistically more elevated, in comparison with other plots.

This proves that the addition to the soil of organic material induces also an increase of humified substances. It is very interesting to observe that green manuring (D) or mulching (B) the soil was increased humified C, that reachs values 2-times higher than data recorded in control plots (E). On the contrary, the amount of not-humified C (NH) is lowest in “D” but elevated whether in control (E) and mulched (B) plots. The difference in "NH" contents between the treatments “D“ and “B” could be depending from different evolution of distributed organic material.

Table 4. **Soil fertility variations of plots differently treated.**

		Treatments				
		A	B	C	D	E
Total N (%)		**0.199 a(*)**	**0.085 b**	**0.118 a**	**0.036 b**	**0.200 a**
$N\text{-}NO_3$	(mg kg^{-1})	**3.39 a**	**0.63 c**	**0.64 c**	**0.60 c**	**1.80 b**
$N\text{-}NH_4$ exch.	(mg kg^{-1})	**2.76 a**	**0.52 c**	**0.53 c**	**0.51c**	**1.50 b**
$NaHCO_3$-P	(mg kg^{-1})	**162 c**	**201 c**	**226 c**	**329 b**	**558 a**
NH_4Ac-K	(mg kg^{-1})	**313 b**	**575 a**	**391 b**	**290 b**	**518 a**
NH_4Ac-Na	(mg kg^{-1})	**74.8 a**	**55.9 b**	**58.6 b**	**72.5 a**	**50.8 b**
NH_4Ac-Ca	(mg kg^{-1})	**2974 b**	**3402 b**	**3438 b**	**3498 b**	**4201 a**
NH_4Ac-Mg	(mg kg^{-1})	**357 b**	**402 a**	**347 b**	**251 c**	**344 b**
pH (H_2O)		**7.80**	**7.76**	**7.56**	**7.70**	**7.86**
Total limestone (%)		**tracks**	**tracks**	**tracks**	**tracks**	**tracks**
ECC (meq 100g^{-1} soil)		**29.88**	**31.02**	**29.98**	**33.80**	**30.18**

(*) The values with different letters are significantly different per P<0.05 (DMRT test) in each line.

The evaluation of humification parameters (Table 4) confirms that the degree and the rate of soil humification have been influenced by the addition of fresh biomass for 24 years, in fact, the plots green manured (D) show degree and rate of humification more elevated than plots differently treated. These results show that the organic fertilization carried out with fresh plant biomass incorporated in the soil not only enriches soil organic matter but modify also its rhythms of humification and/or decomposition, increasing after all the stable humus that, in determined agronomic and micrometeorological conditions, improve the physical property of the soil, the water scheduling, the air-soil ratio, the habitat of microflora and microfauna, it favors the enzymatic activities and it improves also soil nutritional state (Sequi, 1989).

Conclusions

The agronomical practices of “no-tillage” and “weeding at sprouting stage” show the best results on almond yield and shelling percentage, but certainly this positive response depends mainly on weed elimination. As a conclusion in a typical area of the Apulia region in southern Italy no-tillage shows a high efficiency on crop performances only when the weeding is carried out in pre-emergence because the aridity index is very high.
N soil dynamics are affected by differing green biomass treatments; green manured plots contain the lowest contents of organic N because the introduction into the soil of green crop residues with high C/N ratio determines high mineralization of soil N. On the other hand high soil mineral N contents recorded in “A”-treated plots confirm that when is absent the

competition of weeds or other species with the root systems of almond trees, is absent soil nutritional status improves and also yield responses increase.
The variations recorded on available soil phosphate and exchangeable K and Mg seem to indicate the importance of organic material incorporated in the soil: the mobilization and the absorption of soil phosphate, K and Mg increased; moreover this positive effect is poor on almond yield performances, probably because almond tree roots are developed at depth.
Finally the results obtained on soil organic matter variations clearly show that total organic C and humified C increase when green manuring or mulching were carried out; on the other hand a more elevated degree and rate of humification were observed in conventional tillage plots. By varying the speed of soil C humification (through crop residues added to the soil) organic matter turnover was modified long-term soil fertility was protected, but in semiarid areas with very thin shallow soil horizon, agronomical benefits on almond yields, in comparison to drastically treated plots to eliminate the weeds could be not observed.

References

Carter, M.R., 1991. Evaluation of shallow tillage for spring cereals on fine sandy loam. 1. Growth and yield component, N accumulation and tillage economics. Soil Till. Res.,21, 23-35.

De Giorgio, D., Macchia, M., 1989. A twelve years comparison among different methods of tillage control on almond trees grown in a typical of Sothern Italy. Ann. Ist. Sper. Agron., 20, 67-80.

De Giorgio, D., Stelluti, M., 1995. Evalutation of germoplasm collection of almond (Prunus Amygdalus Batsch) through a multivariate analysis. Agricoltura Mediterranea, vol. 125, 329-340.

De Giorgio, D., Stelluti, M., Macchia, M., Lanza, F., 1996. Phenological and productive evaluation on 205 almond tree cultivars during sixteen years of cropping. Agricoltura Ricerca, XVII, n. 162, 3-54.

De Giorgio, D., Macchia, M., Stelluti, M., Lanza, F., 1996. Collection of 205 almond tree cultivars in “seedling rootstocks” field of Istituto Sperimentale Agronomico (BA) descriptive monograph. Agricoltura Ricerca, XVII, n. 162, 55-161.

Ferri, D., Convertini, G., Stelluti, M., Perniola, M., De Giorgio, D., 1996.Three years investigation on biochemical parameters of almond kernels in Southern Italy. Agricoltura Ricerca, XVII, n. 162, 163-184.

Dommergues, Y., Mangenot, F., 1970. Ecologie microbienne du sol. Ed. Masson et. C. ie., pp., 92-289.

Gosz, J.R. and Fischer, F.M., (1984). Influence on selected processes in forest soils. In:”Current perspective in microbial ecology”, M.J. Klug and C.A. Reddy Eds.., Amer.Soc. Microbiol. Publ. pp. 509-530.

Haynes, R.J., 1986. Mineral nitrogen in the plant-soil system. Academic Press, pp.483.

Nannipieri, 1984. Microbiol biomass and activity measurements in soil; ecological significance. M.J. Klug and C.A. Reddy Eds., Amer. Soc. Microbiol., Washington, pp. 515-521.

Streeter, J., 1987. Carbon metabolism and the exchange of metabolites between symbionts in legum nodules. In "Symbiotic nitrogen fixation", F. O'Gara and J.J.Decrevon Eds. In press.

Sequi, P., 1989. Chimica del suolo. Patron Editore.

EFFECT OF DIFFERENT SOIL TILLAGE AND STRAW MANAGEMENT ON NITRATE NITROGEN DYNAMICS IN SOIL PROFILE UNDER WINTER WHEAT IN YEARS 1998 - 2004

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Abstract
In the years 1998 - 2004 the nitrate nitrogen dynamics was studied in the soil profile of the field experiment with winter wheat and with two soil tillage variants and different straw management. The field experiment was established in 1997 in Žabčice (maize-growing region, 184 m above sea level, mean annual temperature 9.2°C, mean annual sum precipitation 483 mm, heavy gleic fluvisol FM_G). On the average over all straw management variants $N\text{-}NO_3^-$ value was higher in the soil tillage with ploughing (i.e. 25.2 mg $N\text{-}NO_3^-.kg^{-1}$) than in the soil tillage with direct seeding (i.e. 22.3 mg $N\text{-}NO_3^-.kg^{-1}$). On the average over all years the effect of different straw management on the soil $N\text{-}NO_3^-$ dynamics differed in dependence on the soil tillage variants. During autumn months $N\text{-}NO_3^-$ value was higher on the soil tillage with ploughing and in other studied months the order of tillage variants was different.

Keywords:
soil tillage, straw management, nitrate nitrogen, winter wheat

Material and methods

In the years 1998 - 2004 the nitrate nitrogen dynamics (further only $N\text{-}NO_3^-$) was studied in the soil profile of the field experiment with winter wheat and with two soil tillage variants and different straw management. The field experiment was established by Department of Agrosystems and Bioclimatology of MUAF in Brno in year 1997 in maize-growing region in Žabčice (184 m above sea level, mean annual temperature 9.2°C, mean annual precipitation sum 483 mm, heavy gleic fluvisol FM_G, neutral pH, humus content in topsoil 2.5 % and content of available phosphor and potassium good. The combination of the following experiment variants were evaluated:
- the soil tillage variants:
I. stubble breaking (0.10 - 0.12 m) + ploughing (0.24 m),
II. stubble breaking (0.10 - 0.12 m) + direct seeding;
- the straw management variants:
1. straw harvested,
2. straw incorporated into soil (5 $t.ha^{-1}$) + BETA-LIQ (i.e. liquid molasses-based organomineral fertiliser),
3. straw incorporated into soil (5 $t.ha^{-1}$) + liquid manure,
4. straw incorporated into soil (5 $t.ha^{-1}$) + DAM 390 (i.e. liquid nitrogen fertiliser with nitrate, ammonium and organic form of nitrogen),
5. straw incorporated into soil (5 $t.ha^{-1}$) + $(NH_4)_2SO_4$ (i.e. solid nitrogen fertiliser with ammonium form of nitrogen).

Soil samples were taken during autumn in October and November and in the following vegetation period during spring in March, April, May and June from 0 - 0.3 m soil depth. Fresh soil samples were used to $N\text{-}NO_3^-$ analyse using ion selective electrodes.

CONTENTS

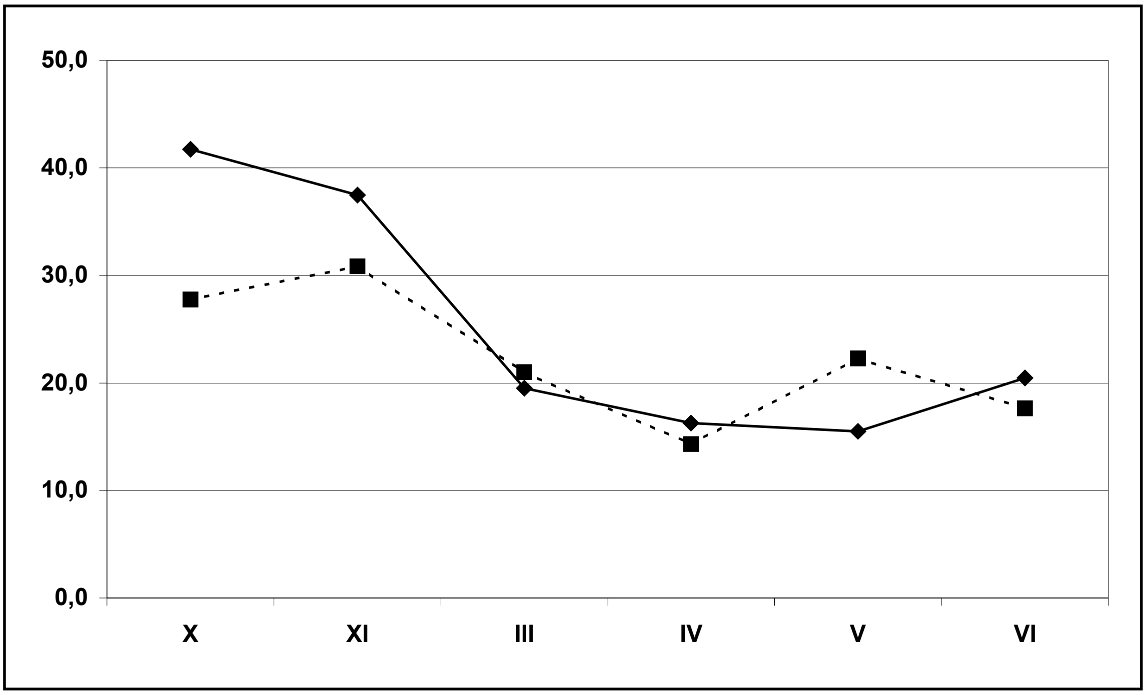
Results

On the average over all experiment years the effect of different straw management on the soil $N\text{-}NO_3^-$ dynamics differed in dependence on the soil tillage variants (Fig. 1). On the average over all straw management variants $N\text{-}NO_3^-$ value was higher in the soil tillage variant with ploughing (i.e. 25.2 mg $N\text{-}NO_3^-.kg^{-1}$) than in the soil tillage variant with direct seeding (i.e. 22.3 mg $N\text{-}NO_3^-.kg^{-1}$). Fig. 1 is showing that in October and November higher $N\text{-}NO_3^-$ value were measured in the samples of the soil tillage variant with ploughing. It is probably influenced by the prosperous conditions for the soil nitrifying processes in this variant. But on the other hand it may be the risk for environment in this autumn period when the fields are blank or growing crops are small. In March and April $N\text{-}NO_3^-$ values from both tillage variants were similar. In the next months, May and June, $N\text{-}NO_3^-$ values were depending in the each soil tillage variant. The interest is the fact that during spring months there wasn´t any expressive elevation of $N\text{-}NO_3^-$ values in the soil tillage variant with ploughing. It is clearly influenced by the dry spring in years 2000 and 2001 (in these weather conditions better status for soil processes can be apparent on the soil tillage variant with direct seeding) or by the another respect, when the function of the soil processes clearly come in delay in this soil tillage variant with direct seeding.

Conclusions

The $N\text{-}NO_3^-$ value during autumn months achieved expectant dynamics of the nitrifying processes that were probably influenced by the prosperous conditions in the soil tillage variant with ploughing. By contraries in the spring months in this soil tillage variant there wasn´t any expressive elevation of $N\text{-}NO_3^-$ values on the average over straw management variants contrary to values of the soil tillage variant with direct seeding.

Figure 1
The dynamics of $N\text{-}NO_3^-$ values on the average over all straw management variants in the soil depth 0 – 0.3 m under winter wheat in the field experiment in Žabčice in years 1998 – 2004.
Axis: x – studied months; y – $N\text{-}NO_3^-$ (mg.kg^{-1}).
Soil tillage variant: stubble breaking + ploughing — ; stubble breaking + direct seeding ----.



References

BIELEK, P. *Dusík v pôde a jeho premeny*. MPHV SSR, 1984, 135 s.

BÍZIK, J., BALOGH, Z. Pohyb a akumulácia anorganického dusíka v hnedozemi. *Rostlinná výroba (Plant Production),* 1994, 40, 10, s. 877–887.

BLOEM, J., et al. Dynamics of microorganisms, microbivores and nitrogen mineralisation in winter wheat fields under conventional and integrated management. *Agriculture, Ecosystems and Environment,* 1994, 51, p. 129-143.

HABERLE, J., SVOBODA, P., KREJČOVÁ, J. Mineral nitrogen content in soil profile and nitrogen accumulation in winter wheat crop. *Rostlinná výroba (Plant Production),* 1997, 43, 10, s. 473-479.

STENBERG, M., et al. Soil mineral nitrogen and nitrate leaching losses in soil tillage systems combined with a catch crop. *Soil and Tillage Research,* 1999, 50, p. 115-125.

VANĚK, V., NĚMEČEK, R., NAJMANOVÁ, J. The effect of site and way of management on the content of mineral and mineralizablenitrogen in soils. *Rostlinná výroba (Plant Production)*, 1997, 43, 10, s. 463–471.

VANĚK, V., ŠILHA, J., NĚMEČEK, R. The level of soil nitrate content at different management of organic fertilizers application. *Plant, Soil and Environment,* 2003, 49, 5, p. 197-202.

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THE NDVI HANDHELD SENSOR TO CHARACTERIZE MAIZE/WHEAT CROP GROWTH UNDER DIFFERENT TILLAGE AND RESIDUE MANAGEMENT

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Introduction

Rainfed cropping predominates agriculture in the altiplano of central Mexico, with rainfall (350-800 mm) occurring during a 4-6 month summer period, followed by dry, frosty winters. Crops, dominated by maize (*Zea mays* L.) but also including beans (*Phaseolus vulgaris* L.), wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.) and potato (*Solanum tuberosum* L.) are planted at or just before the onset of the summer rains. Most rain events are intense afternoon storms with significant dry spells during the cropping season. The soil is bare for much of the year, with all crop residues removed for fodder, grazed and/or burned. Fields are tilled frequently, using mainly small, tractor-drawn disc plows/harrows and field cultivators. Sloping fields, heavy tillage and lack of ground cover lead to extensive erosion and run-off, resulting in loss of water and production potential (Sayre et al., 2001; Fischer et al., 2002). Modest fertilizer use is practised but cereal grain yields are low (< 3 t/ha), crops are often weedy and nitrogen deficient, soil structure is poor and sheet and gully erosion are widespread (Bravo-Espinoza et al., 1993).

A number of technical innovations have been suggested to improve the productivity and sustainability of subtropical highland cropping systems. Crop rotations can break soil pathogen cycles and reduce weed pressure (Karlen et al., 1994), and reduced tillage practices combined with crop residue retention on the soil surface can increase moisture infiltration (Azooz and Arshad, 1996; Shaver et al., 2002), reduce erosion and increase water use efficiency (McGarry, 2002). Crop residues accumulating on the soil surface form a barrier to water loss by evaporation, decrease soil temperatures. More stable soil aggregate structure is present under zero tillage (ZT), compared to conventional tillage (CT) (Elliott and Efetha, 1999).

In this paper we report results from research done in a long-term trial set up in 1991 by CIMMYT. The objective of the long-term trial was to identify practices that would provide high and stable yields for wheat and maize in the target environment. In order to understand and evaluate cropping systems, crop performance over time is a crucial factor. Plant growth and plant performance, resulting in grain yield, can be considered as the optimal integrated evaluation of the soil-water-air complex as influenced by management practices. The objective of this study was to assess crop growth under contrasting tillage and crop residue management throughout the growing season to supplement normal post-season yield evaluation; and to evaluate the NDVI-handheld sensor (GreenSeeker™ Hand Held Optical Sensor Unit NTech Industries, Inc.) as a tool for crop monitoring.

Material and Methods

The experimental station is situated in the semi-arid, subtropical highlands of Central Mexico. The station has monthly average temperatures between 17.5 ^{o}C and 12.5 ^{o}C, with an average annual rainfall of 600 mm, 520 mm of which comes during the growing season (May-October). Short, intense rain showers followed by dry spells typify the rainy season, and evapotranspiration exceeds rainfall throughout the year (total amount of annual potential evapotranspiration is 1,900 mm). Soil is a Cumulic Phaeozem. Located in the area of the former lake of Texcoco, State of Mexico, Mexico, the station's soil has good chemical and physical conditions for farming. The major limitations are periodic drought, periodical water excess and wind and water erosion.

The experimental design consisted of a randomized complete block with two replications. The 32 treatments used comprised varied wheat-maize crop rotations, tillage/planting methods and crop residue management, of which only 16 are considered in this research. Crop treatments included continuous wheat, continuous maize and rotation of wheat and maize. Residue was either kept on the field or removed for fodder. Retained residues were incorporated under the conventional tillage treatment (CT), or left on the flat if no tillage was done (ZT). Individual plot measures were 7.5 m by 22 m. Maize was planted at 60,000 plants/ha in 75 cm rows and wheat in 20 cm rows at 100 kg seed/ha. Both crops were fertilized at the rate of 120 kg N/ha, using NH4NO3 or urea depending on availability, with all N applied to wheat (broadcast) at the 1st node growth stage and to maize (surface-banded) at the 5-6 leaf stage. Weed control used appropriate, available herbicides as needed, and no disease or insect pest controls were utilized. The planting of both maize and wheat depended on the onset of summer rains but was usually done between June 5 and 15.

A GreenSeeker™ Hand Held Optical Sensor Unit (NTech Industries, Inc.) was used to collect normalized difference vegetative index (NDVI) measurements. This device uses a patented technique to measure crop reflectance and to calculate NDVI. The unit senses a 0.6 x 0.01 m spot when held at a distance of approximately 0.6 to 1.0 m from the illuminated surface. The sensed dimensions remain approximately constant over the height range of the sensor. The sensor unit has self-contained illumination in both the red (650 ± 10 nm full width half magnitude (FWHM)) and NIR (770 ± 15 nm FWHM) bands. The device measures the fraction of the emitted light in the sensed area, which is returned to the sensor (reflectance). These fractions are used within the sensor to compute NDVI according to the following formula:

$$NDVI = (NIR - VIS) / (NIR + VIS)$$

Where NIR is the fraction of emitted NIR radiation returned from the sensed area (reflectance), VIS is the fraction of emitted visible red radiation returned from the sensed area (reflectance). The sensor samples at a very high rate (approximately 1000 measurements per second) and averages measurements between outputs. The sensor outputs NDVI at a rate of 10 readings per second. The sensor was passed over the crop at a height of approximately 0.9 m above the crop canopy and oriented so that the 0.6 m sensed width was perpendicular to the row and centered over the row. With advancing stage of growth, sensor height above the ground increased proportionally. Travel velocities were at a slow walking speed of approximately 0.5 m/s, resulting in NDVI readings averaged over distances of < 0.05 m.

The experiment was analyzed as a randomized complete block design with the PROC GLM procedure (SAS Institute, 1994), wheat and maize considered separately with factorial combination of rotation, tillage, and straw management. Variables were further explored under principal component analysis (PCA) (SAS Institute, 1994).

Results and discussion

Correlation between within season crop NDVI and final yield/biomass

The highest correlations between NDVI and final grain yield were obtained for wheat (R= 0.87; P= 0.01) 17 days after flowering (85 days after planting) and for maize (R= 0.56; P= 0.05) 40 days after emergence (51 days after planting) (Table 1 & 2). These correlations are promising especially for wheat. For maize correlations are not as high as expected. The rainfall pattern in 2003 resulted in severe incidence of *Helminthosporium turcicum* leaf blight in maize at the end of the crop cycle. Since, the CIMMYT hybrid used in the trial was susceptible, it became heavily infected. NDVI was measured in the middle of the crop season and indicated a high yield potential for certain treatments, while especially those high yielding treatments suffered most from severe disease incidence with detrimental effects on yield at the end of the cycle. This explains the low correlation for maize. Moreover, more research should be conducted to determine what stage of the crop cycle is optimal for measuring NDVI in maize.

Growth curves

For all treatments the average NDVI value was plotted against time. NDVI values gradually increased with time until a maximum was reached before starting to decrease (Fig. 1 & 2). NDVI measurements provide a representation of a canopy expansion and senescence curve for wheat and maize. Scotford and Miller (2004) found comparable results for winter wheat and Mandal et al. (2003) for wheat grown after transplanted rice. The obtained plant growth curves (GC) were characterized by 2 parameters: slope of the initial increase and the maximum value of the GC. Maximum and slope for wheat treatments are given in Table 3. Wheat grown under ZT with residue retention had a significantly greater GC slope (0.0296; 0.0315) compared to CT with residue retention and in ration with maize (0.0216), while the maximum was equal. ZT with rotation and residue removal had a significant lower NDVI maximum and slope compared to all other treatments. Residue retention resulted in a significant higher slope and higher maximum compared to residue removal. Wheat sown under ZT with residue retention is characterized by a slow take off of the crop, but this is totally compensated by increased crop performance in the later stages, with a more crucial influence on final grain yield. Rotation with maize decreased the maximum of the GC. Rotation of wheat with maize had a slightly negative influence on wheat growth compared to mono cropped wheat.

Differences in GC between treatments for maize were even clearer and more outspoken (Fig. 2; Table 3). The GC of ZT with residue retention and rotation with wheat was characterized by an increased slope and NDVI maximum (slope GC= 0.0482, maximum GC= 0.8540), compared to CT (slope GC= 0.0375; maximum GC= 0.8465). ZT without residue retention showed low maize NDVI throughout the season and a low GC slope especially with continuous maize (maximum GC= 0.7064; slope GC= 0.0190). ZT with residue retention increased as well slope as maximum of the GC compared to CT, as did residue retention compared to residue removal. Rotation significantly increased the maximum of the growth curve compared to continuous maize. Maize benefits from rotation with wheat. Also maize sown under ZT with residue retention is characterized by a slow take off but compensated in the later stages. Rotation with wheat influences maize growth positively. Wheat seems to act as a 'giver' towards maize, while maize can be considered as a 'taker'.

Principal component analysis (PCA) of the different NDVI measurements of maize grouped the NDVI measurements of the initial growth stages (29, 35, 51 days after planting) in the first principal component, whereas the second PC grouped those measured during the later stages of the crop (67, 74, 81 days after planting). The bi-plot of the PCA (Fig. 3) showed a grouping of all treatments into 3 clusters: ZT with residue retention, ZT with residue removal and CT. The PC grouping the late season NDVI measurements was significantly correlated to final yield, in contrast with the PC grouping the earlier measurements. Although ZT has lower NDVI values in the beginning of the crop season, this does not affect yield. This indicates that ZT with residue retention leads to time efficiency in the use of resources (water, nitrogen, …), as opposed to CT, regardless of residue management and ZT with residue removal.

Reports on differences in GC under different management practices are scarce. Riley (1998) reports that plant development was delayed with reduced tillage with spring cereals, but this was compensated later in the season. Vyn and Raimbault (1993) and Raimbault and Vyn (1991) report no-till resulted in slower plant growth compared to all other tillage systems.

Several methods were used to follow up the crop growth. In several studies (Vetsch and Randall, 2004; Moreno et al., 1997; Vyn and Raimbault, 1993) plant height is measured. However, plant height is not directly correlated with plant performance, and only a very limited disperse amount of points can be measured in the field. The use of a SPAD chlorophyle meter (Vetsch and Randall, 2004) solved the first issue but not the second. Harvesting all above ground plant material (Riley, 1998) solves again the first issue, but can only be done a limited times per crop season and will affect the experiment. The handheld sensor solves all issues: NDVI is correlated to plant performance/plant health, is non-destructive and the sensor samples at a very high rate (approximately 1000 measurements per second) and can easily and time-efficiently measure a whole plot representative area. Mandal et al. (2003) successfully used a NDVI based GC measured by a hand held Spectrometer to characterize crop growth for different green manuring systems.

Conclusions and recommendations

The NDVI handheld sensor is a perfect tool in order to monitor efficiently and in real time crop growth under different management systems. It is important to monitor crop growth under different management systems in order to adjust timing and practice of input supply (fertilizer, irrigation, …) in a holistic way in each system, integrating the agronomic factors. Therefore, in the future we will monitor all long-term experiments more intensively in order to better understand the different cropping systems. ZT with residue retention is characterized by a slow take off of the crop, but this is totally compensated by increased crop performance in the later stages, with a more crucial influence on final grain yield. This production practice leads to time efficiency in the use of resources, as opposed to CT, regardless of residue management and ZT with residue removal.

Reference

Azooz, R.H., Arshad, M.A., 1996. Soil infiltration and hydraulic conductivity under long-term no-tillage and conventional tillage systems. Canadian Journal of Soil Science 76, 143-152.

Bravo-Espinoza, M., van Nieuwkoop, M., Contreras, J.R., Jimenez, J.L., Morales-Guerra, M., 1993. El potencial de la labranza de conservacion en la Mixteca Oaxaquena. International Maize and Wheat Improvement Center, Mexico, D.F.

Elliott, J.A., Efetha, A.A., 1999. Influence of tillage and cropping system on soil organic matter, structure and infiltration in a rolling landscape. Canadian Journal of Soil Science 79, 457-463.

Fischer, R.A., Santiveri, F., Vidal, I.R., 2002. Crop rotation, tillage and crop residue management for wheat and maize in the sub-humid tropical highlands I. Wheat and legume performance. Field Crops Research 79, 107-122.

Karlen, D.L., Varvel, G.E., Bullock, D.G., Cruse, R.M., 1994. Crop Rotations for the 21St-Century. Advances in Agronomy, 53, 1-45.

Mandal, U.K., Singh, G., Victor, U.S., Sharma, K.L., 2003. Green manuring: its effect on soil properties and crop growth under rice-wheat cropping system. European Journal of Agronomy 19, 225-237.

McGarry, D. 2002. Conservation agriculture practices for sustainable cotton production, through impro0ved soil structure and increased water use efficiency. Proceedings of the workshop on Conservation Agriculture for Sustainable Wheat Production in Rotation with Cotton in Limited Water Resource Areas, 14-18 october 2002, Tshkent, Uzbekistan. 10-14-2002.

Moreno, F., Pelegrin, F., Fernandez, J.E., Murillo, J.M., 1997. Soil physical properties, water depletion and crop development under traditional and conservation tillage in southern Spain. Soil & Tillage Research 41, 25-42.

Raimbault, B.A., Vyn, T.J., 1991. Crop-Rotation and Tillage Effects on Corn Growth and Soil Structural Stability. Agronomy Journal 83, 979-985.

Riley, H.C.F., 1998. Soil mineral-N and N-fertilizer requirements of spring cereals in two long-term tillage trials on loam soil in southeast Norway. Soil & Tillage Research 48, 265-274.

SAS Institute, 1994. SAS User's Guide. SAS Inst., Cary, NC, USA.

Sayre, K. D., Mezzalama, M., and Martinez, A. 2001 Tillage, crop rotation and crop residue management effects on maize and wheat production for rainfed conditions in the altiplano of central Mexico. In: Garcia-Torres, L., Benites, J., and Martinez-Vilela, A Conservation Agriculture a worldwide challange. I World Congress on Conservation Agriculture. Cordoba, Spain, XUL. Madrid. Pp. 575-585.

Shaver, T.M., Peterson, G.A., Ahuja, L.R., Westfall, D.G., Sherrod, L.A., Dunn, G., 2002. Surface soil physical properties after twelve years of dryland no-till management. Soil Science Society of America Journal 66, 1296-1303.

Vetsch, J.A., Randall, G.W., 2004. Corn production as affected by nitrogen application timing and tillage. Agronomy Journal 96, 502-509.

Vyn, T.J., Raimbault, B.A., 1993. Long-Term Effect of 5 Tillage Systems on Corn Response and Soil-Structure. Agronomy Journal 85, 1074-1079.

Table 1. Correlation between wheat final grain yield / crop biomass and NDVI; CIMMYT long-term sustainability trial El Batan, Mexico

Days after planting	26	32	48	64	71	78	85	96	110	123
Correlation Coefficient										
Yield (12% H2O)	NS	NS	0.76 *	0.71 *	0.71 *	0.82 *	0.87 **	0.81 *	NS	NS
Biomass	NS	NS	0.77 *	0.71 *	0.71 *	0.81 *	0.85 **	0.81 *	NS	0.76 *

* = P<0.05 ** = P<0.01 NS = Not significant

Table 2. Correlation between maize final grain yield / crop biomass and NDVI; CIMMYT long-term sustainability trial El Batan, Mexico

Days after planting	29	35	51	67	74	81
Correlation Coefficient						
Yield (12% H2O)	NS	NS	0.56 *	0.53 *	0.53 *	NS
Biomass	NS	NS	0.53 *	NS	NS	NS

* = P<0.05 ** = <0.01 NS = Not significant

Table 3. Wheat and maize growth curve (NDVI vs Days after planting) slope and maximum; CIMMYT long-term sustainability trial El Batan, Mexico

	Wheat		Maize	
Treatment	Slope	Maximum	Slope	Maximum
Continuous cropping, CT, residue retention	0.0288 AB	0.8405 A	0.0235 C	0.8524 AB
Continuous cropping, CT, residue removal	0.0210 C	0.7831 A	0.0220 C	0.8425 AB
Continuous cropping, ZT, residue retention	0.0315 A	0.9680 A	0.0442 AB	0.8649 A
Continuous cropping, ZT, residue removal	0.0234 BC	0.8745 A	0.0190 C	0.7064 C
Rotation, CT, residue retention	0.0216 C	0.8391 A	0.0375 B	0.8465 AB
Rotation, CT, residue removal	0.0226 C	0.8232 A	0.0384 B	0.8570 AB
Rotation, ZT, residue retention	0.0296 A	0.8565 A	0.0482 A	0.8540 AB
Rotation, ZT, residue removal	0.0139 D	0.5423 B	0.0387 B	0.8296 B
Least Significant Difference	0.0061	0.0939	0.0085	0.0333
Rotation	*	**	***	**
Tillage	NS	NS	**	**
Residue	***	**	**	**
Tillage*Residue	NS	*	**	***
Rotation*Residue	NS	**	*	***
Rotation*Tillage	NS	**	NS	**
Rotation*Tillage*Residue	NS	**	NS	**

* = P<0.05 ** = P<0.01 ***= P<0.001 NS = Not significant
ZT= Zero tillage, CT= Conventional tillage

Figure 1. Wheat growth curve (NDVI vs Days after planting); CIMMYT long-term sustainability trial El Batan, Mexico

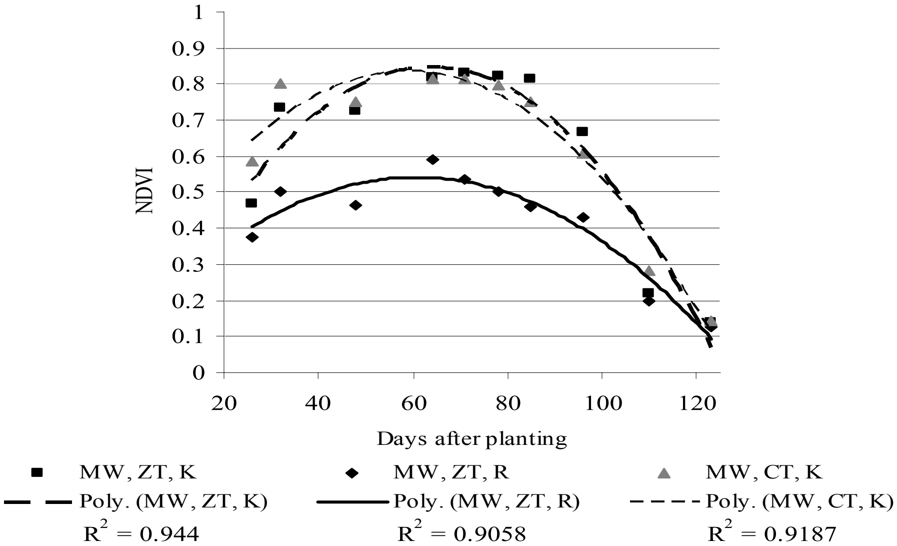


Figure 2. Maize growth curve (NDVI vs Days after planting); CIMMYT long-term sustainability trial El Batan, Mexico

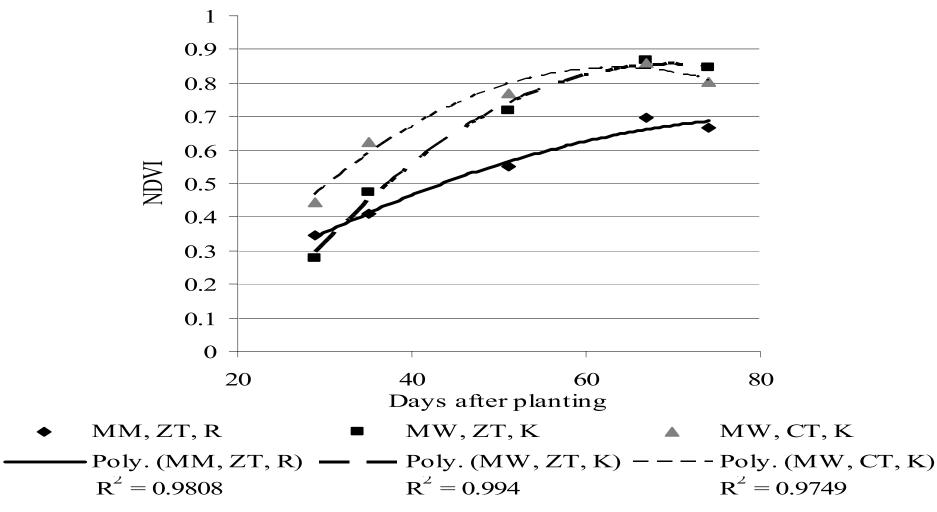
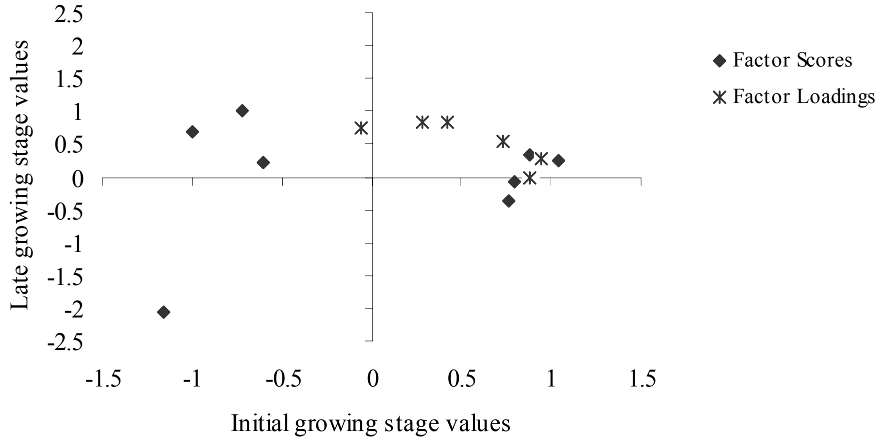


Figure 3. PCA biplot of maize NDVI measured along the growing season; CIMMYT long-term sustainability trial El Batan, Mexico



SOIL STRUCTURE IN RELATION TO DIFFERENT STRAW MANAGEMENT

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Abstract

The structural condition of soil was assessed by the soil structure coefficient (QS), which expresses the relationship between agronomically relevant and less relevant soil separates (the higher the proportion of agronomically more favourable aggregates, the higher the soil structure coefficient).

$$\text{COEFFICIENT OF SOIL STRUCTURE (QS)} = \frac{\sum \text{ \% of proportion of aggregates } 10 - 0.25 \text{ mm}}{\sum \text{ \% of proportion of aggregates } > 10 \text{ mm} + < 0.25 \text{ mm}}$$

In a six-field crop rotation, six straw management and tillage treatments were evaluated:

1. Crushed straw incorporation in the soil by a tiller to a depth of 0.12-0.15 m, ploughing as deep as 0.22 m.
2. Crushed straw incorporation in the soil by a tiller to a depth of 0.12-0.15 m.
3. Crushed straw incorporation in the soil by a tiller to a depth of 0.12-0.15 m, seeding by a HORSCH exaktor
4. Straw harvest, soil cultivation by a tiller to a depth of 0.12-0.15 m.
5. Straw burning, soil cultivation by a tiller to a depth of 0.12-0.15 m.
6. Spraying of crushed straw with a preparation BETA-LIQ (1.5 $t.ha^{-1}$) and incorporation in the soil by a tiller to a depth of 0.12-0.15 m.

A positive effect on soil structure was observed with lower intensity of soil tillage and simultaneous incorporation of straw or with treatments consisting of lower intensity of tillage and straw harvest or straw burning.

Key words: crop residue management**,** soil tillage

Introduction

Soil structure is one of essential soil properties and it also determines soil fertility. It is the resultant state of the total set of soil particles and their aggregates. It is conditioned by the ability to bind solid state particles or disaggregate large bodies of soil material and thus create structure aggregates.

Soil structure is the result of action of several factors - both primary (soil forming substrate, soil structure, water, and climate) and secondary (man's activity – soil tillage, fertilizer application). Soil structure is also a factor that has an effect on processes taking place in the soil.

An important factor of maintaining favourable soil structure is the supply of organic matter to the soil either in the form of post-harvest residues, straw incorporation, green manure or manure. The organic matter affects the soil structure forming process of agronomically valuable soil structure elements which develop the potential of soil moisture retention and its protection against evaporation and water or wind erosion. Other effects on soil structure are associated with different agronomy measures.

Material and Methods

An on-site small-plot field trial was established in the year 1997 in a sugar-beet growing area on a plot of the Forage Crop Research Institute Ltd. (altitude of 270m) with a long-plot design and four replications.

Crop rotation:

1. pea,
2. winter wheat,
3. spring barley,
4. winter rape,
5. winter wheat,
6. winter wheat.

Soil tillage and straw management treatments:

1. Crushed straw incorporation in the soil by a tiller to a depth of 0.12-0.15 m, ploughing as deep as 0.22 m.
2. Crushed straw incorporation in the soil by a tiller to a depth of 0.12-0.15 m.
3. Crushed straw incorporation in the soil by a tiller to a depth of 0.12-0.15 m, seeding by a Horsch exaktor
4. Straw harvesting, soil cultivation by a tiller to a depth of 0.12-0.15 m
5. Straw burning, soil cultivation by a tiller to a depth of 0.12-0.15 m
6. Spraying of crushed straw with the preparation BETA-LIQ (1.5 $t.ha^{-1}$) and incorporation in the soil by a tiller to a depth of 0.12-0.15 m.

BETA-LIQ preparation – treated sugar beet molasses stillage with higher contents of residual sugar
Seeding exaktor – a seeding machine for sowing into shallow tilled or zero-tilled soil, after sowing with an exaktor most post-harvest residues and straw remain on the surface of the soil as mulch

After winter wheat and spring barley all six treatments were applied. After rape and pea harvest there was no straw harvest or burning, straw in treatments 4 and 5 was crushed and shallow incorporated in the soil like in treatment 2. After pea harvest there was no application of the BETA-LIQ preparation.

Mineral fertilisers were applied in accordance with the methodology of plant nutrition (NEUBERG 1990). A compensation rate of N was 0.8 kg N per 100 kg of cereal straw and 0.6 kg N per 100 kg of winter rape straw. When the preparation BETA-LIQ was used, correction for nutrient contents in the preparation was made.

Soil samples were taken in the year 2001 to 2003 (in May) after pea emergence with three replications to a depth of 0 - 20 cm.

After soil drying at the laboratory temperature, soil samples were separated using a sieve with screen holes of 0.25, 0.5, 1, 5, 10 mm in diameter. Each structural fraction was weighed separately and its proportion of the total sample weight was determined. The structure of the soil was evaluated using the coefficient of soil structure (QS), which expresses the relationship between agronomically valuable and less valuable separates (the higher the proportion of agronomically favourable aggregates, the higher the QS).

$$\text{COEFFICIENT OF SOIL STRUCTURE (QS)} = \frac{\sum \text{ \% proportion of aggregates } 10 - 0.25 \text{ mm}}{\sum \text{ \% proportion of aggregates } > 10 \text{ mm} + < 0{,}25 \text{ mm}}$$

Statistical evaluation was made using a program STAGRAPHICS Plus 4.0 by analysis of variance with subsequent testing.

Results and Discussion

The average values of soil structure coefficients (Table 1) for a period under study (2001 to 2003) showed that lower intensity of soil tillage had a more favourable effect on soil structure, compared with ploughing and sowing with a seeding exaktor. The difference was statistically significant between treatments 1 and 4. A favourable effect on soil structure was exhibited in treatments with straw incorporated by cultivation and in treatments with straw harvest and burning. The preparation BETA-LIQ had a positive effect on straw degradation and the yield of subsequent crops (PROCHÁZKOVÁ, DOVRTĚL 2000, PROCHÁZKOVÁ, MÁLEK, DOVRTĚL, 2002). However, higher potassium content and regular application of this preparation might have a negative effect on soil structure.

Table 1: Coefficients of soil structure with different straw management – an average from observations over the years 2001 to 2003

Treatment	Structure coefficient	Standard deviation
1. Crushed straw incorporation in the soil by a tiller to a depth of 0.12-0.15 m, ploughing as deep as 0.22 m.	1.43	0.76
2. Crushed straw incorporation in the soil by a tiller to a depth of 0.12-0.15 m.	1.66	0.95
3. Crushed straw incorporation in the soil by a tiller to a depth of 0.12-0.15 m, sowing with an seeding exaktor	1.37	0.68
4. Straw harvest, soil cultivation by a tiller to a depth of 0.12-0.15 m	1.87	1.12
5. Straw burning, soil cultivation by a tiller to a depth of 0.12-0.15 m	1.68	0.76
6. Spraying of crushed straw with BETA-LIQ preparation and incorporation in the soil by a tiller to a depth of 0.12-0.15 m.	1.47	0.96

Conclusion

A favourable effect on soil structure was observed with a lower level of soil tillage and simultaneous straw incorporation in the soil or in treatments with a lower level of soil tillage and straw harvest or burning.

Literature

NEUBERG, J. a kol. (1990): Komplexní metodika výživy rostlin. UVTIZ Praha, 327 s.

PROCHÁZKOVÁ B., DOVRTĚL J. (2000): Vliv různého zpracování půdy na výnosy ozimé pšenice. Rostlinná výroba, 46, 10: 437-442

PROCHÁZKOVÁ B., MÁLEK J., DOVRTĚL J. (2002): Effect of different straw management practices on yields on continuous spring barely. Plant production, 48, 1: 27-32

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STUDY ON THE POSSIBILITIES OF WATER AND SOIL CONSERVATION ON ARABLE LANDS IN THE HILLY AREA OF THE MOLDAVIAN PLAIN (NORTH-EASTERN OF ROMANIA)

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Summary
On sloping cultivated lands of the Moldavian Plain, changes, which appeared in the structure of land property after 1990, resulted in removing from the agricultural circuit of an area of almost 1000 ha.
The enforcement of the Law of Land Property (18/1991) which stipulates the retrocession of cultivated land to its owners on the sites from 1949 resulted in an excessive land fragmentation in plots until 2 ha, of elongated shape, directed on slopes, on the direction of maximum slope. Therefore, the concerns for soil protection diminished, slopes being in continuous degradation.
In this natural frame, favourable to erosion processes, maintaining water, soil and nutrients losses within the allowable limits on slopes of 10 - 12 %, requires limiting the proportion of cultivating row crops in rotation at 40 % and practising strip cropping systems with buffer strips.

Key words: soil erosion, conservation of soil fertility, strip crops, buffer strips

The hilly Moldavian Plain, situated in North-Eastern Romania, occupies about 800,000 ha, which represent almost 3.4 % of the country area.
Sculptural landforms, expressed by quasi-horizontal interfluves and slopes between 5 and 25 %, the dominance of clayey-marled lithological facies, rainfall torrential character in the second warm half period of the year and man's intervention on the natural frame created very favourable conditions for great slope processes in the area.
Although there were many concerns for diminishing these processes, the changes which appeared after 1990 in the property structure of cultivated lands determined the acceleration of the rate of soil degradation on slopes, especially by erosion and land slide, on high areas of the territory.
As a result we considered necessary to estimate the risk of deteriorating yield capacity of these lands and to determine the technical solutions for conserving soil fertility characteristics and environment quality, generally.

Material and methods

For pointing out the evolution of land resources and anti-erosion concerns, land record data have been used from mayor's offices in the territory and from Boards Agriculture and Rural Development from Iasi and Botosani counties, topographical maps of the area (scale 1: 25,000 and 1: 50,000) and authors observations as a result of studies carried out in this area.
The mechanism of erosion process was studied in the field of anti-erosion crop management at the Agricultural Research and Development Station of Podu-Iloaiei, Iasi county, by using 8

plots for controlling surface runoffs (4 × 25 m^2) placed with the short side on the direction of contour lines, on a slope with loamy-clayey cambic chernozem, having the average size of 11% Plots, isolated by iron plate strips, have at the downstream end basins and devices for runoff division, of which were taken water and soil samples for the determination of turbidity and nutrients content.
The values obtained have been extrapolated at the scale of the watershed Popesti-Iugani, with the area of 159 ha and the average slope of 11%, arranged anti-erosion with buffer strips and having in the control section hydrometrical apparatus, for pointing out the effect of vegetation, crop structure and soil tilling systems on the erosion process.

Results and discussions

In the Moldavian Plain, the cultivated land represent 3/4 of the total area, of which more than 60 % are placed on higher than 5 % slopes. In the structure of use categories, the arable land has the weight of 71.3 %, followed by pastures and hay fields - 24.6 %, vineyard and fruit-trees plantations representing only 2.3 % and 1.8 %, respectively. On the whole, the slopping cultivated area diminished by 0.3 %, through the passage of 926 ha to non-farming categories (especially, by the extension of the built-up area), while in the structure of cultivated land, an increase in arable areas by 1.6 % and a limitation of pastures by 4.5 % have occurred (Table 1).
The high potential of water erosion required the application, on slopes and torrent valleys of watersheds from the territory, of measures and soil protection tillage and reduction of torrential flood. On about 91 % of sloping arable land, tillage was done on the direction of contour line and extended to all farms, strip cropping and buffer strip systems.

Table 1

Evolution of cultivated land on higher than 5 % slope in the Moldavian Plain

Land utilization category	Ground			
	1990		2004	
	ha	%	ha	%
Arable land	256.320	70,0	260.367	71,3
Vineyard plantations	8.625	2,4	8.312	2,3
Orchards	6.406	1,8	6.479	1,8
Pastures	73.972	20,2	70.619	19,3
Hay fields	20.645	5,6	19.265	5,3
Total	365.968	100	365.042	100

Anti-erosion cropping systems were also applied in vineyard and orchard plantations and pastures were improved and arranged for sustainable grazing on more than 41 % of the area.
Anti-erosion cropping systems applied until 1990 on studied area fields proved their technical efficiency in time, by gradual runoff reduction and infiltration increase, diminution of soil and fertilizing elements losses, as well as by flood attenuation on torrent valleys, at high waters production. As a result, soil fertility on slopes registered an improvement process, reflected by yield increase.
Nowadays, the hydroammeliorative efficiency of anti-erosion works applied 1 - 4 decades ago on watersheds with the most active erosion processes were differentiated according to works type, vulnerable character to man's aggression and interconditioning of natural factors. In the last years, the arrangements on slopes were highly affected compared to the works on torrent riverbeds and ravines, due to the wrong enforcement of Land Low (Low 18/1991).

After 1990, on sloping arable lands, anti-erosion cropping systems were abandoned, which was pointed out by an increase by about 6.8 times of areas tilled from upstream to downstream.
Concomitantly, the area exploited according at to the general direction of contour lines diminished at half and strip cropping with buffer strip systems were used on lower areas by 6.5 and 4.7 times, respectively (Table 2).
The main cause of these changes which appeared in a relatively short interval was represented by dividing the sloping areas into over 150,000 plots of rectangular shape, having the area until 1-2 ha and which were directed on mountain sides with the long side on the direction of the greatest slope, which compelled that ploughing should be done from hill to valley. Worser was that anti-erosion works carried out before 1990 were not managed adequately or even destroyed. On arable lands where Low 18/1991 did not influence areas, as well as on those where land retrocession was done reasonably, anti-erosion systems were not affected.
The danger of erosion process intensification on slopes used as arable land was magnified by the dominance of row crops - especially of maize - in the crop structure.

Table2

Changes appeared in the structure of cropping systems practiced on arable lands with a higher 5 % slope
in the Moldavian Plain

Cropping system	Area				Condition in 2004 compared to 1990
	1990		2004		
	ha	%	ha	%	
Tillage on the direction hill-valley, without anti-erosion measures	23.611	9,2	161.542	62,1	Increases by 6.8 times
Tillage on the direction of contour lines	170.736	66,6	87.251	33,5	Diminishes by 48.9%
Strip crops	34.266	13,4	5.286	2,0	Diminishes by 6.5 times
Buffer strip crops	26.535	10,4	5.702	2,2	Diminishes by 4.7 times
Crops on broadbase terraces and agro-terraces	1.145	0,4	598	0,2	Diminishes by 47.8%
Total	256.320	100	260.367	101,6	Increases by 1.6%

The sloping arable area on which are still used anti-erosion cropping systems be longs especially to trade societies with State capital and to over 300 private associations, made up after 1990 according to diverse criteria.
For preserving the productive soil potential on slopes and environment protection, it is necessary to be adopted an adequate legislation and material stimulation of farmers for the creation of favourable frame of increasing the areas of working units (by buying, renting, association) which allow the use of anti-erosion management and reassessment of special projects for soil erosion control.
Processing the data registered during 1983 - 2004 in the anti-erosion management field of Podu-Iloaiei Station, Iasi county, showed that from the mean rainfall amount of 539.6 mm, 359.3 mm (66.6 %) caused surface runoff, which differentiated as value according to the degree of soil covering by plants, corresponding to cropping technology and vegetation stage varying between 5.6 mm in perennial grasses on the 11nd year of vegetation and 15.1 mm in sunflower. Average amounts of eroded soil at the same period had extreme values in the same crops, being of 0.5 t/year in perennial grasses on the 11nd year of vegetation and of 11.8 t/ha/year in sunflower (Table 3).

Table 3

Liquid runoff and soil losses under different crops
(ARDS Podu-Iloaiei, Iasi county, 1983 - 2004)

Specification	Bare	Pea	Wheat	Maize	Sunflower	Beans	Perennial grasses	
							Year I	Year II
Runoff water (mm)	16,7	7,7	6,9	14,2	15,1	9,9	7,3	5,6
Eroded soil (t/ha·an)	12,8	3,2	1,8	11,4	11,8	5,6	2,9	0,5

Analysing the runoff values during 1983 - 2004, in case of rainfall with greater than 0.15 mm/min intensity, it was found that runoff occurred during Mai-July when maize and sunflower crops protected weakly the field, resulting in losing soil amounts, comprised between 0.4 - 3.1 t/ha/year, in case of a single rainfall event, the erosion process being higher in case of successive rainfall. Under maize crop, during 28 - 30 May 1988, was eroded a soil amount of 4.7 t/ha and within the interval 6 - 9 June 2004 - of 4.1 t/ha. These results showed the temporal variability of the erosion process as well as the importance of knowing the critical erosion season for the adoption of soil protection measures.

Concomitantly to water and soil losses, important amounts of humus and nutrients have been removed, which determined the diminution of the degree of using fertilizers and/or soil fertility, affecting at the same time the quality of environment. Under maize and sunflower crops, 22 - 23 kg/ha nitrogen, 2 - 3 kg/ ha phosphorus and 4 - 5 kg/ha potassium have been lost (Table 4), which represent, on the average, 8 - 11 % of the necessary of mineral fertilizers of these plants for getting good yields.

Table 4

Mean annual humus and nutrients losses by erosion on slopes of 11%
not-arranged anti-erosion (ARDS Podu Iloaiei, Iasi county, 1983 - 2004)

Specification	Bare	Pea	Wheat	Maize	Sunflower	Beans	Perennial grasses	
							Year I	Year II
Humus (kg/ha)	459	111	67	396	411	195	97	14
N_t (kg/ha)	24,5	6,3	4,1	21,2	22,6	10,9	5,6	1,3
P-Al (kg/ha)	2,4	0,5	0,3	1,8	2,1	1,1	0,5	0,1
K-Al (kg/ha)	4,7	1,1	0,7	4,1	4,3	2,0	1,0	0,2

On the basis of data obtained in runoff control plots on the influence of cultivated plants on erosion and determinations carried out in the Popesti-Iugani watershed, it was possible the assessment of anti-erosion effect and cropping systems.

The introduction since 1981 of strip cropping combined with buffer strips system, the adoption of an adequate crop structure (38 % winter cereals, 20 % annual grain legumes, 36 % maize + sunflower and 6 % perennial grasses) and a reasonable rotation, had as effect the great diminution of water and soil losses, compared to those produced on the neighboring area, not-arranged anti-erosion.

Table 5

Mean values of liquid runoff and soil losses on lands with slope of 11 %
exploited in the buffer strip cropping system (ARDS Podu Iloaiei, Iasi county, 1983 - 2004)

Specification	Pea	Wheat	Maize	Sunflower	Beans	Perennial grasses
Runoff water (mm)	5,1	3,6	10,3	12,1	6,7	3,1
Eroded soil (t/ha·an)	1,0	0,8	4,2	4,8	1,8	0,2

Table 6

Mean annual losses of humus and nutrients by erosion on slopes of 11 %, arranged anti-erosion (buffer strip cultivated crops) (ARDS Podu Iloaiei, Iasi county, 1983 - 2004)

Specification	Pea	Wheat	Maize	Sunflower	Beans	Perennial grasses
Humus (kg/ha)	33	18	124	143	58	12
N_t (kg/ha)	1,8	1,5	7,9	9,3	3,3	0,9
P-Al (kg/ha)	0,2	0,1	0,8	0,9	0,3	0,1
K-Al (kg/ha)	0,6	0,3	1,6	1,8	0,7	0,2

From the total multiannual mean amount of rainfall of 502.3 mm, 232.1 mm (46.2 %) determined runoff. On the arranged area, water runoff was between 3.1 mm in perennial grasses and 12.1 mm in sunflower (table 5). Under these conditions, the mean amounts of eroded soil, which varied between 0.2 t/ha/year in perennial grasses and 4.8 t/ha /year in sunflower (table 5) as well as humus and nutrients amounts (table 6) were within normal limits compared to soil natural recovering capacity.

On the basis of these results, we considered that on lands with slope of 10 - 12 % should be practiced the combined system of strip cropping with buffer strips, as well as crop rotations of 3 or 4 years, so that soil yield potential on slopes and environment quality should not be damaged.

Conclusions

1. Under conditions of the diminution after 1990 of anti-erosion concerns on sloping cultivated lands in the Moldavian Plain, due to land fragmentation, into small plots, directed uncorrespondingly on slopes, it is necessary measures and works for soil erosion prevention and control and other sloping processes, having in view the natural conditions favourable for these phenomena production.
2. Torrential rainfall which fell in May - July during 1983 - 2004 caused on loamy-clayey cambic chernozem of Podu-Iloaiei, in maize and sunflower crops - cultivated on plots with mean slope of 11 % - soil losses which varied between 0.4 and 3.1 t/ha at one case of rainfall event, the amounts being higher in case of successive rainfall which fell at short time intervals.
3. Concomitantly to liquid and solid losses, important humus and nutrients amounts have been removed, which diminished the degree of fertilizer use and/or soil fertility, affecting at the same time the environment quality. In maize and sunflower, 22 - 23 kg/ha nitrogen, 2 - 3 kg/ha phosphorus and 4 - 5 kg/ha potassium were lost, which represent, on the average, 8 - 11 % of the necessary of plant mineral fertilizers for getting high yields.
4. On arable lands of the Moldavian Plain, with mean slope of 10 - 12 %, water, soil and nutrients losses by erosion can be maintained at allowable values under conditions of practicing the combined system of strip cropping with buffer strips and adopting a crop structure where row crops (plants sown at spaced rows) should not be found at higher than 40 % proportion.
5. The spreading of unfavourable effects of soil erosion and methods for prevention and control could persuade owners of small sloping fields about the importance and necessity of soil tillage according to the norms of anti-erosion soil management.

References

Dario C., 2003 - *Tecnica delle sistemazioni idraulico forestali*, Edagricole, Bologna.
Morgan R. P. C., 2004 - *Soil erosion & conservation*, (3rd Ed.), Blackwell Publishing.
Terrence J. Toy J. T., Foster R. G., Renard G. K., 2002 - *Soil Erosion: Processes, Prediction, Measurement, and Control*, John Wiley & Sons.

EFFECTS OF CONVENTIONAL AND REDUCED TILLAGE SYSTEMS IN WINTER WHEAT – SOYBEAN CROP ROTATION ON CROPS BIOMASS DEVELOPMENT

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Abstract

Croatian Baranja region contains soils with highly quality crop production properties, but the knowledge of the effects of reduced tillage systems is lacking. Our investigations were conducted under field conditions at Knezevo site chernozem in four replications. They included four soil tillage systems (CT: conventional tillage, with ploughing up to the 30 cm as a primary tillage; DS: diskharrowing up to the 15 cm; CH: chiselling up to the 30 cm + diskharrowing; NT: no-till seed drilling) for winter wheat (*Triticum aestivum L.*) - soybean (*Glycine max L.*) crop rotation during three growing seasons (2002-2004). All measured crop properties were strongly affected by different seasons, especially with the season of 2003 with extreme drought. Crop biomass in five growth stages for winter wheat showed that at the beginning DS and CH had stronger growth than CT and NT, but differences vanished toward final stages. Winter wheat grain yield achieved by reduced tillage systems was in average either higher (CH=5.59 t ha^{-1}) or not different (5.38 and 5.23 t ha^{-1} for DS and NT, respectively) than CT (5.28 t ha^{-1}). Soybean growth was consistently the most impaired at NT system, especially at the full maturity stage, where also DS and CH had lower biomass than CT. Soybean grain yield confirmed biomass results, since NT (2.11 t ha^{-1}) had always the lowest yield, when compared with other tillage systems (CT=2.88, CH=2.77 and DS=2.72 t ha^{-1}). Our conclusion is that within the Croatian Baranja environmental conditions is possible to replace soil tillage based on the ploughing for winter wheat and soybean with reduced soil tillage systems based on disking and chiselling, whereas no-till system still needs solution which will address drought-related problems.

Key words: winter wheat, soybean, ploughing, diskharrowing, chiselling, no-till

Introduction

In the Republic of Croatia, different trials of reduced tillage have been performed (Butorac et all, 1979, Juric et all, 1998, Zugec et all, 2000, Husnjak et all, 2002), with different results and conclusions, ranging from the full acceptability of certain reduced tillage systems, up to the conditional or even complete unsuitability of other systems, mostly due to the inherited soil and weather limitations. This is the main reason why the acreage under reduced tillage systems in Croatia is still very low, even at highly producible soils such are chernozems and eutric cambisols which are prevailing in Eastern Croatia, in spite the fact that scientists from different agriecological conditions confirmed possibilities of reduced tillage in more harsh environments, especially for winter wheat - soybean crop rotation (Vyn et all, 1991; Prasad, 1996; Vyn et all, 1998; Kelley et all, 2003), which is very interesting for Croatian farmers due to the traditional, technological and especially economical reasons, whose analyses were given very noticeably by DosSantos et all (1997).

The aim of this research was to explore replacements for soil tillage based on ploughing and their effects on winter wheat and soybean growth and grain yield in environmental conditions of Eastern Croatia.

Materials and methods

The research was conducted near Knezevo in northern part of Croatian Baranja, at Agricultural Industrial Complex "Belje" Ltd., farm unit "Knezevo" land, for the winter wheat (*Triticum aestivum L.*) - soybeans (*Glycine max L.*) in crop rotation during period 2002-2004. The dominant soil type was determined as a chernozem. The main experimental set-up was a complete randomised block design in four replications, with four soil tillage systems: CT) Conventional Tillage: ploughing up to 30 cm depth, followed by diskharrowing, sowing preparation and sowing with no-till driller John Deere 750A; DS) Diskharrowing and sowing as for CT; CH) Chiselling on up to 30 cm depth, diskharrowing and sowing as for CT; NT) No-Tillage sowing without any primary tillage operation. The size of basic experimental plot was 900 m^2. The winter wheat cultivar "*Demetra*" was sown at the planned rate of 700 germinating seeds m^{-2}, at the inter-row distance of 16.5 cm. The soybean cultivar "*Tisa*" was sown at the planned rate of 55 germinating seeds m^{-2}, with inter-row distance of 33 cm, by closing every odd seeding dispenser on the no-till driller. The fertilization was uniform across treatments and years for each crop, and it consisted of 121 kg N ha^{-1} for winter wheat and 40 kg N ha^{-1} for soybean, 130 kg P_2O_5 ha^{-1} and 130 kg K_2O ha^{-1} each season. The soybean seed was inoculated with nitrate-fixing symbiotic bacteria *Bradyrhizobium japonicum* (trade-mark name "Biofixin-S"). The plant protection was performed uniformly for each crop by local farm manager recommendations. The winter wheat shoot biomass was collected from four 0.25 m^2 randomly collected on each experimental plot, during five growth stages: beginning of erect growth, visible flag leaf, flowering, milky ripeness and full maturity, determined by Feekes as F=4.0, F=8.0, F=10.5.1., F=11.1 and F=11.4, respectively. The soybean above ground biomass was collected by the very same procedure in first trifoliate growth stage (V3), bloom beginning (R1), full bloom (R2), full pod (R4) and full maturity (R8) growth stage. Collected biomass was dried at 65ºC in three days, cut, mixed and weighed. The yield from each experimental plot was weighed at heavy duty bridge scale, grain moisture was recorded by moisture-meter "Dickey-John GAC2100" at the same time, and yield was recalculated on uniform moisture for each crop. The split-plot ANOVA was performed for all measurement results, with seasons as the main level and tillage as sub-level, and Fisher protected LSD means comparisons were performed at $P<0.05$ significance level by using SAS V8.0 (SAS Institute 2001, Cary, NC, USA).

Results and discussion

Winter wheat

As is shown in the Figure 1, the winter wheat biomass was significantly affected by different soil tillage systems mostly in first two sampled stages, beginning of wheat erect growth and during the growth of flag leaf, and fourth sampled growth stage, during the milky ripening. However, differences vanished at the end of vegetation, during the full maturity stage, presumably due to the nutrient allocation into grain. Similar development was observed also by some other authors (Busscher et all, 2000), but, results of Izumi et all (2004) showed inconsistence of wheat shoot biomass in relation with tillage, where greater biomass was recorded for no-tillage than tilled plots in third year of their experiment.

However, the grain yield data (Table 1) showed inconsistence between biomass and final yield of winter wheat, both within each season (biomass data not shown) and in tillage yield means. In the first season, during the year 2002, with relatively favourable weather conditions for winter wheat growth, CT had the lowest yield, lower than DS and significantly lower than CH and NT. The highest yield at NT in this year could be also attributed partially toward residual effect of pre-trial soil tillage, as suggested by results of Frederick et all (2001).
Extremely droughty spring of year 2003 showed different situation, and all yields were rather low, within 1/3 of usually expected winter wheat yields. The drought-related stresses were the most expressed at NT, presumably due to the lacking of water accumulation during the winter period, and poor water conservation, since the soil surface was not covered fully with the mulch from previous crop, given it was only the second year of no-till practice. In third year, again with relatively usual precipitation pattern, but with colder spring temperatures, there was no difference between CT and other tillage systems.
Significant difference was recorded between CH, with maximal yield in this trial (7.05 t ha^{-1}) and NT, which yield was the lowest (6.49 t ha^{-1}), but not statistically different from other two tillage systems in the year 2004, CT and DS. Overall, the highest yield in average was achieved by CH, since it was the most consistent system. The second best was DS, followed by CT and NT, which were not statistically different among themselves. Lund et all (1993) recorded also inconsistent effects of ploughing and no-tillage systems at winter wheat yields not only in winter wheat – soybean rotation, but also for monoculture and crop rotations which included winter wheat, soybean and maize. In contrast, Prasad (1996) showed no effects of tillage on winter wheat yield.

Soybean

Although constantly with the highest biomass (Fig. 2), CT was not significantly higher than DS and CH until the full maturity growth stage. Only at that growth stage, the most tilled soil under CT showed advantage over other tillage systems. The NT in all stages had significantly the lowest biomass recorded, which leads toward assumption that the soybean plant is more dependable on root proliferation within the soil in final stage than the winter wheat. Vyn et all (1998) suggested that delayed growth and consequently lower soybean yield was a consequence of wheat residues. Problems with shallow tillage were observed also by Busscher et all (2000), whose results suggested that deeper tillage can increase yields both for soybean and winter wheat.
The recorded biomass data were more consistent with grain yields (Table 2) in the sense of tillage treatment yield results relations (CT>CH>DS>NT), not only in grand mean, but in each year separately. In most cases CT, CH and DS were not different among themselves, all having significantly higher yield than NT. Some other authors (Lueshcen et all, 1992; Prasad, 1996) had not recorded dependence of tillage systems and soybean yield.
Deeper tillage importance for given ecological conditions in soybean production was expressed in drought during the year 2003, when CT and CH, with soil tilled up to the 30 cm depth, accumulated and conserved winter water needed for soybean growth better than shallow DS and NT systems.

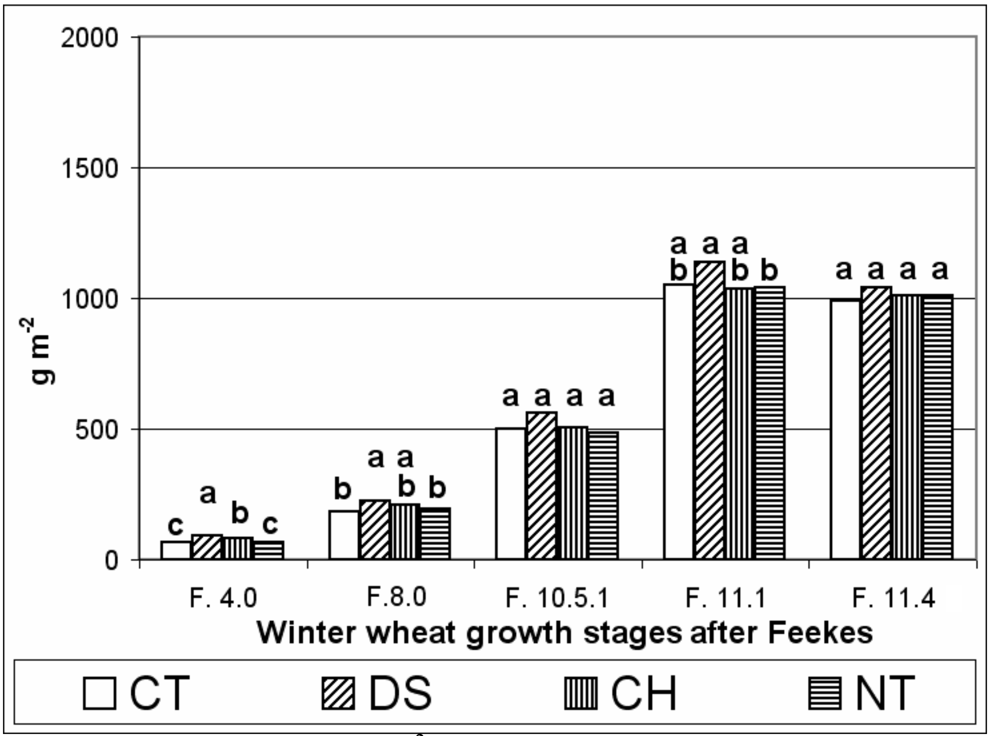

Fig. 1. The winter wheat biomass (g m^{-2}) at five growth stages (after Feekes): beginning of erect growth (F.4), flag leaf visible (F.8), flowering (F.10.5.1), milky ripe (F.11.1) and full maturity (F.11.4), Knezevo site, Croatian Baranja region, 2002-2004. The means within the same stage with the same lowercase letters are not different at P<0.05 significance level.

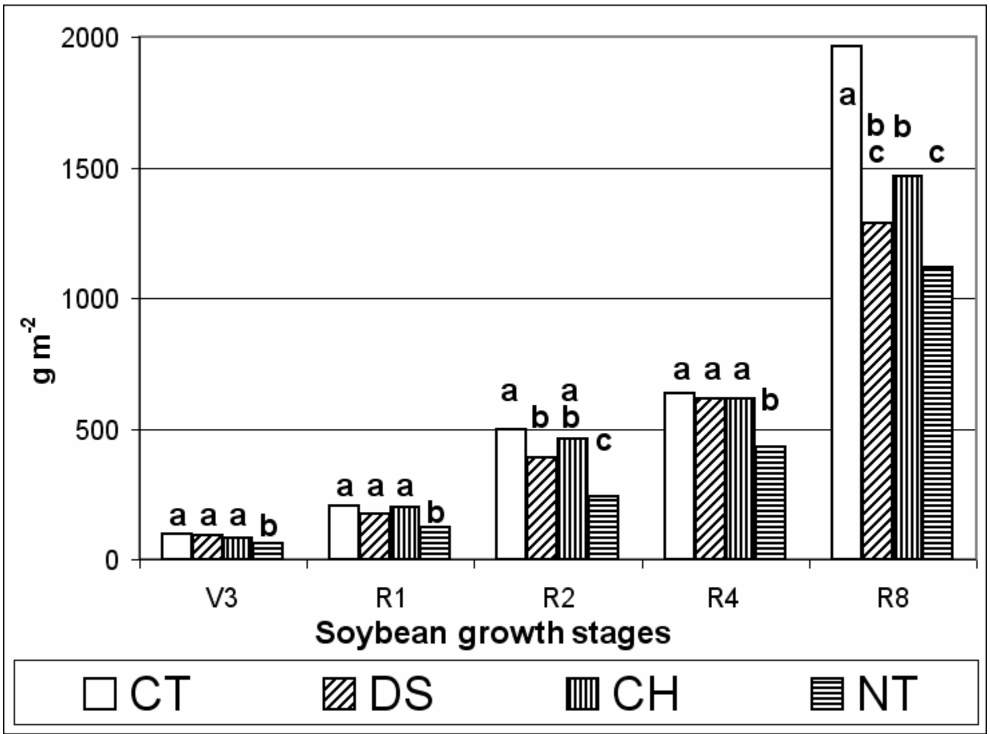

Fig. 2. The soybean biomass (g m^{-2}) at five growth stages: first trifoliate (V3), bloom beginning (R1), full bloom (R2), full pod (R4) and full maturity (R8), Knezevo site, Croatian Baranja region, 2002-2004. The means within the same stage with the same lowercase letters are not different at P<0.05 significance level.

Table 1
Influence of soil tillage system on the grain yield of winter wheat (t ha^{-1}) in Knezevo, Croatian Baranja region, for 2002-2004 period.

Soil tillage	Year 2002	Year 2003	Year 2004	Tillage mean
1) CT	6.40b†	2.74a	6.69ab	5.28 B‡
2) DS	6.71ab	2.64a	6.80ab	5.38AB
3) CH	6.96 a	2.78a	7.05a	5.59A
4) NT	7.01 a	2.20 b	6.49 b	5.23 B

	Tillage	Tillage|Year	Tillage x Year
LSD (P<0.05)	0.20	0.41	0.46

† Means within the same year with the same lowercase letter(s) are not significantly different at P<0.05 level
‡ Means with the same uppercase letter(s) are not significantly different at P<0.05 level

Table 2
Influence of soil tillage system on the grain yield of soybean (t ha^{-1}) in Knezevo, Croatian Baranja region, for 2002-2004 period.

Soil tillage	Year 2002	Year 2003	Year 2004	Tillage mean
1) CT	3.27a†	2.40a	2.96a	2.88A‡
2) DS	3.24a	2.03 b	2.90a	2.72A
3) CH	3.28a	2.18ab	2.85a	2.77A
4) NT	2.90 b	1.25 c	2.17 b	2.11 B

	Tillage	Tillage|Year	Tillage x Year
LSD (P<0.05)	0.17	0.25	0.33

† Means within the same year with the same lowercase letter(s) are not significantly different at P<0.05 level
‡ Means with the same uppercase letter(s) are not significantly different at P<0.05 level

Conclusion

The reduced soil tillage for winter wheat - soybean crop rotation grown by conventional tillage in Croatian Baranja agriclimatic conditions is equally applicable through either replacement of ploughing with diskharrowing only or diskharrowing in combination with chiselling as a primary tillage. No-till system in winter wheat production is still deprived in drought conditions, but otherwise it can replace other tillage systems without limitations. For soybean, no-till technology can show disadvantages even at highly productive soil such as chernozem, which can be additionally worsen with weather extremes. The further research is required for better no-till system adoption for soybean production.

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References

Butorac, A., Lackovic, L., Bestak, T., Vasilj, D., Seiwerth, V. 1979. Interrelationship of soil tillage and ferilizing in growing main field crops on hypogley. Proceedings of the 8th ISTRO Conference, Hohenheim, Stuttgart, Germany

Busscher, W.J., Frederick, J.R., Bauer, P.J. 2000. Timing effects of deep tillage on penetration resistance and wheat and soybean yield. SOIL SCI SOC AMER J, Vol 64/3, pp. 999-1003.

DosSantos, H.P., Fancelli, A.L., Andia, L.H. 1997. Economic analysis of crop rotation systems for wheat, over a two-year period, under no-tillage. PESQUISA AGR BRASIL, Vol 32/11, pp. 1111-1117.

Frederick, J.R., Bauer, P.J., Busscher, W.J. 2001. Grain yield and yield components of doublecropped winter wheat as affected by wheat and previous soybean production practices. CROP SCI, Vol 41/3, pp. 778-784.

Husnjak, S., Filipovic, D., Kosutic, S. 2002. Influence of different tillage systems on soil physical properties and crop yield. ROSTL VYROBA, Vol 48/6, pp. 249-254.

Izumi, Y., Uchida, K., Iijima, M. 2004. Crop production in successive wheat-soybean rotation with no-tillage practice in relation to the root system development. PLANT PROD SCI, Vol 7/3, pp. 329-336.

Juric, I., Zugec, I., Gorsteta, D., Ivanusic, M., Stipesevic, B., Kelava, I. 1998. Stanje tala i obrađenost poljoprivrednih površina u Hrvatskoj. Agronomski Glasnik 60/5-6, pp. 305-321.

Kelley, K.W., Long, J.H., Todd, T.C. 2003. Long-term crop rotations affect soybean yield, seed weight, and soil chemical properties. FIELD CROP RES, Vol 83/1, pp. 41-50.

Lueschen, W.E., Ford, J.H., Evans, S.D., Kanne, B.K., Hoverstad, T.R., Randall G.W., Orf, J.H., Hicks, D.R. 1992. Tillage, row spacing, and planting date effects on soybean following corn or wheat. J PROD AGRIC, Vol 5/2, pp. 254-260.

Lund, M.G., Carter, P.R., Oplinger, E.S. 1993. Tillage and crop-rotation affect corn, soybean, and winter-wheat yields. J PROD AGRIC, Vol 6/2, pp. 207-213.

Prasad, J. 1996. A comparison between a rotavator and conventional tillage equipment for wheat-soybean rotations on a vertisol in Central India. SOIL TILL RES, Vol 37/2-3, pp. 191-199.

Vyn, T.J., Opoku, G., Swanton, C.J. 1998. Residue management and minimum tillage systems for soybean following wheat. AGRON J, Vol 90/2, pp. 131-138.

Vyn, T.J., Sutton, J.C., Raimbault, B.A. 1991. Crop sequence and tillage effects on winter-wheat development and yield. CAN J PLANT SCI, Vol 71/3, pp. 669-676.

Zugec, I., Stipesevic, B., Kelava, I. 2000. Rational soil tillage for cereals (Winter Wheat - *Triticum aestivum L.* and Spring Barley - *Hordeum vulgare L.*) in Eastern Croatia. Proceedings of the 15th ISTRO Conference, Fort Worth, Texas, USA

EFFICACY OF FERTILIZATION SYSTEMS DIFFEERING IN INTENSITY ON A HEAVY SOIL

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Abstract

A high content of physical clay particles and low humus content in clay loam soils result in the manifestation of negative physical properties of the soil. At the Lithuanian Institute of Agriculture`s Joniskelis Research Station trials were carried out over the period 1996-2000 on a *Endocalcari-Endohypogleyic-Cambisol*, clay loam, in a five-course crop rotation were we investigated mineral, organic, and organic-mineral fertilisation systems with a view to increasing humus content and improving physical properties of clay soils. In the crop rotation with: sugar beet, barley undersown with perennial grasses, perennial grasses of the 1^{-st} and 2^{-nd} year of use and winter wheat in the mineral fertilizations system, an average annual mineral fertilizer rate was $N_{56}P_{48}K_{60}$ the soil humus content remained dose to the initial, crop rotation productivity increased by 52.3 % compared with unfertilized treatment. In the organic-mineral fertilization system application of 40; 60 and 80 t ha^{-1} of farmyard manure and NPK fertilizers as much as in the mineral fertilization system resulted in the following increases-soil humus content by 0.18; 0.24 and 0.21 percentage units respectively, compared with the mineral fertilisation system. Through fertilisation the soil structurality was by 3.3; 3.4 and 3.3 percentage units higher than in mineral fertilization, its bulk density declined by 4.8-4.8 and 4.1 % and the total porosity increased by 6.9-7.4-5.3 % respectively. Application of different rates of farmyard manure in the organic-mineral fertilization systems resulted in 5.8; 7.1 and 7.3 % increase in average crop rotation productivity, compared with the mineral fertilization system. In the organic fertilization system application of only 80 t ha^{-1} of farmyard manure, compared with mineral fertilization system, resulted in a humus content increase in the plough layer by 0.12 percentage units, improved soil structure 1.4 percentage units, and reduced bulk density by 4.1 %, and increased total porosity by 3.2 %. In this system the crop productivity, compared with unfertilized crops, increased by 32.2 %, however, compared with mineral fertilization system, declined by 13.2 %.

Key words: clay loam soil; fertilisation systems; physical properties; rotation; humus; crop yield

Introduction

Intensive soil tillage technology, especially in the case of growing longer, soil-depleting cereal links, where a small amount of low-quality plant residues and roots, that do not take part in the biological soil structuring, are involved in the small biological matter circulation, results in the manifestation of negative soil properties in heavy soils with a high content of clay particles (Eich, 1989; Maiksteniene et. al., 1994). One of the key factors, maintaining high productivity and improving clay soils properties, is fertilisation with organic and mineral fertilisers, which consequently increases humus, mobile phosphorus, and potassium contents in the soil, activates microbiological processes, and improves physical soil properties (Edmedes, 2003). In clay soils it is essential to maintain a stable humus content, as agrophysical properties of these soils are very much dependent on it (Janzen, H., H., 1991).

Deterioration of agrophysical soil properties results in a poor utilisation of these soils potential productivity and low yields in separate years (Korschens, M., 1998). One of the most efficient ways of humus content increasing is supplementary introduction of organic matter in the soil. It is believed that farmyard manure guarantees a positive humus balance only if its annual distribution is not lower than 10.0 t ha^{-1} (Hofman, 1986). Foreign and Lithuanian experimental evidence suggests that farmyard manure, compared with NPK fertilisers, gives a greater improvement of soil biological activity and structure, as well as reduction in bulk density and increase in total porosity (Lacko-Bartašova et. al., 1999, Marinari, S., et al 2000). Agrophysical properties of clay soils are relatively stable, and their variation depends not only on the amount of organic matter applied but also on how much of it and at which rate it is converted in humus (Maiksteniene, S., 1995). When farmyard manure was applied at 60 t ha^{-1} once per rotation, the content of water stable aggregates in the arable layer, as compared with the control, increased in spring by 4.2 %, and in autumn by 7.8 %. In long-term experiments we ascertained that 80 t ha^{-1} of farmyard manure applied on a sod calcareous soil increased nutrient content in the soil and improved soil physical properties (Maiksteniene, S., 1995). The data obtained by many authors indicate that application of the organic fertilisation system increases humus content in the soil by 3.4 %, total porosity by 8.1 % and the content of agronomically valuable soil structural aggregates by 0.1-1.0 percentage unit, where as in the organic-mineral fertilisation system the increase was much more distinct: humus-8.0 %, and agronomically valuable aggregates – 3.4-3.9 percentage units (Six et. al., 2000). The objective of this study was to assess the effect of different fertilisation systems on the improvement of soil physical properties of a clay loam Gleyic Cambisol.

Materials and methods

With a view determining variation of specific properties of clay-textured soils using different fertilisation systems experiments were carried out at the Lithuanian Institute of Agriculture`s Joniskelis Research Station over the period 1996-2000 in a five-course crop rotation. The trial was set up on *Endocalcari Endohypogleyic Cambisol*, clay loam soil lying on silty clay. At trial establishment agrochemical characteristics of the topsoil were as follows: pH-6.0, humus – 2.0 %, mobile P_2O_5-65-129 mg kg^{-1}, K_2O – 175-218 mg kg^{-1} of soil. The following fertilisation systems were investigated in this crop rotation: mineral, organic – mineral and organic. The experimental design of fertilization systems – treatments and distribution of fertilizers for the different crops of the rotation are provided in Table 1.

Table 1. Distribution of fertilisers for rotation crops

Fertilisation systems (treatment)	Sugar beet	Spring barley	Perennial grasses of the 1^{-st} year of use	Perennial grasses of the 2^{-nd} year of use	Winter wheat
I. Without fertilisers	-	-	-	-	-
II. Mineral NPK	$N_{120}P_{90}K_{120}$	$N_{30}P_{60}K_{60}$	$P_{50}K_{60}$	N_{60}	$N_{70}P_{40}K_{60}$
III. Organic-mineral	FYM* 40 t ha^{-1} $N_{120}P_{90}K_{120}$	$N_{30}P_{60}K_{60}$	$P_{50}K_{60}$	N_{60}	$N_{70}P_{40}K_{60}$
IV. Organic-mineral	FYM 60 t ha^{-1} $N_{120}P_{120}K_{120}$	$N_{30}P_{60}K_{60}$	$P_{50}K_{60}$	N_{60}	$N_{70}P_{40}K_{60}$
V. Organic-mineral	FYM 80 t ha^{-1} $N_{120}P_{90}K_{120}$	$N_{30}P_{60}K_{60}$	$P_{50}K_{60}$	N_{60}	$N_{70}P_{40}K_{60}$
VI. Organic	FYM 80 t ha^{-1}	-	-	-	-

FYM* - Farmyard manure.

Different rates of farmyard manure (40; 60 and 80 t ha^{-1}) were applied to sugar beets. In the form of mineral fertilisers 1 ha received on average $N_{56}P_{48}K_{60}$ kg per rotation annually. Soil samples were taken in the autumn (after harvesting) from 0-10 and 10-20 cm depth. Agrophysical and agrochemical analyses of soil were done using the following methods: pH_{KCl}-potentiometrically, available P and K in the soil were determined by ammonium lactate (A-L) extraction (Egner et. al., 1960), humus was measured by the method of Tiurin (Safonov, 1987), dry soil bulk density and total porosity according to - N. Kachinsky, the amount of soil <0.25-<5 mm aggregates by Savinov (Nierpin, 1967). The coefficient for determination of soil aggregation characteristics was calculated according to the following formula (Nierpin, 1967):

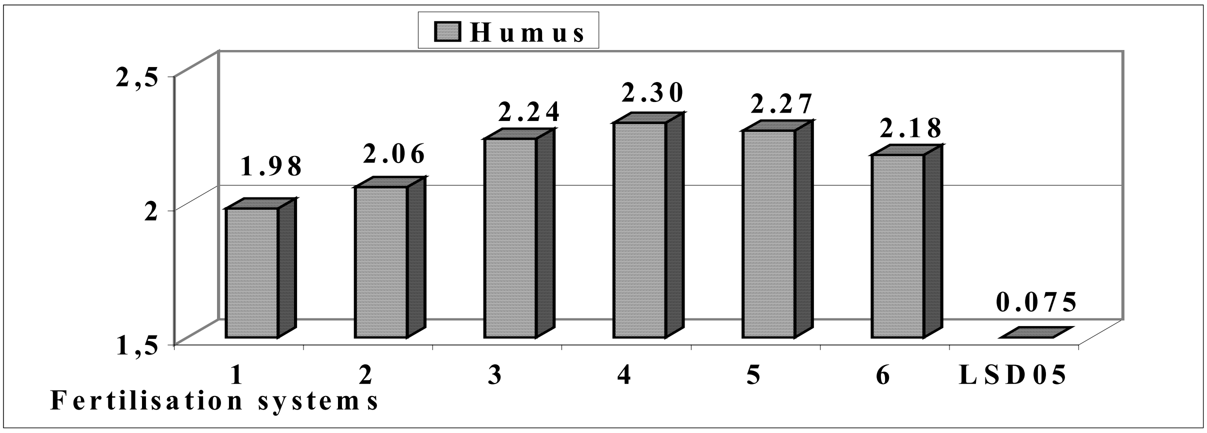
$$C = \frac{\text{content 0.25-5 mm of soil aggregates}}{\text{content of >5 mm aggregates+content of <0.25 mm aggregates}}$$

Environmental conditions. Hydrothermal regimen of the experimental years was characterised having calculated coefficient (HTC) according to Selianinov. The vegetative growth period was optimally wet in 1996 (1.12) in 1997 (1.26) and in 1999 (1.27), wet in 1998 (2.09) and droughty in 2000 (0.90).

Statistics. The experimental data were processed by ANOVA and STATENG (* - 95%, ** - 99% probability level) (Tarakanovas, 1999). Significant differences are presented at 95% probability level.

Experimental results and discussion

Studies carried out at the LIA Joniskelis Research Station on a clay loam soil showed that application of different rates of farmyard manure and mineral fertilisers during the five-course crop rotation resulted in a humus content increase and improvement of agrophysical soil properties. Changes in humus content in the topsoil resulting from the effect of fertilisation systems during the crop rotation are provided in Figure 1.



Fertilisation systems: 1. Without fertilisers; 2. Mineral NPK; 3. Organic (40 t ha^{-1}) – mineral; 4. Organic (60 t ha^{-1}) – mineral; 5. Organic (80 t ha^{-1}) – mineral; 6. Organic 80 t ha^{-1}.

Fig. 1. Effect of fertilisation systems on soil humus content 0-20 cm

In the mineral fertilisation system an average mineral fertilizer rate was $N_{56}P_{48}K_{60}$ the soil humus content, compared with the unfertilised treatment, was by 4.0 % higher. In the organic-mineral fertilization systems application of 40; 60 and 80 t ha^{-1} of farmyard manure and NPK fertilizers, as much in the mineral fertilizations system resulted is the following increases – 0.26-0.32-0.29 percentage units respectively compared with unfertilized treatment. In the

organic – mineral fertilisation system application of 40 t ha^{-1} of farmyard manure resulted in humus content increase in the topsoil by 0.18 percentage units, 60 t ha^{-1} of FYM gave a humus increase of 0.24 percentage units, and 80 t ha^{-1} of FYM – 0.21 percentage units, as compared with mineral fertilisation system. Increasing FYM rates (40, 60 and 80 t ha^{-1}) did not increase humus content significantly. In the organic fertilisation system humus content, compared with the unfertilised treatment, was by 0.20 percentage units higher. When clay loam soil was fertilised only with 80 t ha^{-1} FYM (or 16.0 t ha^{-1} per year) humus content increased by 0.12 percentage units, compared with the mineral fertilisation system.
In various fertilisation systems an increase in humus content had a positive effect on the physical properties of clay loam soil. One of the key parameters determining soil productivity is its structure, therefore seed emergence and development of plants is to a great extent dependent on the structurality of the topsoil and stability of structural aggregates. The least content (46.7 and 45.2 %) of the most valuable structural aggregates in the 0-10 and 10-20 cm layer was found in the treatments without fertiliser use (Table 2). Averaged experimental findings show that during the five – course crop rotation a higher content of agronomically valuable (0.25-5 mm) structural aggregates in the upper topsoil layer (0-10 cm) was present in the organic – mineral fertilisation systems.

Table 2. Effect of fertilisation systems on soil structurality and structural stability. Average of 1996-2000.

Fertilization system	Depth cm	Amount of structural aggregates %			Stable aggregates >0.25 mm %	Structural coefficient
		>5 mm	0.25-5 mm	<0.25 mm		
I. Without fertilisers	0-10	49.2	46.7	4.1	84.3	0.88
	10-20	51.2	45.2	3.6	84.8	0.83
II. Mineral NPK	0-10	44.5	51.2	4.3	85.7	1.06
	10-20	47.9	47.7	4.4	85.5	0.91
III. Organic-mineral	0-10	42.5	54.5	3.0	85.9	1.20
	10-20	46.0	49.3	4.7	86.9	0.97
IV. Organic-mineral	0-10	42.1	54.6	3.3	86.8	1.20
	10-20	46.5	50.2	3.3	86.6	1.01
V. Organic-mineral	0-10	41.7	54.5	3.8	86.2	1.20
	10-20	46.1	50.2	3.7	86.8	1.01
VI. Organic	0-10	43.8	52.6	3.6	87.2	1.12
	10-20	46.8	49.6	3.6	87.6	0.98
LSD_{05}	0-10	1.17	0.76	1.08	1.86	0.047
	10-20	1.69	1.41	1.18	1.91	0.057

In the organic – mineral systems (40, 60 and 80 t ha^{-1} FYM) an increase in soil humus content resulted in a reduction of the content of structural aggregates (>5 mm) in the upper topsoil (0-10 cm) layer by 13.6-14.4-15.2 % respectively and in an increase of the most valuable structural aggregates (0.25-5 mm) by 16.7-16.9-16.7 % respectively, as compared with the unfertilised treatment, and in the deeper (10-20 cm) layer the increase was 9.1-11.1-11.1 % respectively. In the organic – mineral fertilisation systems having applied different rates of manure (40, 60 and 80 t ha^{-1}) and having compared with the mineral fertilisation system we see that in the topsoil layer (0-10 cm) the content of structural aggregates >5 mm declined by 4.5-5.4-6.3 % respectively, while that of the most valuable aggregates increased by 6.4-6.4-6.6 %.

In the organic fertilisation system an increase in humus content in the soil resulted in 12.6 % higher content of the most valuable structural aggregates in the soil, compared with unfertilised treatment and 2.7 % higher content than in the mineral fertilisation system. A strong inverse – linear correlation was established between the content of structural aggregates >5 mm in the topsoil and humus content (y_1=88.078-20.312 x; r=-0.927**) and a strong direct – linear correlation between agronomically most valuable (0.25-5 mm) structural aggregates and structurality and humus content: y_2=2.066+23.147 x r=0.953**. The obtained findings show that with an increase in soil humus content the amount of soil aggregates >5 mm in the topsoil declined, and that of the most valuable ones (0.25-5 mm) increased.

The lowest content of particles (<0.25 mm), that determine manifestation of negative clay soil properties was identified in the organic and organic – mineral fertilisation systems, however, no marked differences between the fertilisation systems were revealed. The highest content of these particles was identified in unfertilised soil and mineral fertilisation system.

In the organic fertilisation system application of 80 t ha^{-1} of farmyard manure resulted in 3.4 % increase in stable soil structural aggregates (>0.25 mm) in the upper topsoil layer, in the organic (60 t ha^{-1}) – mineral fertilisation system –3.0 %, and in the deeper layers of the topsoil their content increased by 3.3 and 2.1 %, as compared with the unfertilised treatment.

In the mineral fertilisation system an average mineral fertiliser rates was $N_{56}P_{48}K_{60}$ the coefficient of structural content, compared with unfertilised treatment, was by 20.5 %, higher. In the organic-mineral fertilisation systems having applied diffent rate of manure (40; 60 and 80 t ha^{-1}) and having, compared with the mineral fertilisation system we see that in the topsoil layer (0-10 cm) the content of coefficient structural increased by 13.2 %, and in the organic fertilisation system – 5.7 %.

In the mineral fertilisation system in the upper layer of topsoil (0-10 cm) physical properties, as compared with unfertilised treatment, changed insignificantly: bulk density declined by 1.4 %, total porosity increased by 1.6 %, and in the deeper 10-20 cm layer bulk density did not change, while soil porosity increased by 1.2 % (Table 3). An increase in the content of organic matter and humus in the topsoil occurred in line with a reduction in the bulk density of topsoil layer and a increase in total porosity.

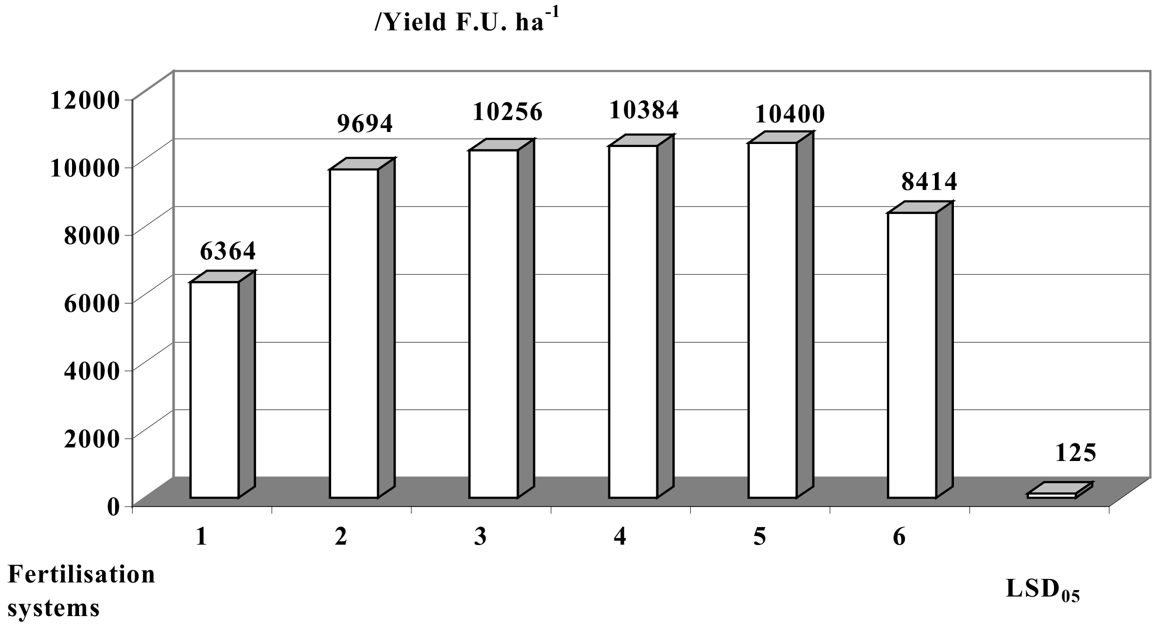
Table 3. Effect of fertilisation systems on soil physical properties. Average of 1996-2000.

Fertilisation systems	Sampling depth cm	Moisture %	Bulk density Mg m^{-3}	Total porosity %
I. Without fertilisers	0-10	15.4	1.48	42.7
	10-20	15.9	1.54	40.6
II. Mineral NPK	0-10	15.8	1.46	43.4
	10-20	15.9	1.53	41.1
III. Organic-mineral	0-10	16.1	1.39	46.4
	10-20	16.1	1.49	42.5
IV. Organic-mineral	0-10	16.3	1.39	46.6
	10-20	16.5	1.52	41.7
V. Organic-mineral	0-10	16.0	1.40	45.7
	10-20	16.1	1.51	42.0
VI. Organic	0-10	15.7	1.40	44.8
	10-20	15.7	1.53	41.3
LSD_{05}	0-10	0.82	0.017	0.68
	10-20	0.78	0.02	0.64

Having applied 40; 60 and 80 t ha^{-1} of farmyard manure and NPK fertilisers in the organic – mineral fertilisation systems the content of humus increased and soil bulk density in the 0-10 cm layer declined by 4.8-4.8-4.1 %, total porosity increased by 6.9-7.4-5.3 % respectively. In the deeper 10-20 cm layer soil bulk density in these fertilisation systems had an insignificant trend of declining and total porosity tended to increase. Having applied different rates of manure (40, 60 and 80 t ha^{-1}) in the organic – mineral fertilisation systems we did not find any significant difference in soil bulk density and total porosity. Having applied 80 t ha^{-1} of farmyard manure in the organic fertilisation system humus content in the topsoil (0-10 cm) layer increased, which consequently decreased soil bulk density by 4.1 % and increased total porosity by 3.2 %, as compared with the mineral fertilisation system.

A strong inverse linear correlation was determined between the bulk density and the humus content in topsoil. This relationship is described by the following regression equation: $y_1=2.071-0.3x$; $r=-0.922^{**}$. Also a strong linear – direct correlation was determined between total porosity and soil humus content. This relationship is described by the following regression equation: $y_2=18.15+12.333x$; $r=0.973^{**}$. The obtained results suggest that with an increase in soil humus content soil bulk density declines and total porosity increases. Application of organic (60 t ha^{-1}) and mineral fertilisers on clay loam soil resulted in 5.8 % higher moisture content in the upper layer of topsoil. In the other organic – mineral fertilisation systems we determined a trend of insignificant moisture content increase in the topsoil layer.

An increase in the humus content in clay loamy soils and an improvement in physical soil properties increased the productivity of crop rotation plants. In the mineral fertilisation system, an average annual mineral fertilised by 52.3 % comparedwith unfertilised treatment (Fig. 2).



Fertilisation systems: 1. Without fertilisers; 2. Mineral NPK; 3. Organic (40 t ha^{-1}) – mineral; 4. Organic (60 t ha^{-1}) – mineral; 5. Organic (80 t ha^{-1}) – mineral; 6. Organic 80 t ha^{-1}.

Fig. 2. Effect of fertilisation systems on the crop rotation productivity

The highest average yield of the crop rotation plants was determined in the organic – mineral fertilisation systems, here the differences were significant and made up 61.2-63.2-63.4 % respectively, as compared with the unfertilised treatment and 5.8; 7.1 and 8.1 % compared with the mineral fertilisation system. In the organic fertilisation system application of only 80 t ha^{-1} of farmyard manure increased the productivity of the crop rotation plants by 32.2 %.

Conclusions

Organic fertilisation on clay loam soil during the five-course crop rotation had a positive effect on the humus content in the topsoil in all the fertilisation systems. In the organic – mineral fertilisation systems (40, 60 and 80 t ha^{-1} FYM) humus content in the topsoil incerased by 0.26-0.32-0.29 percentage units per rotation, and in the organic fertilisation system (80 t ha^{-1} FYM) by 0.20 percentage units, as compared with unfertilised treatment.

In the organic – mineral systems having applied different rates of farmyard manure (40, 60 and 80 t ha^{-1}) and when the soil contained a higher humus content, the content of valuable structural aggregates (0.25-5 mm) in the upper layer of topsoil increased by 3.2-3.4-3.2 percentage units, in the deeper layer by – 1.6-2.5-2.5 percentage units, as compared with the mineral fertilisation system. Having applied 80 t ha^{-1} of farmyard manure in the organic fertilisation system the content of valuable structural aggregates was found to be 2.7 % higher.

The content of stable structural aggregates in the soil increased in the organic fertilisation system having applied 80 t ha^{-1} of farmyard manure and in organic (60 t ha^{-1} FYM) – mineral fertilisation system in the upper layer of topsoil by 3.4 % and 3.0 %, and in the lower layer by 3.3 and 2.1 % respectively, as compared with unfertilised treatment.

Application of different rates of farmyard manure in the organic – mineral fertilisation systems increased humus content in the topsoil layer, which resulted in 4.8-4.8-4.1 %, reduction in soil hulk density and 6.9-7.4-5.3 % increase in total porosity, as compared with mineral fertilisation system. In the organic fertilisation system soil bulk density declined by 4.1 %, and total porosity increased by 3.2 %.

Improvement in humus status in the soil and physical soil properties, resulting from the application of different rates of farmyard manure gave a 61.2-63.2-64.7 % annual yield increase of the crop rotation plants in the organic – mineral fertilisation systems, and a 32.2 % increase in the organic system, as compared with the unfertilised treatment.

References

Balesdent, J., Chenu, C., Balabane, M., (2000): Relationship of soil organic matter dynamics to physical protection and tillage. Soil Tillage Res. 53, 215-230.

Edmedes, D.C. (2003): Title the long term effects of manures and fertilisers on soil productivity and quality. In: Nutrient Cycling in Agroecosystems. 66. 2.165-180.

Egner, H., Riehm, H., Domingo, W.R. (1960): Unfersuchungen uber die chemische Boden-Analyse als Grundlage fur die Beurteilung des Nä hrstoffzustandes der Boden. Kungl.Lantbrukshogskolans Annaler. Vol. 26. P. 199-215.

Eich, D., (1989): Erfahrungen, der LPG Pflanzenprodution Nächst Neundorf bei der Verlorgung der Böden mit organischer substanz. Feldwritschaft. 8, 350-353.

Hofman, G. (1986): Nitrogen supply from some soil types with various organic-matter treatments. Plant Soil. 91.3. 411-415.

Janzen, H., H., (1991): Fertilization promotes soil organic matter. Better, pp.10-11.

Korschens, M., (1999): Soil organic matter and sustainable lande use. Advances in GeoEcology, 31: 423-430.

Lacko – Bartašova, M., Zaujec, A., Števlikova, T., (1999): Effect of ecological and integrated arable farming systems on crop productivity and soil fertility. Designing and Testing Crop Rotations for organic Farming – Danish Research Centre for Organic Farming.- p. 297-304

Maiksteniene, S., (1995): Ivairiu organiniu medziagu poveikis sunkios granuliometrines sudeties dirvu savybems. Zemes ukio mokslai. Nr.3.12-17.

Maiksteniene, S., and Velykis, A., (1994): Improvement of Agrophysical and Agrochemical Heavy Loam Soils Properties by Deep Loosening and Organic Matter. Land and soil protection: ecological and economic consequences. 136-140.

Marinari, S., Masciandaro, G., Ceccanti, B., Grego, S., (2000): Influence of organic and mineral fertilisers on soil biological and physical properties. Bioresource Technology, Vol. 72, 9-17.

Nierpin, S. Čudnovskij, A., (1967): Fizika počvy. Moskva: Nauka, 13-18.

Safonov, A., (1987): K metodikie podgotovki obrazcov počv dlia opredielienija gumus. Gumus ir azot v zemledelii nečernoziemnoj zony RSFSR. Lieningrad, 14-16.

Six, J., Paustian, K., Elliott, E.T., Combrink, C., (2000): Soil structure and organic matter: I Distribution of aggregate-size classes and aggregate-associated carbon. In: Soil Science Society of America Journal, 64. 681-689.

A METHOD FOR CHARACTERIZING THE QUALITY OF TILLAGE IN A LONG-TERM FIELD EXPERIMENT

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Introduction

Soil condition can be examined holistically by considering the chemical, biological, and physical factors affected by tillage. This approach is consistent with the concept of soil quality that has been extensively researched by Karlen et al. (1999). Simply defined, soil quality is the capacity of the soil to function. Tillage has many purposes including the creation of a suitable seedbed for germination and plant growth, incorporation of agricultural chemicals and crop residues, burying weeds, or construction of certain land structures for erosion control. Many of the benefits of tillage are well known, but the amount necessary to achieve optimum soil conditions is not. The tilth or soil condition resulting from the use of different tillage tools depends on both the type of implement used and the soil condition when tillage occurs. At present, it is not possible to consistently predict the resulting soil conditions from any tillage operation (Tapela and Colvin, 2002). Previous attempts to quantify the seedbed conditions following tillage have been made, but it has been difficult to determine which soil physical properties should be used to measure tilth and to characterize the quality of tillage. Researchers often use porosity, bulk density, structure, compaction, particle size distribution, and clod size distribution (Luttrell, 1963; Fragin, 1986; Hakansson, 1990; Steyn and Tolmay, 1995; ESCAP, 1995). Indirectly, the yields measured in the specific tillage treatments and their components as a soil quality indicators are also suitable for qualifying the performed soil operation (Ritchie et al., 1993).
The objectives of this study were to characterize the quality of different tillage methods with the yield of maize plant, as well as with the yield components (plant population, grain weight per plant) and to express the quality of seedbed, covering the soil layer extending to the root depth of plants and specifically the cultivated layer.

Materials and methods

Site and soil characteristics

This study was conducted in 2004, at the Látókép Experimental Station of Center for Agricultural Sciences, Debrecen University (47” 30’N, 21” 36’E, 121m elevation). The soil of the experimental site is lowland pseudomiceliar chernozem (Mollisol-Calciustoll or Vermustoll, silt loam; USDA taxonomy). The experimental station is located at the North-eastern part of the Great Hungarian Plain. The location of the examinations was the multi-factorial long-term field experiment set up the experimental station. The long-term experiment was set up in split-split-plot arrangement. In the main blocks different tillage and irrigation treatments were applied without replication. On the prime sub-blocks maize hybrids were sown at a plant density of 50 and 70 thousand respectively, while on the secondary sub-blocks treatments of fertilization were set up with four replications in random order. Tillage treatments were winter plowing to a depth of 27 cm, spring plowing to a depth of 22 cm and shallow spring disk tillage to a depth of 12 cm. Fertilizers were applied at a rate of 0, 120, 240 kg ha^{-1} N, 0, 90, 180 kg ha^{-1} P, and 0, 106, 212 kg ha^{-1} K. Corn hybrids (LG 2305, Celest (Syngenta), DeKalb AW 043) were sown at a rate of 75,000 kernels ha^{-1} at the end of April. The examinations were carried out on unfertilized and fertilized (N_{120}, N_{240} kg ha^{-1}) plots, in non-irrigated treatments.

Calculations

We have characterized the quality of different tillage methods with the yield of maize plant, as well as with the yield components. We have assumed that the quality of seed bed is well described by the emergence percentage and its deviation. The nutrient supply and water supply capability of the soil in the remaining vegetation period can be characterized by the grain weight per plant and its deviation. Thus we have created the simple mathematical model of maize yields for unit areas, which is as follows:

$$y = xpg \quad (1)$$

where:

y : yield (kg plot^{-1})
x : number of seeds sown (pc.)
p : seedling emergence (%)
g : grain weight per plant (g plant^{-1})

The deviation of yield depends on the variation of seedling emergence percentage (variability) and the deviation of individual production. Deviation for unit area:

$$s_y = \sqrt{\left(\frac{\partial y}{\partial p}\right)^2 s_p^2 + \left(\frac{\partial y}{\partial g}\right)^2 s_g^2} \quad (2)$$

where:

s_y : standard deviation of yield (kg plot^{-1})
s_p : standard deviation of seedling emergence (%)
s_g : standard deviation of grain weight per plant (g plant^{-1})

After performing the partial derivation, we have used the following formulas during calculations:

$$\frac{\partial y}{\partial p} = xg \quad (3)$$

$$\frac{\partial y}{\partial g} = xp \quad (4)$$

Furthermore, we have used the relationships of frequency or the deviation of emergence percentage, which is as follows:

$$s_p^2 = p(1-p) \quad (5)$$

Plant population of maize was determined by counting all plants in each tillage treatment at various stages of development (seedling emergence, silking, maturity). Grain yield was obtained by harvesting the plots with microcombine and corrected to 15.5 % water to allow comparisons. The amount of grain yield per plant and its deviation was determined on the basis of the (1) and (2) relationship.

Data analysis

Statistical analysis for all parameters was performed using the procedures from SPSS for Windows 11.0 computer software package. Analysis of variance was used to examine the effect of tillage on plant population and grain yield and grain weight per plant. The F-test was used to determine significant tillage effects, and the least significant difference test was used to separate treatment means at 5 % level of significance.

Results and discussion

Only comparing yields for unit areas in soil cultivation experiments does not always provide enough information for separating treatment effects. If the elements of expected yield, plant number and individual grain yield production are examined separately then we will get greater reliability than by using a complex or separate evaluation of treatments. Soil cultivation can modify both factors. Below, we have evaluated yield components and their relationships in the average of three maize hybrids.

Grain yield

Favourable, almost optimal weather conditions have resulted in the formation of excellent yield results in 2004. According to the results of examinations, soil cultivation methods set up on the experimental area did not influence the yield of maize significantly. The highest yields – were harvested from the plots where spring plowing was applied, both in fertilized and unfertilized treatments. The yield results of winter plowing and spring shallow tillage in fertilized conditions were only 3-4% less, while on plots with natural nutrient supply yield results were 12-14% less than the values of spring plowing (figure 1.).

Plant density

The formation of maize plant density per hectare was characterized by the seedling percentage in the individual tillage treatments. The depth of soil cultivation, the quality of the seedbed can influence the number of seedling, thus the plant density per unit area. According to our examinations the best quality seedbed, thus the highest ratio of emergence was ensured by winter plowing for maize. In case of spring plowing or shallow, spring disk tillage the field emergence and plant density was lower by only a small degree from that of winter plowing values. Plant density deviation from average values was low in all three tillage treatments. The different tillage methods did not modify the degree of field emergence or plant density significantly, we could not detect a reliable difference among soil cultivation methods (figure 2.).

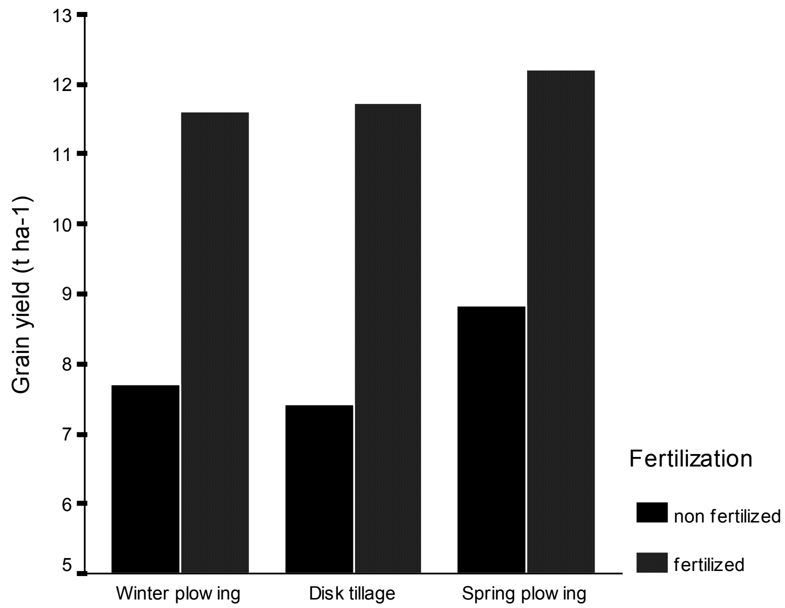

Figure 1. **Effect of tillage and fertilization on grain yield (Debrecen, 2004)**

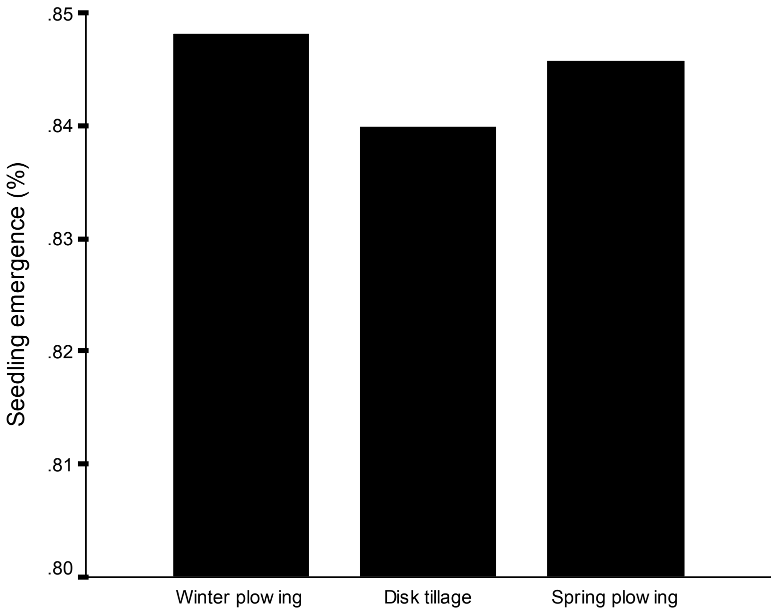

Figure 2. **Effect of tillage systems on seedling emergence of maize (Debrecen, 2004)**

Grain weight per plant

Figures 3 and 4 display the degree of production for maize as well as the deviation from the average in the specific soil cultivation treatments. The highest individual production – similarly to the harvested grain yield per hectare – was measured in the case of spring plowing both in fertilized and unfertilized treatments. We have recorded an almost identical individual production with both winter plowing and shallow, disk tillage, which only differed by a minimal degree from the values of spring plowing. The deviation of individual production was highest in the plots of shallow, disk tillage, while the lowest deviation and thus an even plant stock was registered in the case of ploughed treatments. Deviation values in winter and spring plowing plots did not differ significantly.

Conclusions

In practice, usually the physical characteristics of seedbed and the agronomical structure of soil are taken into account when determining tillage quality. However, weather and soil moisture conditions can significantly modify the values of examinations, thus the values can vary in space and time, making them heterogenous. Indirectly, the yields measured in the specific tillage treatments and their components are also suitable for qualifying the performed soil operation. Only comparing yields for unit areas however does not always supply sufficient information for separating treatment effects. If the elements of expected yield, plant number and individual grain yield production are examined separately then we will get greater reliability than by using a complex or separate evaluation of treatments. Tillage can modify both factors. In our publication we have introduced such a method, which allows for expressing the quality of seedbed, covering the soil layer extending to the root depth of plants and specifically the cultivated layer. Changes caused by the different tillage methods were characterized field emergence, grain weight per plant, grain yield and their deviation measured on plots.

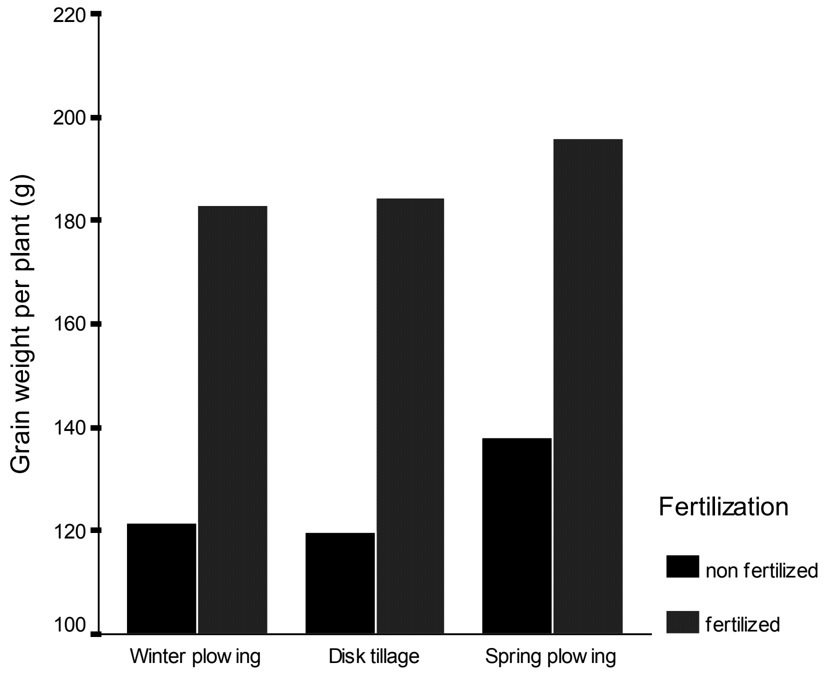

Figure 3. **Grain weight per plant, in the function of tillage and fertilization (Debrecen, 2004)**

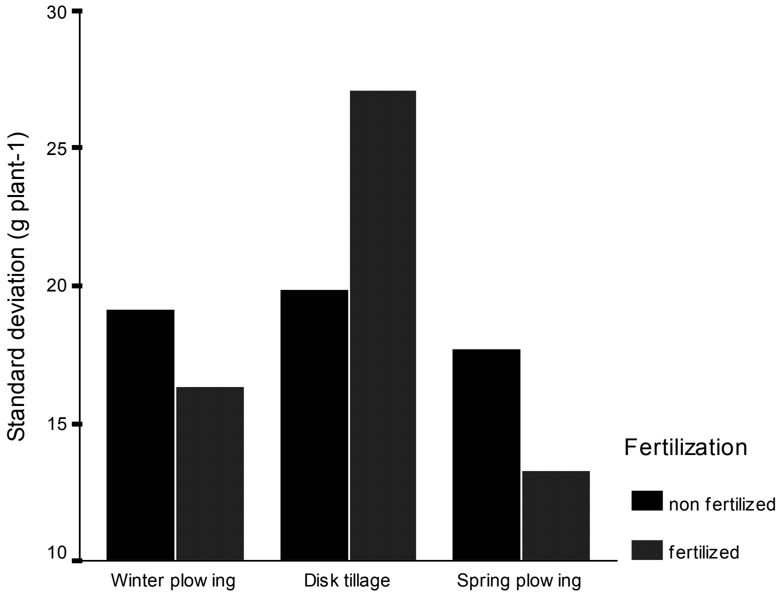

Figure 4. **Standard deviation of grain weight per plant, in the function of tillage and fertilization (Debrecen, 2004)**

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References

ESCAP, 1995. RNAM Test Codes and Procedures for Farm Machinery, 2nd Edition, Technical Series No. 12. Economic and Social Commission for Asia and the Pacific. Regional

Fragin, A.G., 1986. Mathematical–experimental method of estimating the structural state of the soil. Sov. Soil Sci. 18 (3), 125–127.

Hakansson, I., 1990. A method for characterizing the state of compactness of the plough layer. Soil Till. Res. 16, 105–120.

Karlen, D.L., Rosek, M.J., Gardner, J.C., Allan, D.L., Alms, M.J., Bezdicek, D.F., Flock, M., Huggins, D.R., Miller, B.S., Staben, M.L., 1999. Conservation Reserve Program effects on soil quality indicators. J. Soil Water Conserv. 54 (1), 439–444.

Luttrell, D.H., 1963. The effect of tillage operations on bulk density and other physical properties of the soil. Ph.D. Dissertation. Iowa State University, Ames, IA.

Network for Agricultural Machinery. UN-ESCAP, Bangkok, pp. 10–11.

Ritchie, S.W., Hanway, J.J., Benson, G.O., 1993. How a Corn Plant Develops, Special Report No. 48. Cooperative Extension Service, Iowa State University, Ames, IA.

Steyn, J.T., Tolmay, J.P.C., 1995. The effects of tillage systems on soil bulk density and penetrometer resistance of a sandy clay loam soil. S. Afr. J. Plant Soil 12 (2), 86–90.

Tapela, M., Colvin, T.S., 2002. Quantifying seedbed condition using soil physical properties.Soil Till. Res. 64, 203–210.

CONTENTS

COMPARATIVE ANALYSIS OF SELECTED PARAMETERS OF THE TOPSOIL STRUCTURE IN A LONG-TERM CONVENTIONAL TILLAGE AND DIRECT DRILLING

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Abstract

The performed investigations showed a distinctly more advantageous influence on the parameters of the aggregate structure of the direct drilling in comparison with the conventional tillage. At similar dynamic and static water resistance of aggregates their secondary aggregation turned out more advantageous as the sum of aggregates bigger than 0.25 mm increased by about 10% in the case of direct drilling. In the overall balance, also the water properties improved – maximum water holding capacity increased, on average, by over 3%. After a 9-year long maize experiment, it turned out that the content of humus in the aggregates collected from plots cultivated in the direct drilling was, on average, by about 0.14% and the porosity – by about 5.5% higher than on plots cultivated in traditionally.
Key words: soil structure, conventional tillage (CT), no-till (NT), direct drilling, water resistance, secondary aggregation, water capacity.

Introduction

Global deficit as well as the systematic, continuous increase of energy prices but also various factors associated with the protection of natural environment made it necessary to search for other pro-ecological and, at the same time, economically profitable technologies of soil cultivation [Radecki 1986; Dzienia and Sosnowski 1990; Dzienia 1995; Malicki et al., 1996]. The experiments and investigations conducted so far indicate that there is a wide spectrum of possibilities to reduce the depth and frequency of ploughings and their replacement by other tools, including direct drilling. Factors affecting the success or failure of no-till operations include: the type of soil, its compaction, structure and content of organic matter [Gantzer and Blake 1978; Blevis et al., 1984; Rassmusen 1997; Ne Smith et al., 1987; Hargrove 1990; Tollner et al., 1984]. The aim of the performed investigations was to compare the impact of two cultivations systems – conventional tillage and direct drilling – of some structural parameters of the topsoil in the result of using specialised research methods of natural structures in strictly controlled conditions.

Research object and methods

The experimental object was established in the Swadzim Experimental Station near Poznań on the experimental field of the Department of Plant Cultivation at the Poznań Agricultural University (series ll) on which, for 9 years, maize was in the monoculture system was cultivated. From selected plots, 1 cm^3 aggregates were collected from the depth of 7.5 and

22.5 cm in which the following physical-mechanical properties were analysed: compaction, static and dynamic water resistance, secondary aggregation after static and dynamic water action and capillary water capacity, i.e. parameters that characterise the condition of the soil aggregate structure [Rząsa and Owczarzak 1983, 2004]:

- dynamic water resistance of soil aggregates (DW) – the determination consisted in the measurement of energy needed to break up the soil aggregate of V = 1 cm^3 by impacts of falling water drops of 0,05 g weight from the height of 1 m (kinetic energy of 1 drop - E= $4.905 \cdot 10^{-4}$ J),
- static water resistance of soil aggregates (SW) – the measurement of this trait consisted in the determination of the time of break up ("time of waterlogging") of aggregated immersed in water,
- state of secondary aggregation after the dynamic (Adw) and static (Asw) water action – this was determined by the wet sieve method on a set of sieves with the following mesh diameter: 7, 5, 3, 1, 0.25 and 0.25 mm. Sieves were immersed in a container with water where aggregates were segregated into fractions.
- the speed of the capillary rise and the capillary water capacity connected with it was determined on a special filtration set, where the time of the minimum capillary rise (Tkmin) corresponded to the moment of wetting of the top surface of the cylinder-shaped aggregate and that of the maximum (Tkmax) – to the moment when convex menisci appeared on the top aggregate surface. At the above states of aggregate water saturation, their minimal (Vkmin) and maximal (Vkmax) water capacities were determined.

In addition, soil texture by the Prószyński aerometric method as well as the content of organic matter by the Tiurin method were determined in the collected soil samples [Mocek et al., 2000].

Results and discussion

The topsoil structure, including its aggregate structure, belongs to the soil properties which are exceptionally diverse and varied both in time and space [Rząsa and Owczarzak 2004]. Already at the moment when the soil mechanical tillage is performed, soil compaction and moisture content in the soil near the surface vary in comparison with the lower zone of this layer and completely different in comparison with the humus surface which does not undergo cultivation. However, towards the end of the vegetation season, these two different states of the three-phase soil medium reach a similar compaction – in the case of the traditional tillage. On the other hand, opinions differ when we compare compaction states of soils cultivated traditionally and in the direct drill system; some researchers maintain that soils exhibit less compaction i.e. higher porosity when cultivated traditionally [Khalilian et al., 1988; Triplett 1988], while others claim that direct drilling, which increases organic matter content and improves the soil structure of the root zone, results in lesser compaction and, consequently, increases porosity [Broder et al., 1984; Doran 1980; Hargrove 1990].

The surface of the experimental field (series ll) is characterised by very uniform texture; the concentration of the colloid fraction (<0.002 mm) ranged from 4.5 - 5.5%, of the dust fraction (0.05-0.002 mm) – from 15.5 – 17.5%, both in the case of plot cultivated traditionally and those with the direct drilling. Differences were observed with regard to the organic matter content; in the case of plots cultivated traditionally it ranged from 1.29-1.52% whereas in the case of direct drilling – 1.47-1.65% (Tab. 1).

The performed experiments showed differences in physical-mechanical properties of the aggregate structure developed in the traditional tillage and direct drilling. The obtained research results confirmed those opinions which reported more advantageous physical and chemical properties of the topsoil structure when direct drilling was applied [Pudełko et al.,

1994]. In the case of this method of cultivation, the examined top soil layers – apart from a distinctly higher humus content (by about 0.14%) – also revealed significantly lower density (about 0.145 $g \cdot cm^{-3}$) and, consequently, higher porosity (about 5.5%).
The observed higher organic matter content and higher porosity decreased considerably (about 15%) the dynamic water resistance but increased slightly (about 5%) the static water resistance of the aggregates collected from the fields with the direct drilling. The result of the dynamic and static action of water is the break-up of primary aggregates into secondary aggregates. Aggregates collected from the plots with the direct drilling revealed a distinctly more advantageous secondary aggregation, both after the dynamic and static water action. The sum of aggregates exceeding 0.25 mm increased by about 8.5-10.0% (Fig 1). At the same time, in this method of cultivation, new larger secondary aggregate fractions developed (>7 mm), while the percentage content of the fraction with dimensions 7-5 mm more than doubled. In general, the mean percentage content of the remaining aggregate diameters increased from 0.6 to 5.4%. As a rule, irrespective of the method of tillage, aggregates collected from the depth of 7.5 cm were characterised by a more favourable aggregation.

Less apparent differences between the analysed ways of soil cultivation were found when water properties of the aggregates were examined (Tab. 1). The time of the capillary rise – to achieve minimal capillary capacity – was, on average, shorter. The time of water relocation caused that the aggregates collected from the plots with direct drilling consumed about 2.3% less water than the aggregates collected from the experimental plots cultivated traditionally. The fact that the aggregates from the direct drilling absorbed water more slowly can be attributed to the higher humus content which markedly (by about 5%) increased their porosity. It is probable that the amount of macro-pores increased and, consequently, the front of moistening on the capillary walls became longer. This was confirmed by the obtained results if studies of the maximum water capacity. When determining this trait, the time of capillary rise – determined on the level of 4 hours – was sufficiently long for both types of aggregates to absorb maximum quantities of water. In this case, it turned out that aggregates collected from the plots with the direct tillage were characterised by a slightly higher (by about 3.2% by vol.) capacity.
When assessing water properties, it is important to pay special attention to the dynamics of moistening changes in both cultivation systems. In traditional tillage, following loosening and relocation of soil, it is aerated much better but this entails considerable losses of moisture. At the present stage of investigations it is difficult to say what – in the total water balance of the topsoil – is better: a slightly worse soil retention capacity or greater water losses as the result of faster evaporation. The results of investigations of the capillary rise and capillary water capacity indicate that, in the case of direct drilling, the evaporation will be smaller because of the smaller rate of moistening and water relocation in the surface layer.

Conclusions

1.The aggregate structure of the topsoil is strongly diversified and changeable in time and space. This is caused by the fact that this layer is shaped in the course of the year by many equally changeable outside factors.
2. The obtained research results confirmed earlier observations and opinions that more advantageous physical and also some chemical properties of the topsoil structure occurred in the no-till system, i.e. in the case of direst drilling.
3.In the case of 9-year long maize monoculture cultivation, a marked improvement in direct sawing was observed in specific properties of the aggregate structure, such as static water resistance but primarily the amount and fraction distribution of secondary aggregates both under dynamic as well as static water action.

References

Blevis R.L., Smith M.S., Thomas G.W.(1984) Changes in soil properties under no-tillage. In: No-tillage agriculture. Principles and practices. Red R.E. Philips, S.H. Philips. Van Nonstrand Reihold, New York. .

Broder M.W., Doran J.W., Peterson S.A., Fenster C.R. (1984): Fallow tillage influence on spring populations of nitrifiens, denitrifiens and available nitrogen. Sopil Sci AM. J. 48: 1060-1067.

Doran J.W. (1980): Soil microbial and biochemical changes associates with reduced tillage. Soil Sci. Soc. Am. J. 44: 765-771.

Dzienia S. (1995): Possibilities of application of direct drilling on the good rye-complex soil in the climatic conditions of the Western Lake District. Rocz. Nauk Roln. Ser. A 109, 2: 157-1759 (in Polish).

Dzienia S., Sosnowski A. (1990): Simplifications in the basic soil cultivation and the level of energy expenditure. Fragm. Agron. 3: 71-79. (in Polish).

Gantzer C.J., Blake G.R. (1978): Physical characteristic of Le Sueur clay loam soil following no-till and conventional tillage. Agron. J. 70: 853-857.

Hargrove W.L. (1990): Role of conservation tillage in sustainable agriculture. Proc. South Cons. Til. Conf. Sp. Bul. 90-1: 28-34.

Khalilian A., Hood C.E., Palmer J.H., Holbrook F. (1988): Interseeding conservation system: compaction and plant response. Proc. 1988 South Cons. Til. Conf. sp. bul. 88-1: 34-37.

Malicki L., Nowicki T., Szwejkowski Z. (1996): Soil cultivation in different management systems. In: Agrotechnical factors in sustainable farming. Mat. Kont. Olsztyn 27-28 czerwca 1996: 40-62 (in Polish).

Mocek A., Drzymała S., Maszner P. (2000): Genesis, analysis and soil classification. Wyd. AR, Poznań (in Polish).

Ne Smith D.S., Radchiffe D.E. Hargrove W.L., Clark R.L. Tollner E.W. (1987): Soil compaction in doublecropped wheat and soybeans on a Ultisol. Soil. Sci. Soc. Am. J. 51: 183-186.

Pudełko J., Wright D.L., Wiatrak P. (1994): Conservation tillage in United States of America. Post. Nauk Roln. 1:153-162 (in Polish).

Radecki A. (1986): Study of possibilities of direct drilling on the Phaozems. Wyd. SGGW-AR, Warszawa (in Polish).

Rassmusen K.J. (1997): Impact of reduced soil tillage on yield and soil quality – a Scandinavian review. Fragm. Agron. (Proc. 14th ISTRO Conf. Puławy) 2B: 551-555.

Rząsa S. Owczarzak W. (1983): Modelling od soil structure and examination methods of water wesistance, capillary rise and mechanical strength of soil aggregates. Ann. Pozn. Agric. Univ. Sci Diss. 135.

Rząsa S. Owczarzak W. (2004): Structure of mineral soils. Wyd AR, Poznań (in Polish).

Tollner E.W., Hargrove W.L., Langdole G.W. (1984): Influence of conventional and no-till practices on soil physical properties in the Southern Piedmont. J. Soil Water Conserv. 39: 73-76.

Triplett G.B. (1988): The tillage revolution and the impact of conservation mandats in the southern region. Proc. 1988 South Cons. Til. Conf.sp. bul. 88-1: 1-5.

Tab.1. Basic physical and chemical properties and dynamic (DW) and static (SW) water resistance and capillary water capacity (Vkmin, Vkmax) of soil aggregates in the conventional tillage and direct drilling

Tillage: A – conventional C - direct drilling	Depth of aggregates sampling (cm)	Fraction content (%)		Organic matter (%)	Bulk density ($g \cdot cm^{-3}$)	Porosity (%)	DW		SW	Time of capillary rise Tkmin */ (s)	Water capacity (% v/v)	
		0,05-0,002 mm	< 0,002 mm				Number of drops	Energy $J \cdot 10^{-2}$	Desintegration time (s)		Vkmin	Vkmax
A1	7,5	17,0	5,5	1,52	1,695	35,1	44	2,16	762	20	31,58	42,61
A1	22,5	17,5	5,0	1,43	1,686	35,4	40	1,96	701	13	29,98	39,05
A2	7,5	15,5	4,5	1,38	1,680	35,6	41	2,01	692	24	28,16	41,70
A2	22,5	16,0	5,5	1,29	1,652	36,7	37	1,81	593	17	28,96	45,13
averages		16,5	5,1	1,41	1,678	35,7	41	1,99	687	19	29,67	41,98
C1	7,5	16,0	5,5	1,65	1,482	43,1	36	1,77	707	19	25,44	46,12
C1	22,5	15,5	5,5	1,47	1,556	40,4	34	1,67	615	14	26,30	42,15
C2	7,5	15,5	5,5	1,56	1,527	41,5	37	1,81	746	18	29,20	48,45
C2	22,5	17,5	5,0	1,50	1,568	39,9	32	1,57	818	16	28,48	43,97
averages		16,0	5,4	1,55	1,533	41,2	35	1,71	722	17	27,36	45,18
% of increase (+) or decrease (-)				+9,9	-8,6	+15,4	-14,6	-14,1	+5,1	-10,5	-7,8	+7,6

***/ period of maximal capillary rise 4h (14 400s)**

ACTUAL ABERRATION OF TOPSOIL BASAL RESPIRATION IN CENTRAL MORAVIA

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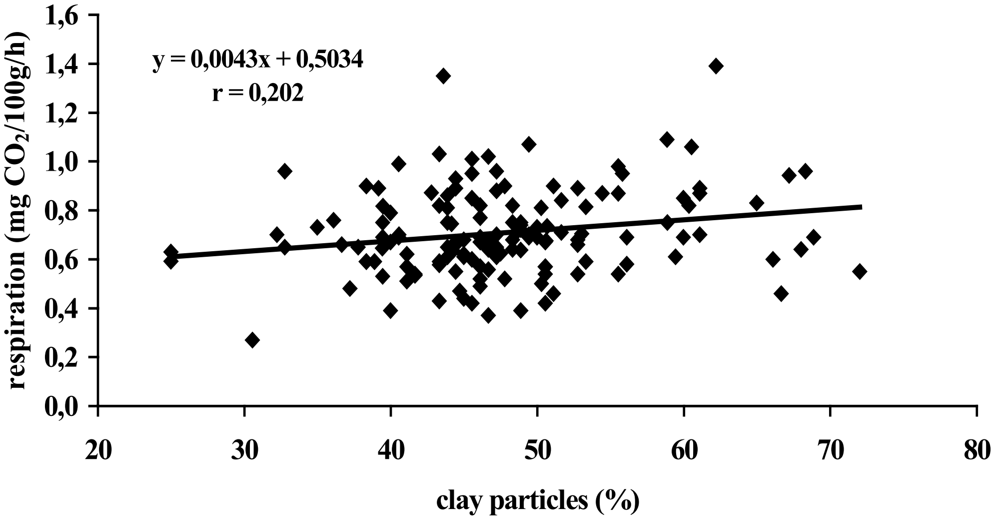
Introduction

Soil aberration can be described as markedly distinct status in comparison with initial average (“normal“) characters and properties. (BEDRNA, 2002). However, exact determination of the term “normal”, which is commonly used in biological sciences, is not available in literature. Its frequent use evidences that it is almost impossible to avoid. The uncertain definition is due to the fact that its hidden prerequisites have not been elucidated yet. VÁCHA (1980) pointed out that practical achievements of special sciences do not avoid uncertainties in their basic concepts, however determination of normal values is considered to be the most important. The method according to HOFFMANN (1963), who assumes that total distribution is a sum of two Gaussion distributions corresponding with healthy/quality and disturbed subsets, was used to assess topsoil aberration.

Material and methods

In 2000-2003, soil samples of Luvi-haplic Chernozem, Orthic Luvisols and Albic Luvisols (NĚMEČEK et al., 2001) were taken from texture-differing fields (n = 144) used as arable land in the region of central Moravia. The undisturbed soil samples were taken from the depth of 15-20 cm using Kopecký´s physical cylinders and the disturbed samples were collected from the soil profile 0-30 cm at the same spot. Soil texture was analysed by the areometric (densimetric) method Casagrande (JANDÁK, 1991), when content of clay particles (< 0.01 mm) was used. Besides physical properties, the samples were analysed for cation exchange capacity (CAC), humus content and quality ($Q_{4/6}$), actual (pH/H_2O) and exchange (pH/KCl) reaction, phosphorus content (according to Egner) and substrate-induced respiration was measured by a method of aerobic incubation of homogenized soil samples at their natural moisture and temperature 28 °C for 24 hours by interferometer (NOVÁK, 1964). The obtained results were statistically assessed, homogeneity of sets was verified and highly significant correlation was confirmed between values of basal respiration and soil texture. Therefore, soil texture was used in further evaluation like the so-called “big factor” (LÁT, 1972). When it was eliminated, two groups of subsets were formed for each property and subjected to the monofactor analysis. To elucidate the effects on basal respiration, methods of correlation, path and partial analyses, and multiple correlation coefficients were used (KOSCHIN et al., 1992).

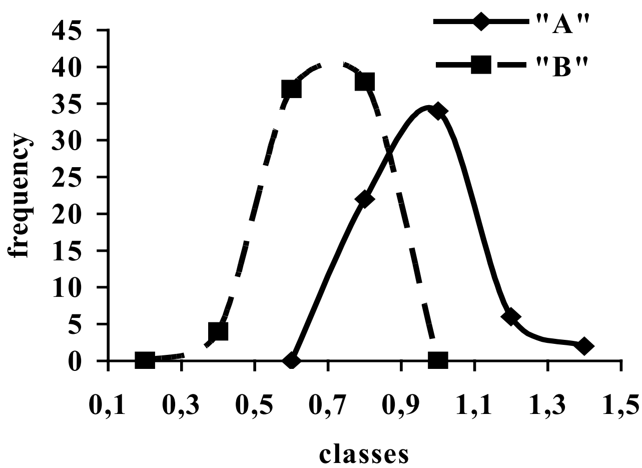
Graph 1: **Relationship between clay particles and basal respiration**



Results and discussion

Values of basal respiration of the topsoil closely correlate with soil texture (McKibbin and Gray, 1932, McGinn and Akinremi, 2001 2001), which was statistically confirmed in our set and used for dividing the set (Graph 1).
A subset of points situated above a regression line was designated "A" (values of basal respiration are, after eliminating the effect of soil texture, the values higher than a mean value of the set and a subset of points lying below the line were designated "B". Values of basal respiration in generated subsets were assessed using the monofactor analysis (Graph 2).
Other examined properties were evaluated in these subsets (Table 1). They were selected using the correlation analysis.

Graph 2: **Basal respiration value distribution in "A" and "B" subsets**



Graph 2 and Table 1 demonstrate that subset "B" exhibits both less asymmetry and excess than subset "A". The values of asymmetry and excess are significant (Rod, 1966). This finding corresponds with Hoffmann´s opinion (1963) concerning Gaussion distributions conforming the healthy/quality and disturbed subsets. Based on his method, we can state that subset "A" is more disturbed than subset "B", and higher values of basal respiration do not necessarily mean that the soil quality is higher. In spite of the fact that similar findings were reported by a number of authors (Němeček, 1990, Novák, 1969), they have not been generalised yet, and biological tests, though referred to as one of main diagnostic methods for soil quality/health (DORAN and PARKIN, 1994), are difficult to use due to high variability in results and their relationships with actual conditions (SÁŇKA, MATERNA, 2004).

Likewise, it is also interesting to compare data obtained for the other properties in the two subsets (Table 1). In the higher-quality subset "B", statistically significant higher humus quality (HA/FA is "B" - 0.69 vs. "A" – 0.56) and higher, statistically insignificant, humus content, higher sorption capacity and a factor of complex influence of carbon and nitrogen ("f"). On the contrary, in subset "B" less favourable physical properties were found (statistically insignificant). The two subsets have identical content of clay particles ("A" – 47.5%, B – 47.8%), which documents homogeneity of the set that is undisturbed by its dividing.

To recognise interrelationships among the examined properties within subsets and a level of their self-regulation ability in greater detail, the results were subjected to partial, path and multiple correlation analyses. They revealed effects of individual properties on a level of basal respiration. Independent variables were selected using correlation analysis (content of clay particles, water capacity, humus quality, saturation of sorption complex, and respiration with glucose addition) (Table 2).

Table 1 – **Results of statistical analysis of subsets ”A” and “B”**

Property	**Bulk density**		**Humus content**		**Humus quality**		**Sorption capacity**	
	(g/cm³)		*(%)*		*(HA/FA)*		*(mmol/kg)*	
Subset	“A“	“B“	“A“	“B“	“A“	“B“	“A“	“B“
Average	1.459	1.471	2.244	2.418	0.559	0.686	211.341	223.942
Error of mean value	0.018	0.015	0.106	0.089	0.032	0.035	6.710	5.518
Median	1.450	1.475	2.070	2.400	0.510	0.740	202.000	214.500
Mode	1.450	1.620	2.020	1.580	0.740	0.870	194.000	200.000
Standard deviation	0.143	0.137	0.845	0.782	0.254	0.305	53.262	48.730
Variance of selection	0.020	0.019	0.714	0.612	0.064	0.093	2836.870	2374.565
Kurtosis	-0.045	-0.432	-0.243	-0.143	**-0.973**	**-1.031**	3.988	1.060
Skewness	0.047	-0.366	0.405	0.223	**0.194**	**-0.138**	1.587	0.790
F-calculated		0.264		1.598		7.073		2.144
F-critical		0.608		3.909		3.909		3.909
P value		3.909		0.208		**0.009**		0.145
Property	**Minimum air content**		**Factor of complex influence of carbon and nitrogen**		Clay particles		**Basal respiration**	
	(%)		*(f)*		*(%)*		*(mg CO_2/100 g/h)*	
Subset	“A“	“B“	“A“	“B“	“A“	“B“	“A“	“B“
Average	6.024	5.146	2.033	2.216	47.455	47.844	0.860	0.592
Error of mean value	0.358	0.285	0.089	0.318	1.130	0.927	0.018	0.011
Median	5.320	4.625	1.904	1.795	46.650	46.650	0.850	0.605
Mode		2.310			48.870	50.530	0.750	0.690
Standard devitation	2.839	2.518	0.708	2.807	8.973	8.187	0.144	0.094
Variance of selection	8.058	6.339	0.501	7.880	80.515	67.019	0.021	0.009
Kurtosis	0.856	0.853	2.240	61.601	0.029	1.513	**3.380**	**1.005**
Skewness	1.133	1.013	0.897	7.534	0.230	0.653	**1.376**	**-1.014**
F-calculated		3.780		0.253		0.072		177.851
F-critical		3.909		3.909		3.909		3.909
P value		0.054		0.616		0.789		**0.000**

The results of statistical analyses show that respiration is affected most by the content of clay particles (14.1%) in subset “A”. A significant relationship was found between basal respiration and respiration with glucose addition (8.2%), which evidences a lack of physiologically available organic substances in the samples of subset “A”. The presented relationships were confirmed by correlation, path and partial coefficients. The significance of the effect of field water capacity and sorption complex saturation was proved by a correlation coefficient only.

In subset “B”, no multivariate analysis confirmed any dependence of basal respiration on the examined factors. The dependence of basal respiration values on the content of clay particles and field water capacity was confirmed by 1st-degree correlation coefficient.

Results of correlation analyses showed that basal respiration in subset “A” is dependent on the factors under study more than in subset “B”. That proves a failure in self-regulation abilities in subset “A”. Measurable characteristics are higher asymmetry and excess in frequency distribution of measured values in the disturbed subset. Better self-regulation abilities in subset “B” were documented by both characteristics of one variable and correlation analysis.

Table 2 – **Statistical analysis of the effect of selected parameters on the extent of basal respiration in "A" and "B" subsets (significant coefficients are in bold)**

Subset "A"				
Parameter	**Correlation coefficients**	**Path coefficients**	**Partial coefficients**	**% of total effect**
Clay particles	**0.403**	**0.349**	**0.295**	14.10
Field water capacity	**0.331**	0.077	0.075	2.60
Humus quality	-0.101	-0.199	0.219	2.00
Saturation of sorpt. complex	**0.333**	0.125	0.132	4.20
Respiration with glucose	**0.300**	**0.272**	**0.301**	8.20
	Multiple coefficient **0.556**			**Total effect** *(%)* 31.10
Subset "B"				
Parameter	**Correlation coefficients**	**Path coefficients**	**Partial coefficients**	**% of total effect**
Clay particles	**0.247**	0.107	0.084	2.60
Field water capacity	**0.267**	0.189	0.149	5.00
Humus quality	0.046	-0.004	0.004	0.02
Saturation of sorpt. complex	0.185	0.181	0.187	3.34
Respiration with glucose	0.140	0.048	0.050	0.06
	Multiple coefficient 0.343			**Total effect** *(%)* 11.02

Conclusions

The HOFFMANN´s method (1963) was used to evaluate the set of values (n = 144) of basal respiration of topsoils from central Moravia assessed according to NOVÁK AND APFELTHALER (1964). The set was, after elimination of the so-called "big factor" that was soil texture, divided into two subsets for which basic statistical parameters were calculated. It was demonstrated that the subset with higher values of basal respiration ("A") was disturbed. It exhibited higher asymmetry and excess (aberration), and a level of respiration markedly depended on soil texture, content of physiologically available organic substances and sorption complex saturation. Self-regulation abilities of the soil environment were disturbed. As for frequency distribution, the subset with lower average respiration ("B") was closer to normal distribution. Multivariate analyses of this subset did not confirm any significant relationships between basal respiration and factors affecting it. That corresponds with properties of dynamically balanced, i.e. undisturbed system. The presented method is a demonstration (using an example of basal respiration) of possibilities of evaluating results of soil properties for determination of aberrations, and thus quality/health of the soil environment.

References

Bedrna, Z. (2002): Environmentálne pôdoznalectvo. Veda, Bratislava, 352 pp.

Doran, J.W., Parkin, T.B. (1994): Methods for assessing soil quality. In: Defining soil quality for sustainable environment. SSSA special publication number 35. SSSA, Inc., American Society of Agronomy, Inc. Madison, Wisconsin, USA, 1994, 3 - 21

Hoffmann, R.G. (1963): JAMA, 185: 864 – 873

Jandák, J. (1991): Cvičení z půdoznalství. VŠZ, Brno, 213 pp.
Koschin, F. et al. (1992): Statgraphics. Grada, Praha, 349 pp.
Lát, J. (1972): Normalita osobnosti. Avicenum, Praha, 22 – 54
Lhotský, J. (1994): Kultivace a rekultivace půd. VÚMOP, Praha, 198 pp.
McGinn, S.M., Akinremi, O.O. (2001): Carbon dioxide of a crop-fallow rotation in western Canada. Canad. Jour. of Soil Sci. 81 (1):121 – 127
McKibbin, R.R., Gray, P.H.H. (1932): Chemical and microbiological factor in some Quebec soil. Canad J. Res. (7): 300 - 327
Němeček, J. et al. (2001): Taxonomický klasifikační systém půd České republiky. ČZU, Praha 2001, 79 pp.
Němeček, J., Smolíková, L., Kutílek, M. (1990): Pedologie a paleopedologie. Academia, Praha, 546 pp.
Novák, B. (1969): Respirace vzorků z profilů hlavních půdních typů. Rostlinná výroba 15: 151 - 155
Novák, B., Apfelthaler, R. (1964): Příspěvěk k metodice stanovení respirace jako indikátoru mikrobiologických pochodů v půdě. Rostlinná výroba 10: 145 – 150
Sáňka, M., Materna, J. (2004): Indikátory kvality zemědělských a lesních půd v ČR. MŽP Praha, Planeta 11/2004, 84 pp.
Vácha, J. (1980): Problém normálnosti v biologii a lékařství. Avicenum, Praha, 178 pp.

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EFFECT OF DIFFERENT SOIL TILLAGE SYSTEMS AND CROP RESIDUE MANAGEMENT ON GRAIN YIELD AND QUALITY IN SPRING BARLEY

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Abstract

In the years 2002 – 2004 the effect of different tillage systems and crop residue management on yield and quality of spring barley following sugar-beet, grain maize and winter wheat was evaluated. The results suggested the suitability of shallow cultivation for spring barley following winter wheat and sugar-beet (shallow incorporation in the soil of winter wheat straw and sugar-beet tops). If spring barley follows grain maize appears to be more efficient turning under of maize straw by ploughing.
With shallow incorporation of crop residues, there was also a positive effect of the preparation BETA-LIQ (promoting breakdown of organic substances), which resulted in higher yields of spring barley after winter wheat. Some effect was also evident in spring barley following sugar-beet and grain maize.
Key words: soil tillage, crop residue management, spring barley, yield, quality

Introduction

Spring barley is the most important spring cereal crop in the Czech Republic. It is a short-season crop, which requires good physical condition of the soil, an adequate supply of air and available nutrients in the soil and appropriate planting dates. The soil tillage and planting system is an important part of cereal cultivation. It affects basic components of stand density and spacing i.e. future conditions for yield formation and its quality. Yield structure influences the utilization of crop production factors. In spring cereals there are very few possibilities (agronomy practices) of compensating for poor stand establishment, therefore the right stand establishment is essential for their successful cultivation.
The tillage system for spring barley must be dependent on site conditions and the preceding crop. The research results in the area of the impact of different soil tillage management on the spring barley yields show the dependence on soil and climatic conditions. Better conditions for utilizing minimum technologies are in dryier and warmer areas (Cannell and Hawes 1994, Malhi et al. 1992, Borresen 1999, Arshad and Gill 1997, Riley 2005 and others). The most favourable conditions for minimum tillage in the Czech Republic are medium heavy structural soils in maize and sugar-beet growing regions. Good results with minimum tillage were achieved when spring barley followed sugar-beet or winter wheat under better soil climatic conditions, even with straw incorporation in the soil. The problems with minimum tillage occurred when spring barley followed grain maize and when large amounts of crop residues (maize straw) were left in the field.

Material and methods

To study the effect of different tillage systems and crop residue management on the yield and quality of spring barley after grain maize and sugar-beet, a small-plot trial was established at the Žabčice locality (gleic fluvisol, maize growing region). For evaluation of different tillage systems and straw management on the yield and quality of spring barley after winter wheat a long-term trial conducted at Troubsko near Brno (chernozem, sugar-beet growing region) was used.
A field trial at Žabčice was established with a long-plot design and 4 replications. The trial involved the Kompakt variety, and the planting rate was 4.5 millions of viable seeds/ha^{-1} in all treatment. The soil on the experimental site was clay-loam, the supply of available phosphorus, potassium and magnesium was good, and the soil reaction was slightly acid.

Treatments – Žabčice, sugar-beet as a preceding crop:
1. Ploughing to a depth on 0.22 m
2. Shallow cultivation to a depth on 0.12 m
3. Shallow cultivation to a depth on 0.12 m, application of BETA-LIQ (1 t.ha^{-1}) to beet tops.

Beet tops were turned under in all treatments. Fertilizer application was identical in all treatments: 60 kg.ha^{-1} N, 85 kg.ha^{-1} P_2O_5 and 125 kg.ha^{-1} K_2O. After determination of nutrients in mineral fertilizers some corrections associated with nutrient contents in BETA-LIQ were made.

Treatments – Žabčice, grain maize as a preceding crop:
1. Ploughing to a depth on 0.22 m
2. Shallow cultivation to a depth on 0.12 m
3. Shallow cultivation to a depth on 0.12 m, application of BETA-LIQ (2 t.ha^{-1}) to maize straw.

Fertilizer application was identical in all treatments: 60 kg.ha^{-1} N, 85 kg.ha^{-1} P_2O_5 and 120 kg.ha^{-1} K_2O. After determination of nutrient rates in mineral fertilizers some corrections associated with nutrient contents in BETA-LIQ were made.

An on-site small-plot field trial was established in a sugar-beet growing region on a plot of the Forage Crops Research Institute at Troubsko (at an altitude of 270 m) with a long plot design and 4 replications. Since the year 1997 studies have been carried out with a 6-field crop rotation (pea, winter wheat, spring barley, winter rape, winter wheat, winter wheat) of the effect of different tillage systems and straw management on crop yields and changes in soil environment. The effect of experimental factors on spring barley yields and quality has been evaluated since the year 2002. The trial involved the spring barley variety Kompakt. The sowing rate was 4.5 millions of viable seeds/ha^{-1} in all treatments. The soil on the experimental plot is loamy, the supply of available phosphorus, potassium and magnesium is good, and the soil reaction is slightly acid.

Tillage and straw management treatments:
1. Straw incorporated in the soil with a soil loosener to a depth on 0.12 – 0.15 m, ploughing to a depth on 0.22 m, seeding with a combine drill
2. Straw incorporated in the soil with a soil loosener to a depth on 0.12 – 0.15 m, seeding with a combine drill
3. Straw incorporated in the soil with a soil loosener to a depth on 0.12 – 0.15 m, seeding with a sowing exactor
4. Straw harvest, cultivation with a soil loosener to a depth on 0.12 – 0.15 m, seeding with a combine drill

5. Straw burning, cultivation with a soil loosener to a depth on 0.12 – 0.15 m, seeding with a combine drill
6. Application of BETA-LIQ (1.5 $t.ha^{-1}$) to straw and its incorporation in the soil with a soil loosener to a depth on 0.12 – 0.15 m, seeding with a combine drill

After winter wheat and spring barley harvest all six treatments were involved. After rape and pea harvest there is no straw harvest and burning, straw is crushed and gently incorporated in the soil in treatments 4 and 5 like in treatment 2. After pea harvest BETA-LIQ is not applied. (BETA-LIQ – treated beet molasses stillage with a higher content of residual sugar)

Table 1 Nutrient rate ($kg.ha^{-1}$) – spring barley after winter wheat

Treatment	N	P_2O_5	K_2O
1	50 + 20 (applicated to straw)	85	90
2	50 + 20 (applicated to straw)	85	90
3	50 + 20 (applicated to straw)	85	90
4	50	85	90
5	50	85	90
6	50 + 20 (applicated to straw)	85	90

After determination of nutrient rates in mineral fertilizers some corrections associated with nutrient contents in BETA-LIQ were made.

Results

Tables 2 – 4 give results from the experiments conducted in the years 2002 - 2004.
The effect of different tillage and crop residue management systems on spring barley yields was dependent on the preceding crop. Average over the years of study (2002 – 2004), spring barley after sugar beet and winter wheat gave the lowest total yields of grain and yields of primary grain after ploughing. In the contrary , spring barley after grain maize gave the highest yields after ploughing. Shallow incorporation of a higher amount of maize straw caused reductions in total grain yields and primary grain yields.
The application of BETA-LIQ (promoting breakdown of organic substances) gave higher yields of spring barley after winter wheat. Some positive effects were also evident in spring barley following sugar-beet and grain maize (comparison of shallow incorporation of crop residues with and without BETA-LIQ).
When spring barley followed sugar-beet and grain maize lower frequency of tillage resulted in reduced protein contents in the grain, especially when the application of BETA-LIQ was combined with shallow cultivation. After winter wheat, however, protein contents in spring barley grain after shallow cultivation was higher and the highest results were recorded in the treatment with BETA-LIQ. Different effects of tillage and BETA-LIQ application might be associated with long-term application of different tillage systems and long-term repeated application of the preparation on changes in the soil environment in the experiment with spring barley after winter wheat. BETA-LIQ has been regularly and repeatedly applied to each crop of the above-mentioned crop rotation (besides winter wheat after peas) since the year 1996.

CONTENTS

Table 2 Effect of different tillage systems and crop residue management on the yield and quality of spring barley after sugar-beet – var. Kompakt, Žabčice, averaged over the years 2002 – 2004

Treatment	Grain yield ($t.ha^{-1}$)	Primary grain proportion (%)	Primary grain yield ($t.ha^{-1}$)	Protein contents in grain (%)
1	6.20	90.10	5.58	10.33
2	6.50	91.31	5.93	10.13
3	6.64	92.08	6.09	10.03
average	6.45	91.16	5.87	10.17
α 0,05			0.48	
α 0,01				

Table 3 Effect of different tillage systems and residue management on the yield and quality of spring barley after grain maize – var. Kompakt, Žabčice, averaged over the years 2002- 2004

Treatment	Grain yield ($t.ha^{-1}$)	Primary grain proportion (%)	Primary grain yield ($t.ha^{-1}$)	Protein contents in grain (%)
1	5.62	90.75	5.10	10.70
2	5.39	87.09	4.69	10.53
3	5.43	86.33	4.69	10.03
Average	5.48	88.05	4.83	10.42
α 0,05			0.30	
α 0,01			0.39	

Table 4 Effect of different tillage systems and residue management on the yield and quality of spring barley after winter wheat – var. Kompakt, Troubsko, averaged over the years 2002- 2004

Treatment	Grain yield ($t.ha^{-1}$)	Primary grain proportion (%)	Primary grain yield ($t.ha^{-1}$)	Protein contents in grain (%)
1	5.40	86.31	4.66	11.17
2	5.58	85.38	4.76	11.30
3	6.30	85.42	5.38	11.27
4	6.24	84.11	5.50	11.40
5	6.58	85.54	5.63	11.67
6	6.64	86.19	5.72	11.93
average	6.12	85.49	5.23	11.46
α 0,05	0.47		0.41	
α 0,01	0.57		0.49	

Conclusions

The evaluation of the effect of different tillage and residue management systems revealed the suitability of shallow cultivation for spring barley after winter wheat and sugar-beet (shallow incorporation of winter wheat straw and sugar-beet tops in the soil). When spring barley follows grain maize, deeper incorporation of maize straw in the soil by ploughing seems more favourable.
With shallow incorporation of crop residues in the soil, the application of BETA-LIQ promoting the breakdown of organic substances is beneficial.

Literature

Cannell, R.Q. – Hawes, J.D. 1994. Trends in tillage practices in relation to suistanable crop production with special reference to temperate climates. Soil and Tillage Research, 30:245-282.

Malhi, S.S. – McAndrew, D.W. – Carter, M.R. 1992. Effect of tillage and N fertilization of a Solonetzic soil on barley production and some soil properties. Soil and Tillage Research, 22:95-103.

Borresen, T. 1999. The effect of straw management and reduced tillage on soil properties and crop yields of spring- sown cereals on two loam soils in Norway. Soil and Tillage Research, 51:91-102.

Arshad, M.A. – Gill, K.S. 1997. Baeley, canola and wheat production under different tillage-fallow-green manure combination on a clay soil in a cold, semiaride climate. Soil and Tillage Research, 43:263-275.

Riley, H.C.F. – Bleken, M. A. - Abrahamsen, S. – Bergjord, A.K. – Bakken, A.K. 2005. Effect of alternative tillage systems on soil quality and yield of spring cereals on silty clay loam and sandy loam soils in the cool, wet climate of central Norway. Soil and Tillage Research, 80:79-93.

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IMPACT OF DIFFERENT SOIL TILLAGE AND STRAW MANAGEMENT ON WEED SPECIES SPECTRUM

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Abstract

The weed infestation was assessed in a field experiment at the Research Institute for Foddder Crops Ltd., Troubsko near Brno in 2001 - 2003. Numbers of individual weed species were determined using a counting method on the area of 0.25 m^2 in winter wheat stands within the 6-crop rotation (peas, winter wheat, spring barley, oilseed rape, winter wheat, winter wheat) in different variants of soil tillage and straw management. The highest weed infestation in all variants was found when winter wheat followed winter wheat. The highest number of weeds was assessed in the variant with stubble tillage to the depth of 0.12-0.15 m, planting with a precision drill and straw chopping. The lowest number of weeds was found in winter wheat after peas in the variant with incorporation of chopped straw using a tiller to 0.12-0.15 m and planting with a drilling combination, and in the variant where chopped straw was sprayed with the BETA-LIQ preparation, incorporation with a tiller to 0.12-0.15 m and planting with a drilling combination.

Key words: straw, soil tillage, weeds

Introduction

Current structural changes in our agriculture generate new conditions as well as new incentives for organic fertilizer management. It is necessary to investigate quality and distribution of these very important components for formation of soil fertility. The crop structure is becoming narrower, concentration of cereals and grain crops in total increases, livestock populations fall down, modern litterless housing is introduced and an increasing number of farms are without livestock production or with livestock production but without need of straw (PROCHÁZKOVÁ, DOVRTĚL, VRKOČ, 1999). Soil tillage systems are reevaluated and minimum management practices used more widely. In association with these changes, there is a problem of straw management in the field and of its most effective use in order not to reduce yields of successive crops.

Methods

The experiment has been conducted in the sugar-beet production region in the field of the Research Institute for Fodder Crops Ltd., Troubsko near Brno since 1996. The altitude of the experiment site is 270 m.
The actual weed infestation was investigated in the 6-crop rotation (peas, winter wheat, spring barley, oilseed rape, winter wheat, winter wheat).
Variants of straw management in cereals:

1. incorporation of chopped straw using a tiller to 0.12-0.15-m depth, ploughing to 0.22 m, planting with a drilling combination

2. incorporation of chopped straw using a tiller to 0.12-0.15-m depth, planting with a drilling combination
3. incorporation of chopped straw using a tiller to 0.12-0.15-m depth, planting with a precision drill
4. straw harvest, loosening to 0.12-0.15 m, planting with a drilling combination
5. straw burning, loosening to 0.12-0.15 m, planting with a drilling combination
6. spray of the chopped straw with the BETA-LIQ preparation and its incorporation to 0.12-0.15-m depth, planting with a drilling combination

The weed infestation was assessed prior to herbicide application in the spring. A counting method was used, i.e. assessment of numbers of individual weed species on the area of 0.25 m^2 in selected crops of the crop rotation (wheat after wheat, wheat after oilseed rape, wheat after peas) in four replicates.

Results

A total of 12 weed species were found in selected variants.
Numbers annual weeds in all variants are presented in Table 1.
In 2001, the lowest number of weeds was assessed in wheat after peas; there were no weeds in variants 2 and 6. A higher occurrence of quackgrass was found in variant 3. If chopped straw was incorporated with a tiller to 0.12-0.15-m depth and a precision drill was used (variant 3), numbers of weeds were the highest even in wheat after wheat and wheat after oilseed rape.
The highest weed density in all variants was in wheat after wheat. The lowest number of weeds was assessed in variant 6 (18 pc.m^{-2}).
The same trend could be seen in weed infestation of selected variants in 2002 and 2003. The total weed infestation in all variants was affected most by the species *Galium aparine L.* and *Viola arvensis Murray.* In wheat after peas the lowest weed density was found in variants 2 and 6. If chopped straw was incorporated with a tiller to 0.12-0.15-m depth and a precision drill was used (variant 3), numbers of weeds were the highest, and the same situation was even in wheat after wheat and wheat after oilseed rape. In variant 3, higher occurrence of *Papaver rhoeas L.* (19 pc.m^{-2}) was found in wheat after peas.
The highest weed infestation was assessed in wheat after wheat in all variants as in 2001. The lowest number of weeds was found in variant 6 (34 pc.m^{-2}). The lowest numbers of weeds were also determined in wheat after oilseed rape (13 pc.m^{-2} in variant 6) and wheat after peas (6 pc.m^{-2}).
Differences in weed densities in individual variants were statistically significant.

Conclusions

The highest weed infestation in all variants studied was assessed in winter wheat after winter wheat.
The largest number of weeds was found in variants with chopped straw incorporation with a tiller to 0.12-0.15 m and sowing with a precision drill. It can be assumed that using this practice, weed seeds are accumulated in a surface layer (which is also favoured by separation of particles at sowing with a precision drill), and thus improvement of conditions for germination.
The lowest numbers of weeds were found in winter wheat after peas in the variant with chopped straw incorporation using a tiller to 0.12-0.15 m and planting with a drilling combination and in the variant where chopped straw is sprayed with the BETA-LIQ preparation, incorporated with a tiller to 0.12-0.15 m and planting with a drilling

combination. The treatment of chopped straw with BETA-LIQ obviously facilitated more intensive decomposition of not only organic matter but as well as of weed seeds. The same situation was also recorded in wheat after rape and wheat after peas.

References

PROCHÁZKOVÁ, B., DOVRTĚL, J., VRKOČ, F., 1999: Systémy organického hnojení a bilance půdní organické hmoty v osevních postupech v různých agroekologických podmínkách. In: Bilancování organických látek a optimální zásoba organické hmoty v půdě, Praha, VÚRV: 43-47.

Table 1 Weed infestation in individual variants, Troubsko, annual weeds, pc.m^{-2}

Crop *(preceding crop)*	Variant	2001	2002	2003
Winter wheat *(oilseed rape)*	**1**	**7**	**18**	**13**
	2	**12**	**30**	**19**
	3	**59**	**38**	**32**
	4	**19**	**23**	**15**
	5	**31**	**29**	**18**
	6	**4**	**13**	**8**
Winter wheat *(winter wheat)*	**1**	**31**	**67**	**21**
	2	**32**	**74**	**24**
	3	**71**	**54**	**45**
	4	**25**	**60**	**24**
	5	**44**	**34**	**26**
	6	**14**	**52**	**22**
Winter wheat *(peas)*	**1**	**8**	**27**	**9**
	2	**0**	**9**	**6**
	3	**10**	**42**	**13**
	4	**1**	**25**	**9**
	5	**7**	**23**	**4**
	6	**0**	**6**	**3**

ISTRO-Conference Brno 2005 – Section II – poster presentation

CHANGES OF SET-ASIDE ARABLE SOIL PROPERTIES

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Abstract

In 1996 a field experiment was established in Prague (chernozem, altitude 281 m a.s.l., average annual precipitation 472 mm, average annual temperature 9.3°C) with *Arrhenatherum elatius* /L./ P.Beauv. ex J.S. et K.B.Presl cv. Median, *Medicago media* Pers. cv. Mediana*, Coronilla varia* L. cv. Eroza + *Bromus marginatus* Nees ex Steud. cv. Tacit, sown to rows 125 mm or fallow. The stands were cut with biomass removal once or three times per year, or mulched once or twice per year. The last harvest (or the only one), was always carried out at the end of vegetation period. The yields of dry mass and the sward and mulch cover in the end of vegetation season were measured. The soil properties - soil physical characteristics (total porosity, bulk density, water retention capacity etc.) and soil chemical characteristics (content of carbonates, organic carbon, humus quality, pH_{H2O}, $pH_{KCl.}$ were evaluated after six years of vegetation. A slight increase of total porosity corresponds to a slight decrease of soil bulk density. Mulching led also to a significant increase of soil moisture. The soil under fallow showed higher moisture compared to the sown plots. Significant impacts of the treatments and crops were shown in the content of carbonates. A similar situation is with both types of pH that are closely related to soil carbonate content. The treatment with three cuts and the mass removal led to stabilization or a slight decrease of soil C_{org} content, while the other treatments increased this content. Both mulching treatments as well as single cutting led to higher input of organic matter to soil. No effects of treatments were shown in humus quality.

Key words: set-aside land, grasses, legumes, fallow, mulching, soil properties

Introduction

The issues of suitable ways of setting aside arable land or grassland are urgent both in the Czech Republic and in the other European countries. The aim of setting arable land aside is to protect it as a natural resource and cultural heritage against erosion and weed infestation, to maintain the soil fertility. Alternative ways of biomass use have to be studied. The influence of mulching on grass stands in the Czech Republic was researched also by Fiala, Gaisler (2000), Kvítek *et al.* (1998), Matušinský, Hrabě (2003).

Mulching or different botanical composition and utilisation of a grass sward can influence the water content by different evapotranspiration or the water consumption by the plants. The real impact on the soil humidity depends also on the soil type (Kvítek et al., 1998, Kvítek, 1998). Also the soil temperature is influenced by the sward (harvested or not harvested in the autumn, mulching, the sward coverage etc.). The changes of temperatuere in uncovered soil are more significant (Kocourková et al., 2004). Then the belowground phytomass development (Meneses et al., 2004), so as the microbial activity (Voříšek et al, 2002) and the other soil properties can be influenced too.

The aim of this experiment was to evaluate the suitability of grasses and legumes under different management systems for temporary setting arable land aside from the point of view of the soil quality.

Methods

In 1996 a field experiment was established in Prague (chernozem, altitude 281 m a.s.l., average annual precipitation 472 mm, average annual temperature 9.3° C) with *Arrhenatherum elatius* /L./ P.Beauv. ex J.S. et K.B.Presl cv. Median, *Medicago media* Pers. cv. Mediana, *Coronilla varia* L. cv. Eroza + *Bromus marginatus* Nees ex Steud. cv. Tacit, sown to rows 125 mm or fallow (spontaneously grassed). The stands were cut with biomass removal once or three times per year, or mulched once or twice per year. The last harvest (or the only one), was always carried out at the end of vegetation period. Instead of the three times cut fallow a black (chemically treated) fallow was maintained. Soil physical characteristics (total porosity, bulk density, water retention capacity etc.) were determined using undisturbed soil samples collected to physical rings of 100 cm^3. Soil chemical characteristics were determined using standard methods: content of carbonates was determined volumetrically after reaction with 10% HCl, organic carbon (C_{org}) was determined oxidimetrically with potassium dichromate by modified Tyurin's method, humus quality was assessed by the ratio of soil 0.05M $Na_4P_2O_7$ extract absorbances at 400 and 600 nm (A_{400}/A_{600}). Soil pH_{H2O} was measured in soil suspension with distilled water (1:2, w/v), pH_{KCl} was determined in soil extract with 1M KCl (1:2.5, w/v). All the characteristics were measured in three soil horizons (0-0,2, 0,2-0,4, 0,4-0,6 m) after six years of vegetation in dependence on the way of setting the soil aside (the used forage species, the sward management). The results were evaluated by the analysis of variance (Tukey α=0.05) by the Statgraphics Plus programme, version 4.0.

Results and discussion

The swards have to produce a certain minimal yield of aboveground biomass to serve the erosion control purposes. The amount of the produced aboveground biomass and the quantity of the mulch can influence the processes in the soil and its properties. *Arrhenatherum elatius* was one of the highest yielding grass. It produced 3.7 (3 cuts per year) – 6.5 $t.ha^{-1}$(2 times per year mulched) of dry mass in average of the 3rd - 6th vegetation year without any fertilisation (tab. 1). The yields of the spontaneously grassed plots were similar. Medicago media yields were two times higher under 2-3 harvests per year (7.5-8.5 $t.ha^{-1}$) in comparison with the plots once per year harvested. The mixture of *Bromus marginatus* mixed with *Coronilla varia* produced the highest amount of dry mass on the twice per year mulched plot (in average 12.2 t ha^{-1}).
The ability of the sward to protect the soil surface against erosion depends also on its coverage all the year round. The winter season when the stands are harvested is most hazardous from this aspect. The best sward coverage in the end of vegetation season was in average 40-80% (in dependence on the species and the sward management – tab. 1), the mulch covered in average 28-56% of the area on the twice per year mulched plots and 48-71% on the once per year mulched ones. All the mulched biomass managed to decompose continuously and it did not accumulate on the soil surface. Generally the grasses had a higher coverage than the legumes, but there were some gaps even in their swards. The mulch serves as a good soil surface protection, because there were nearly no gaps on the mulched plots. The significantly highest proportion of gaps (uncovered soil surface without plants or mulch) was found on the one-cut variant (more than 30%). But mulching can have also some undesirable ecological impacts (serves as a hiding place for field mouse, spreading of weed seeds etc.).
The effect of different treatments on soil properties was generally low. No significant effect was shown on soil porosity (table 2). Nevertheless, a slight increase of total porosity can be seen for the mulched plots; this increase was related mainly to an increase of the volume of

non-capillary pores. The increase of total porosity corresponds to a slight decrease of soil bulk density (table 2). Mulching led also to a significant increase of soil moisture (by 2-3%), which can be expected due to an inhibition of evaporation from soil surface (table 2). Soil under fallow showed higher moisture compared to the sown plots (by 2%), which may be attributed to a limited transpiration.

Significant influences of the treatments and crops were shown in the content of carbonates (the range 0.2-3.4% in the top layer) – table 3. However, according to the differences in the carbonate content in deeper soil layers and according to the differences found already in the first year of vegetation, the differences between treatments can be caused also by spatial heterogeneity of the plots that hide the potential real effect of the treatments. A similar situation is with both types of pH (table 3) that are closely related to soil carbonate content.

The treatment with three cuttings and the mass removal led to stabilization or a slight decrease of soil C_{org} content (table 2), while the other treatments increased this content (till by 0.6%). Both mulching treatments as well as single cutting led to higher input of organic matter to soil. A moderate increase of organic carbon content was found also in the middle layer, especially in case of mulching twice a year; the C_{org} content in the deepest layer was not affected. These findings apply even for the fallow. In contrast, no effects of treatments were shown in humus quality as described by the A_{400}/A_{600} ratio (table 2).

Conclusions

Setting soil aside is an actual problem of the contemporary agriculture. Its impact on the soil quality depends on the chosen species and the way of the sward management. But the soil processes are complicated, dependent among them, and in some aspects they are very slow. It can be summarised, according to our results, that setting soil aside by forage crops and extensive soil management, represented by limited cutting and by mulching, did not exhibit any significant adverse effects on soil properties. On the contrary, some soil characteristics like porosity, moisture or organic carbon content can improve.

References

Fiala, J. – Gaisler, J., 2000: The production of biomass by different management of grasslands without using for forage production. Rostlinná Výroba, 46, 269-272

Kocourková, D. - Fuksa, P. - Mrkvička, J., 2004: Influence of stand exploitation on soil temperature during winter period. Sborník z mezinárodní vědecké konference Produkčné, ekologické a krajinotvorné funkcie trávnych ekosystémov , FAPZ SPU Nitra, 30.9.2004, s. 269-270.

Kvítek, T. – Klímová, P. – Šonka, J., 1998: The influence of mulching on botanical composition and coverage of meadow stand, evapotranspiration and soil moisture. Rostlinná Výroba, 44, 553-560.

Kvítek, T., 1998: Evapotranspiration of permanent grassland in different experimental regimes. Rostlinná výroba, 44, s. 193-201.

Matušinský, P. - Hrabě F., 2003: Dynamics of stand composition changes in grass and grass-clover stands and relations between dominant species. Plant, Soil and Environment, 49, 119-125.

Meneses, L. - Guerovich, M. - Mrkvička, J., 2004: The effects of mowing and mulching frequencies on meadow belowground phytomass. Sborník z mezinárodní vědecké konference Produkčné, ekologické a krajinotvorné funkcie trávnych ekosystémov , FAPZ SPU Nitra, 30.9.2004, s. 276-277.

Voříšek, K. – Růžek, L. – Svobodová, M., - Šantrůček, J. – Strnadová, S. – Popelářová E., 2002: The influence of grassing and harvest management on microbial parameters after setting arable land aside. Rostlinná výroba 48, 9, p. 382-388.

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Table 1. Sward characteristics (average of the 3rd - 6th year)

Sown species	Treatment	Average DM yield $t.ha^{-1}$	Average sward cover (%D)	Average mulch cover in winter (%D)
fallow	black	0	0	0
	2 mulching	5,27	68,5	28,5
	1 mulching	3,34	49,9	50,4
	1 cut	3,36	63,1	1,4
A. elatius	3 cuts	3,68	73,8	2,3
	2 mulching	6,45	69,2	35
	1 mulching	4,24	39,7	71,1
	1 cut	4,09	49,4	10,6
M. media	3 cuts	8,49	60,3	0
	2 mulching	7,51	47,5	54,9
	1 mulching	3,42	56,4	48,3
	1 cut	3,98	60,6	6,2
C. varia +	3 cuts	7,89	81,2	0
B. marginatus	2 mulching	12,18	51,4	56,2
	1 mulching	4,87	36,6	69
	1 cut	5,95	40,8	3,3

Table 2. Chosen soil properties in the 6th vegetation year

	NCP (%)	P tot. (%)	M (%)
3 cuts	15,8	46,7	17,7
2 mulching	17,2	49,1	**20,2**
1 mulching	16,8	48,1	**21,2**
1 cut	14,7	47,1	18,8
D_{min005}			*3,4*
fallow	15,9	47,3	20,9
A. elatius	17,1	48,4	18,8
M. media	16,0	47,4	18,4
C. varia + B. marginatus	15,6	47,8	19,9
$D_{min}005$			

	C_{org}/1 (%)	C_{org}/2 (%)	C_{org}/3 (%)
3 cuts	1,72	1,29	0,51
2 mulching	**2,14**	1,85	0,51
1 mulching	**2,32**	1,57	0,69
1 cut	2,20	1,57	0,61
$D_{min}005$	*0,45*		
fallow	2,07	1,40	0,46
A. elatius	2,33	1,71	0,69
M. media	1,98	1,54	0,73
C. varia + B. marginatus	2,01	1,63	0,44
$D_{min}005$			

	Hum/1 (%)	Hum/2 (%)	Hum/3 (%)
3 cuts	2,96	2,23	0,88
2 mulching	**3,70**	**3,19**	0,88
1 mulching	**4,00**	2,71	1,19
1 cut	3,79	2,70	1,05
D_{min005}	*0,79*		
fallow	3,56	2,41	0,78
A. elatius	4,01	2,95	1,19
M. media	3,41	2,66	1,26
C. varia + B. marginatus	3,46	2,81	0,76
$D_{min}005$			

NCP - noncapilar porosity…/1, 2, 3 - soil layer 0-0,2m, 0,2-0,4m, 0,4-0,6m
Ptot - total porosity
M - soil moisture content
SBD - soil bulk density
Hum – humus

Table 3. Chosen soil properties in the 6th vegetation year

	$CaCO_3$/1	$CaCO_3$/2	$CaCO_3$/3
3 cuts	**3,36**	**4,73**	**17,35**
2 mulching	**3,02**	**2,56**	**14,55**
1 mulching	1,01	1,35	9,60
1 cut	0,27	0,15	11,55
D_{min}005	*3,40*	*3,70*	
fallow	0,53	0,75	7,81
A. elatius	0,30	0,36	8,49
M. media	**3,10**	**3,86**	**19,75**
C. varia + B. marginatus	**3,72**	**3,81**	**17,00**
D_{min}005	*3,40*	*3,70*	*11,00*

	pH_{KCl}/1	pH_{KCl}/2	pH_{KCl}/3
3 cuts	**7,4**	**7,4**	7,8
2 mulching	**7,2**	**7,5**	7,7
1 mulching	7,0	7,1	7,6
1 cut	6,6	6,9	7,7
D_{min}005	*0,6*	*0,5*	
fallow	6,8	7,3	7,6
A. elatius	6,7	7,0	7,6
M. media	**7,3**	7,3	7,7
C. varia + B. marginatus	**7,3**	7,3	7,8
D_{min}005	*0,6*		

	pH_{H2O}/1	pH_{H2O}/2	pH_{H20}/3
3 cuts	**7,5**	**7,4**	7,9
2 mulching	**7,4**	**7,4**	7,8
1 mulching	6,9	7,3	7,8
1 cut	6,7	7,0	7,8
D_{min}005	*0,5*	*0,4*	
fallow	6,7	7,1	7,7
A. elatius	6,9	7,1	7,7
M. media	**7,4**	**7,5**	7,9
C. varia + B. marginatus	**7,5**	**7,5**	7,9
D_{min}005	*0,5*	*0,4*	

…/1, 2, 3 - soil layer 0-0,2m, 0,2-0,4m, 0,4-0,6m

CONTENTS

MONITORING SOIL COMPRESSION IN ENDURING GROWTHS

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Abstract

Mechanized operating sequence are linked with repeat soil crossing. The soil is compaction to the various measurements in their incidence. Compression is specially perceptible in lasting out planting (orchard, vineyard). Numerous crossing of mechanization across tracked lines are these reasons. If compression reach over critical limit show this state itself with weighly incidence (sinking of decree, increasing of power costingness at processing). Soil compression is linked with other accompanying phenomena, e.g.:
- water erosion developed in implication of limiting soil permeability
- increasing power severity on soil cultivation
- restriction of nutrient uptake
- higher stages of mortification of trees and shrubs

Solution of these situations consists in utilization of organic masses, which is using on fertilization of this soil. Beside standard organic fertilizers (cowshed manure, green manure) find exercise composting waste too (outlet wood, mulch mass) and bio-humus (vermikompost).

Key words: soil compaction; organic masses; lasting out planting; soil crossing

Introduction

Viniculture go through in passed by a few years vehement development. Act partly about growth produce surface, intensity working progress, but also namely above all about development used mechanization resources. Dealer's viniculture techniques bidding wide spectrum machine and overlaying by most work stages Grower are to purchase special viniculture mechanization obliged always on the up grade prices hand work, and too higher efficiency and effectiveness machinely effected washing. Owing to frequent crossing in same track happen to indefatigable stress on the soil, which negatively makes it felt on physical properties soil. In dependence on election production process prosecution, act in vineyard about 15 – 20 crossing behind some growing season (in fruit out planting 25 as much as 30 crossing). Above all at chemical wardships are grower obliged driving in on land and at that time, is-if soil unfit stand for cultivation (high moisture).
Oppressing soil traversing machinery and soil tillage in humidity untimely state (especially in plastic consistence), at the same time beside pressure function and effect plasticization, lead to disturbances soil construction and textures in mould and above all below mould and oversize when harmful compaction. This technological concretion has negative incidence for produce and except-produce function soil. Degradation soil textures and structure owing to compression makes decrease content leek, decrease conductivity basis for waters and air and expansion resistance soil. Incidence are technological difficulties at soil tillage and yield depression, occurrence transient waterlogg on plains, increasing overland flow and erosion on

the slopes, limitation utility of a waters and nutrients below mould and offscourings owing to shallow rooting, cost increase and energy title at soil tillage (VALIGURSKA, LHOTSKY, 1984).

On qualities soil textures notably exercise fertilization – fertilization industrial fertilizers mostly negatively (BOGIS, 1987; CHEN *et al al*, 1983; HUNCHED, VANEK, 1980 *in* LHOTSKY, 2000), fertilization organic fertilizers mostly positively (KREJCIR, RIMOVSKY, 1980; JURENCAK, 1979; PAGLIATI *et al*., 1983 *in* LHOTSKY, 2000) soil structure has many-sided meaning for fertility and use of land. Influence reception, retention and transfer waters in soil (BEVEN, GERMAN. 1982; PRITCHARD, 1985 *in* LHOTSKY, 2000). Assert on intensity soil washing nutrients, influence erosion soil and rooting plants and is rootage influence. Next to moisture are decisive factor carrying-capacity soil and her immunity against deformation.

Action compaction is primary series cry up pressure. Compression is accumulate suit, where is addition dollar gap shortage influence over soil. To the pressure 0,10 MPa (behind positive humidity state) it is possible do arithmetic's with reverse change, at higher pressure tell another factors. Pressure 0,15 MPa is disply manifest to the 0,35 – 0,40 m, higher pressure more deeply.

Means of mechanisation		Pressure [MPa]	Depth [m]
Tank car		0,35	0,50 – 0,65
Tractor [120 kW]		0,13 – 0,15	0,35 – 0,40
Threshing-machine	Front tyres	0,15 – 0,18	0,40
	Hind tyres	0,24	0,40 – 0,50

Tab. 1.: Dependence depths concretion on pressure wheels in tyres (HŮLA-ŠIMON, 1989)

Character field washing	Limiting value		
	Sandy bottom	Sand clay and loamy soil	Till and clay
Spring works	0,05	0,08	0,08
Work in summer and in autumn	0,08	0,15	0,2

Tab. 2.: Limiting value contact stress on the soil v MPa (PETELKAU, 1986 *in* HŮLA-ŠIMON, 1989)

What is he immunity mould against pressure and skid smaller (after deep ploughing), by concretion display manifest to the bigger depths. At the same time sandy soil have not almost ability spontaneous regeneration concretion horizon, meanwhile what near heavy soil there have been factors, which make possible reversible processes (activation soil textures). Belongs to here freeze, cubical changes (swelling and retraction) and incidence roots. At the same time is reverse suit less slower, wherewith stretch concretion more deeply and be a person of good character only functional, no morphological (LHOTSKY, 2000). Conception concretion has generally two content:

- content morphological, whose expression is increasing cubical weight, deformation system porosity and changes in quality leek;

- content ecological, demonstrative influence over transport processes and tramp important to supply herbage nutriment, waters and oxygen.

Dull systems transport waters and oxygen protracts stressed construction sequence cases herbage and decline decree. At the same time was inquest, do you rootage penetrating concretion soil they need on the contrary more oxygen. However relationship between intensity concretion and decree is no linear (Chancellor, 1976).

Pic. 1.: Appearances by lack of nutrients on shrub guilty vine, incurrence bad agricultural

Method a metering

Institute horticulture techniques ZF MZLU in Brno in his experimental activities deal with too problem undesirable concretion soil in enduring growths, especially then in vineyard. Therefore was of the year 2003 found experiment in operational conditions three vineyards subject in regions Břeclav and Brno - venkov. Single experimental stand find in tree soil different locations. Advances were found with intention watch influence organic masses on physical properties soil in vineyard.
In autumn of the year 2003 be on every stand placement organic matter in the form of cowshed manure (tax 7,5 kg.m$^{2),}$ compost (dues 3 kg.mand 8 kg.m$^{2)}$ and straw (2 kg.m$^{2).}$ organic matter was placement deep 15 cm by the help of turntable recruit.
At the same time was initiation monitoring crossing mechanization resources after metering interlinear, where will go out at plotting contact stress on the soil.
Alone monitoring physical properties are provided by the help of standard Kopecky roller and evaluation is provided by the help of methodology, which features JANDAK, a kol. 1987. Safety soil sample will withdrawal three times yearly from tree depths 0,15 m, 0,30 m and 0,45 m.

Assessment contact force wills fulfilment according to methodics, which processed GRECENKO (1994).

Diagnostic unhealthy concretion soil

Even if are mutual interrelations between agricultural mechanization, soil and plant are principle know, their quantification is however difficult in consequence time and cubic

variability soil and weather in process growth increases (RAGHAVAN *et al*, 1990). Know, do you happen to degradation, is however possibly understand her suit, causes and factor and recognize limit funds soil quality, after whose overfullfilment happen to substantial limitation function soil.
VALIGURSKA and LHOTSKY (1985) evidence higher propensity to concretion at higher moisture at the same time but, what is he higher starting relative concretion by influence moisture exercise relatively less. Concretion clayey soil is lower than soil sandy, likewise as is smaller near soil with humus than in soil without humus (ERMICH *et al*., 1978). BERAN (1990) found out do you activation concretions effects only undercarriage last one year (behind succour freeze through soil profile), repeated undercarriage two years.
LHOTSKY *et al* (1987, 1988) in laboratory conditions acknowledge, do you size plastic (no reversible) deformation is indirectly proportional starting voluminous materiality, do you ground bearing capacity with hightes voluminous materiality soars and do you in single case relations above all quantitatively distinguish in dependencies on by other quality soil, especially on content humus. Pressure 50 kPa incurred deformation only surface, infancy destructive changes spring from pressure 70 – 100 kPa.

Soil property	Soil type					
	C	CB, BC	B	SB	BS	S
Porosity (%)	<48	<47	<45	<42	<40	<38
Volume weight [g.cm^{-3}]	>1,35	>1,40	>1,45	>1,55	>1,60	>1,70
Penetr. resistance [MPa]	2,8 – 3,2	3,2 – 3,7	3,7 – 4,2	4,5 – 5,0	5,5	6,0
At moisture (%)	28 – 24	24 - 20	18 - 16	13 -15	12	10

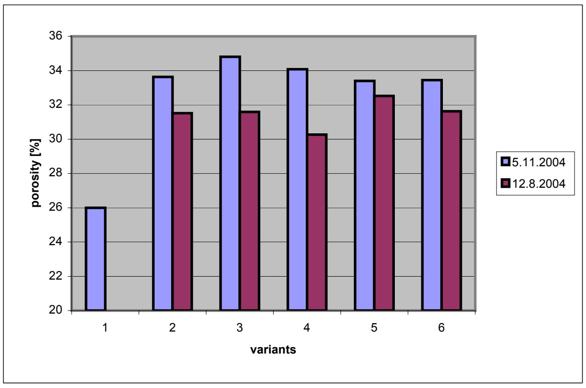
Tab.3: Limiting value critical quality concretion soil (LHOTSKÝ, 2000).

Manifestation concretion are perceptible in soil horizon as late as deep 2 m. biggest tension however offer in depths 0,4 – 0,6 m.

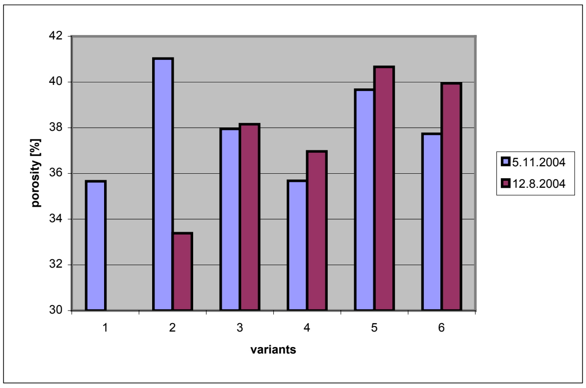
Results and discussion

From metering performed in first year after defray were fixed term first preliminary results. Taking of intact samples get in course of the year three times. Terms were fixed term in dependence on phenological phase vine. First taking was fulfilment after phase winter calm and before phase sprouting (before traversing mechanization), second taking in period blow-up cluster and last taking after harvest, when already subsequently no happen to any crossing mechanization.
From first partial results from, to improvement physical properties soil happen at that time, is-if in soil visible sufficient number organic masses. At comparison resultant funds physical properties near soil unmanured with soil to which was delivery quantity compost in shot 3 kg.mnot enough to expressive changes, however at comparison unmanured variants with variants other get to changes. This changes were especially perceptible in depths 0,30 and 0,45 m. on you-amended variants was as well following stronger substitution soil edaphon, which so his activity indirectly work degree of compaction soil.
Delivery organic masses directly improve physical properties in depths 0,30 m and 0,45 m, apparently on picture. 2. (1 – starting position, 2 – fertilizing compost 3 chg.^{2,} 3 – fertilizing compost 8 kg.m^{2,} 4 – fertilizing manure 7,5 kg.m^{2,} 5 – fertilizing straw 2 kg.m$^{2).}$ In depth 0,15

no happen to so apparent interference, but rather to easement implication traversing mechanization, it is perceptible on Picture. 1. in both case happen to most apparent interference on variants defray cowshed manure and straw.



Pic. 2.: Changes porosity in depth 0,15 m stand Žabčice



Pic. 3.: Changes porosity in depth 0,30 m stand Žabčice

Act however only about preliminary results, which will amplified edition about record from year 2005 and individual funds will given to the relation with accrued value contact pressure.

Conclusion

Routing in enduring growth, especially in viniculture and fruit growing are linked with repeated crossover soil same tracked lines. In their incidence is soil compaction. Exceed-if concretion soils critical balk; approve one this condition weighty incidence, which near lasting growth makes itself felt gradual outage shrub or tree. Generally has concretion whole order by other negative incidence (decrease decree, increasing power heftiness at processing concretion soil). Concretion soil in enduring growth is linked with next fall-out, like e.g.:

-water erosion developed effect limitation soil permeability -increasing power heftiness on soil tillage

-limitation uptake of nutrients

Causes hereof state seen in decrease levels of fertilization organic manures and often-unsuitable setting mechanization resources in hard conditions. Alarm from stress illness make them do grower more frequently crossing, you creates behind dampness track, which after get dry again quickly edit opener or tiller. Contribution with this too endeavour grower about lasting dispraise share needlework in technological process and her stopgaps mechanized operation (cultivation beistem zone, chipping, defoliation, harvest).

Institute horticulture techniques ZF in Lednice processed project on check utilization organic masses using at fertilization these soil. Purposes project is verify influence applied organic fertilizers different kind on improvement physical properties soil.

Experimental stand was found in select piece of land, vineyard out planting in village Velké Bilovice, on SZP Žabčice and SViS Valtice, that differ in soil condition.

Today proceeds basic metering with the view of detection basic physical properties soil, when are following: bulk weight, porosity, MKWK MAK.

Metering are provided in depths 0,15 m, 0,35 m and 0,55 m. analytic gained record will possibility use to determination optimal variants fertilization for given to locations, relative compaction with way on quantity organic masses and number crossing.

Further will following throughout growing season number crossing and sort's mechanization resources appearance to weigh and type tyres (contact force).
This project should contribute by to resolution deteriorative qualitative state soil in enduring growth, especially in vineyard, that is of concededly linked with absence organic masses and with increasing numbers of crossing in inovation production process.

Literature

BERAN, P. a kol.: Vymezení mechanicko-fyzikálních negativních faktorů úrodnosti půd; (Research report) Praha, 1987, VÚZZP 1990. 28 p.

ERMICH, D.: Studies on the compressive loads depending on substrate and moisture and on measures for reducing ground pressure; Tagungsber. d. deutsch. Akad. d. Landwirtschaftswiss, 1978, Vol. 166, p. 229 - 237

FIC, V.: Soustava mechanizace racionálního zpracování půdy ve středních sponech révy vinné; Doctoral dissertation work, Brno: VŠZ, 1983

FIC, V.: Soustava mechanizace racionálního zpracování půdy ve středních sponech révy vinné; Brno: VŠZ, 1984

GREČENKO, A.: Vlastnosti terénních vozidel; Zemědělská technika, 1997. t. 43, p. 41 - 58

HLUŠEK, J.: Základy výživy a hnojení zeleniny a ovocných kultur; Praha: Institute of Upbringing and Schooling Ministry of Agriculture ČR in Prague, 1996. ISBN 80-7105-111-X

HŮLA, J.-ABRHAM, Z.-BAUER, F.: Zpracování půdy; Praha: Brázda s.r.o.,1997. ISBN 80-209-0265-1

HŮLA, J.: Opatření k minimalizaci negativních vlivů zemědělské techniky na půdní prostředí; Praha: Institute scientific and technical information for agriculture, 1988

HŮLA, J.-ŠIMON, J.: Systémy zpracování půdy a způsoby snižování nadměrného tlaku na půdu; Praha: Institute scientific and technical information for agriculture, 1989.

CHANCELLOR, J.: Compaction of soil by agricultural equipment; In: Bull. of Univ. of California 1976.

LHOTSKÝ, J.: Zhutňování půd a opatření proti němu; Praha: Institute agricultural and grocery information, 2000. ISBN 80-7271-067-2

LHOTSKÝ, J.-VÁCHAL, J.-EHRLICH, P.: Soustava opatření k zúrodňování zhutnělých půd; Praha: Institute scientific and technical information for agriculture, 1984.

PYTKA, J., KONSTANKIEWICZ, K.: A new optical method for soil stress and strain investigation; www.sciencedirect.com

RAGHAVAN, G. S. V., ALVO, P., Mc KYES, E.: Soil compaction in agriculture: A view toward managing problem; Advances in Soil Sci., 1990, Vol. 11, p. 1 - 36

RICHTER, R.-ŘÍMOVSKÝ, K.: Organická hnojiva, jejich výroba a použití; Praha: Institute of Upbringing and Schooling Ministry of Agriculture ČR in Prague, 1996

ŠKODA, V.-CHOLENSKÝ, J.: Konvenční a perspektivní způsoby zpracování a kultivace půdy; Praha: Institute of Upbringing and Schooling Ministry of Agriculture ČR in Prague, 1993. ISBN 80-7105-048-2

UHL, W.: Ein Plug für alle Fälle; Das Dutsche Winmagazin, 1995, t. 4, p. 27 – 30

VALIGURSKÁ, L.-LHOTSKÝ, J.: Vliv různé intenzity zhutnění na změny fyzikálních vlastností půdy; Rostlinná výroba, 1985, t. 31, p. 603 - 612

ZEMÁNEK, P.-ŽUFÁNEK, J.: Systém hodnocení využití mechanizačních prostředků ve vinohradnictví, Memorial volume from international conference trends in the development of agricultural techniques", practised on the occasion of meeting teacher's desk in Brno, 4.4. 1997

THE EFFECT OF SOIL PROPERTIES ON DEPTH AND ROOT DENSITY IN SELECTED CROPS

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Introduction

The well developed root system and the rate of root growth to depth are important preconditions for effective uptake of water and nutrients.

The development of root system depends on many factors, especially on the growth of aboveground parts, nutrients and water availability, weather conditions and related soil properties as soil temperature, moisture and aeration. For example, roots need a minimal water content for a good growth - roots do not grow in soil layers where soil moisture is under wilting point. On the contrary, the roots do not grow well in saturated soil layers (e.g. in soil with a high water table). Generally, in more humid regions cereals show rather greater proportion of roots in upper layers, while in dry regions roots tend to grow to depth and to utilize water supply in subsoil layers.

The site characteristics, especially soil properties, influence root growth. Crops have most of roots in upper fertile soil layers, with favourable physical and chemical conditions. With increasing depth root density decreases but the general trend may be modified according to local conditions in the layers of a soil profile.

The contribution presents selected results of experiments aimed at investigation of root development under different conditions in Czech Republic.

Methods

Root growth and root traits of selected crops were studied from 1996 at sites with different soil-climate conditions, Ruzyně at Praha, Lukavec at Pacov and other sites not shown here.

Experimental crops studied were mainly cereals (winter wheat, oats, spring wheat), mustard, winter rape and sunflower.

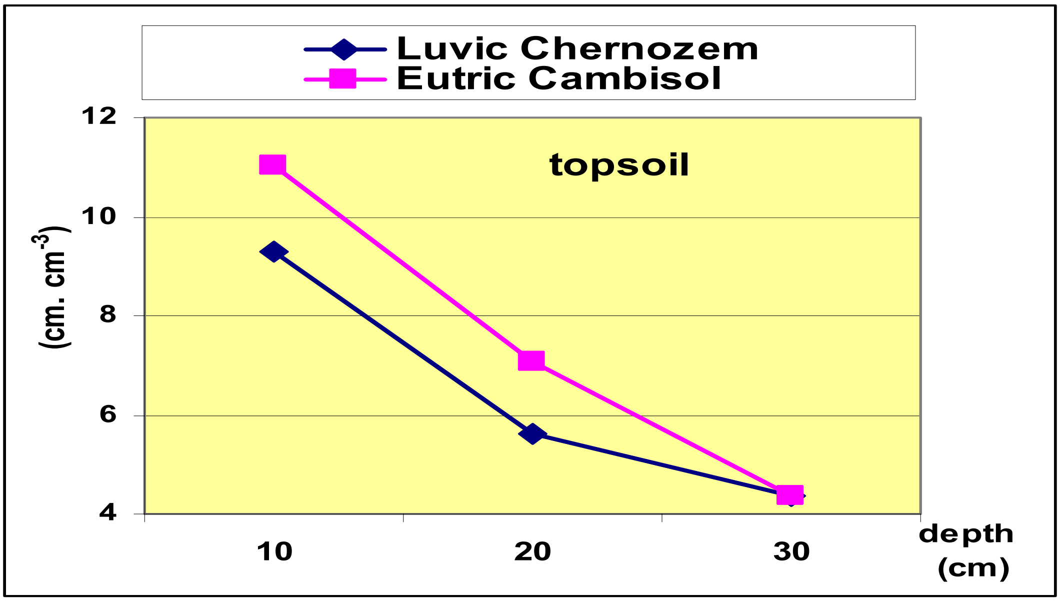
Soil samples were taken in 10 cm increments down under the zone where deepest roots were observed. Roots were sampled during plant growth and at the period of maximum root depth (after flowering). Roots were washed on set of sieves, preserved in refrigerator and cleaned. Root length was calculated according Tennant (1975) and dry weight determined.

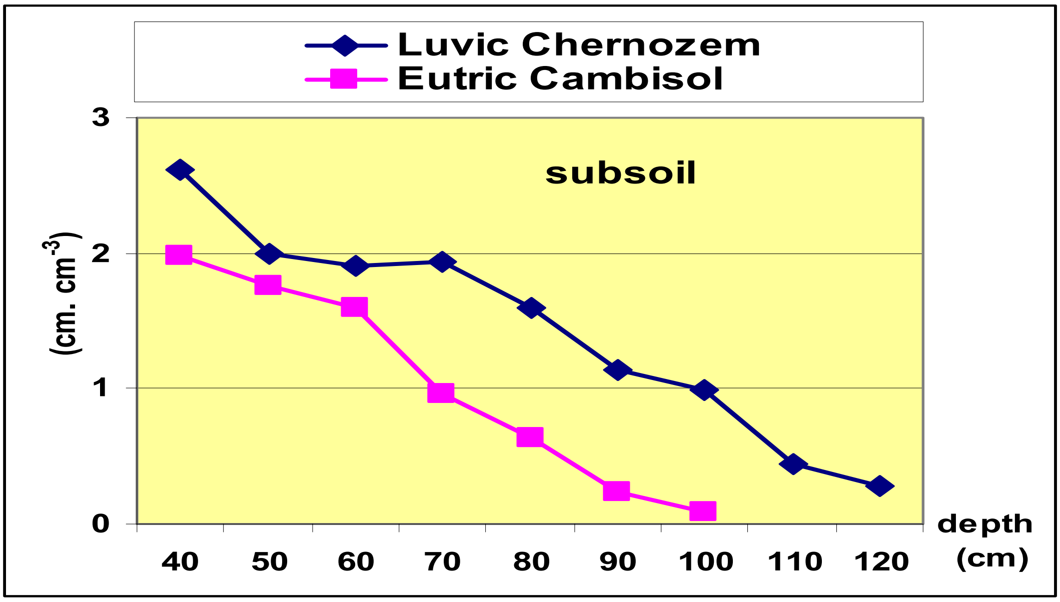
Results

Root parameters of winter wheat observed at experimental site Ruzyně (Luvic Chernozem and Orthic Luvisol, altitude 340 m, long-term average precipitation and temperature: 530 mm per year and 7,9 ^{o}C, resp.) were different from data found at site Lukavec (Eutric Cambisol, altitude 610 m, long-term average precipitation and temperature: 666 mm per year and 7,6 ^{o}C, resp.).

Roots of winter wheat reached greater depths at Ruzyně than the site with a sandy-loam topsoil and sandy subsoil at Lukavec. However, root density in arable layer was higher in Lukavec than at Ruzyně.

Fig. 1: Root density of winter wheat in layers of the soil profile at Ruzyně (Luvic Chernozem) and Lukavec (Eutric Cambisol). Average of years.

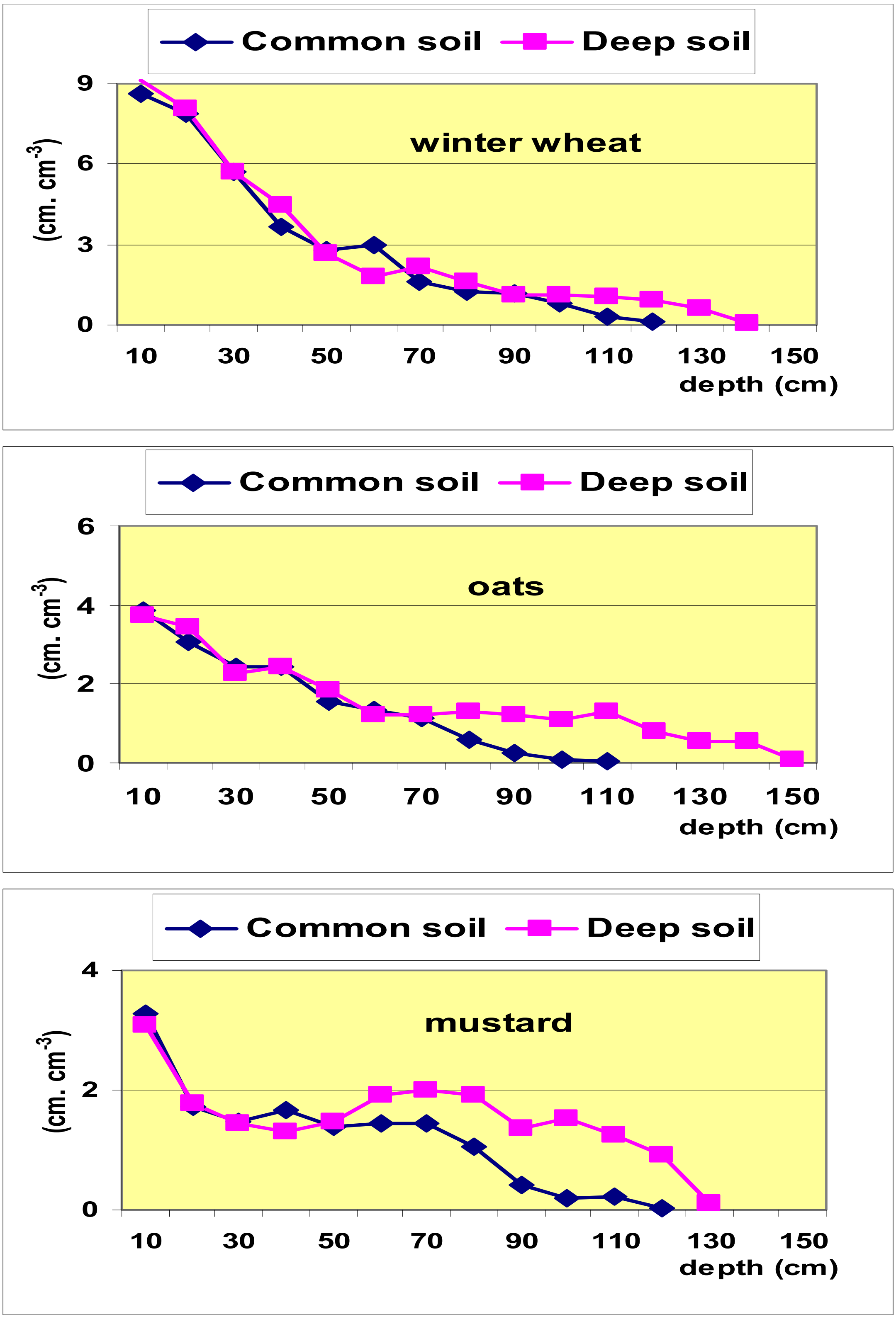




Soil conditions may differ within a single field. Due to terrain configuration superficial layers of soil rich in organic matter are washed downslope and accumulate at depressions, producing sites with a deep organic horizon. Thickness of soil layers showing different chemical and physical conditions change conditions for root growth.

We found greater root density in subsoil and greater root depth in such locations in experimental field at Ruzyně where spatial variability of soil and crop traits have been studied. The effect was observed during several years in winter wheat, oats and mustard.

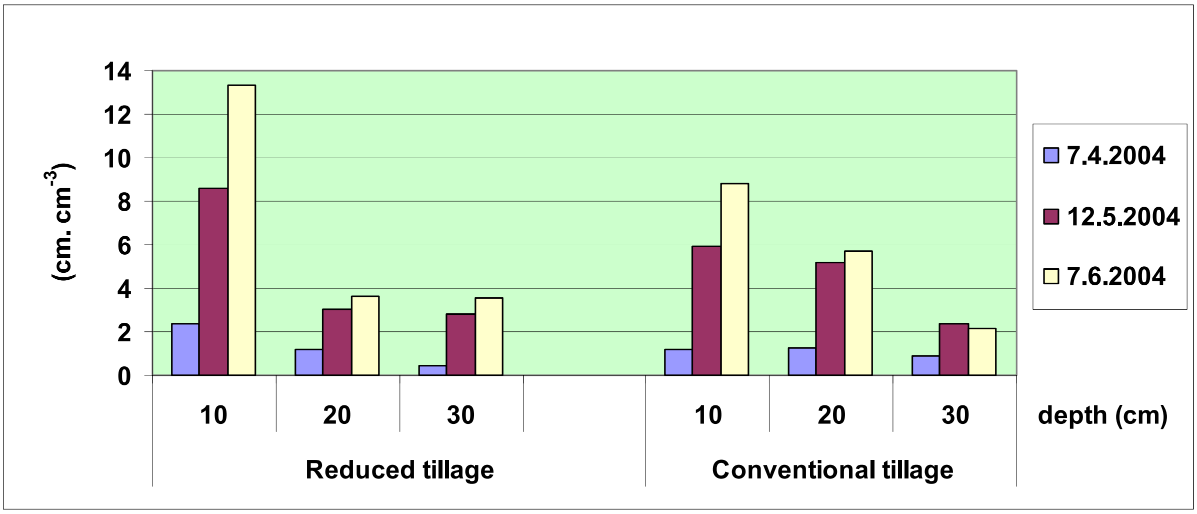
Fig. 2: The example of root growth differences within the same field



Soil conditions are not only product of soil-forming processes and climate, but they are also affected by farming practices and soil tillage. Root growth is adversely altered by soil compaction. Soil compaction is increased by frequent passes of farm machinery, especially at spring when soil is often near saturation under Czech climate conditions. Compacted layers modify root growth direction and root morphology - branching pattern and diameter of roots. The example is sugar beet that show undesirable branching of main root or sunflower that responds to compacted layer by bending of main root in right angle.
Roots may penetrate under such unfavourable conditions through biopores formed by decayed roots of pre-crops or soil biota and along old fissures (planes) filled with different soil material.
There is lack of data on root growth under different soil management in Czech Republic and available data do not provide consistent useful information for farming.

We observed the effect of different tillage on root parameters in arable layer in spring in experiment with winter wheat at Lukavec, in subsoil (under 25 cm) the differences diminished. Wheat had most of roots concentrated in top 10 cm soil layer under reduced soil tillage, while root length in layer 10-20 cm was noticeably less in comparison with root length under conventional soil tillage. The results suggest that roots of wheat are more regularly distributed in soil profile during spring under conventional tillage. This type of root distribution was observed during the whole studied period, from tillering to the start of heading.

Fig 3: The effect of different soil tillage on root length in topsoil layers



Conclusions

The results of several years study of root systems of selected crops showed the effect of soil conditions on root parameters in selected crops. The first results also proved that root development is affected not only by soil conditions but also by tillage. The effect of various factors on root density and depth should be taken into consideration with the aim of optimal utilization of nutrients and water for yield and good quality of products.

References

Haberle, J.- Svoboda, P.- Krejčová, J.: Effect of soil mineral nitrogen distribution on root growth and water use in winter wheat cultivars. In: Proc. of *5th Int.Symp. on structure and function of roots*, Stará Lesná, 1998: 52.

Haberle, J., Svoboda, P.: Rooting depth and the depletion of water from deep soil layers by winter wheat. *Scientia Agriculturae Bohemica 31* (3), 2000, 171-179.

Haberle J., Svoboda P., Trčková M. 2002 Available supply of soil water in relation to development of root system of wheat. In: *Ecophysiology of Plant Stress.* Proc.5th Int. Conf. Nitra, July 3-4 2002, 158-159.

Svoboda P., Kunzová E.: Kořenový systém slunečnice. Úroda 1/2004 : s. 15 – 16

Svoboda, P. , Haberle, J., Krejčová, J.: The relation between nitrogen supply in rooted soil volume and plant nitrogen status. In: 3rd International Crop Science Congress 2000. Hamburg, 17-22 August 2000, p. 166.

Tennant, D. 1975. A test of a modified line intersect method of estimating root length. J. Ecol. 63, 995-1001

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CONTENTS

BIOLOGICAL AND PHYSICAL SOIL PROPERTIES IN A LONG – TERM TILLAGE TRIAL IN GERMANY

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Abstract

After 37 years of different soil tillage treatments in a long term field experiment in Germany a number of biological and physical soil characteristics were measured. The field trial comprised of 6 major treatments with different implements and various depth. In this paper, results from a comparison of long term use of a plough (to 25 cm depth), a chisel plough (to 15 cm depth) and no-till are presented. The biological soil characteristics measured in this project include the organic carbon content, the number and biomass of earthworms and enzyme activities. Long term use of a chisel plough and no-tillage increased the organic carbon content in the uppermost soil layer (0-10 cm) compared with the plough treatment. Additionally the chisel plough caused an increase in number and biomass of earthworms compared to both other tillage treatments. Differences in earthworm numbers and biomass between ploughing and no-till were not statistically significant. The microbial activity (arginine-ammonification, β-glucosidase and catalase) decreased with depth in all treatments. Arginine-ammonification and catalase were higher in the plough treatment in soil layers 10 to 30 cm.
The effect of the different soil tillage treatments on soil physical properties were less pronounced, although water content and saturated hydraulic conductivity were more favourable after long term conservation tillage (chisel plough, no-till) compared with ploughing.

Keywords: organic carbon content, earthworms, enzyme activities, field capacity, saturated hydraulic conductivity

Introduction

The long term effects of husbandry treatments on soil characteristics are an important indicator for sustainable agricultural systems. This applies especially to differences in soil tillage treatments with its fundamental effect on the interaction of soil biological activity, soil physical properties and following long term changes in soil carbon content.
Those interactions were studied in a long term field experiment with different tillage treatments in Germany. The soil parameters measured in the experiment comprise of organic carbon, earthworm number and biomass, enzyme activities as well as various soil physical parameters.

Materials and Methods

The experimental site “Seehausen” is located close to the city of Leipzig in the German state “Saxony”. The experimental site represents one of the major agricultural regions of Germany.

At “Seehausen” the precipitation averages c. 552 mm, and the long-term mean air temperature is 9.1 °C (1963 – 1999). The soil is a sandy loam classified as a Stagno-Luvic Gleysol. It is susceptible to surface sealing and crust formation; the growth of crops may be adversely affected by water logging and drought stress. Lack of available water is in most years the limiting factor for crop yields. The top 30 cm of the soil can be described as follows: texture 10 percent clay, 46 percent silt and 44 percent sand, cation exchange capacity 109 mval/kg and ph (water) 6.7. The field experiment started in 1965 with a crop rotation of 67 percent of small grains and 33 percent of either sugar beet or potatoes. In 1991 a constant rotation of winter oilseed rape, winter wheat and winter barley was established and continued until the end of the field trial in 2002. With the change in crop rotation in 1990/1991, the tillage treatments were also changed:

1. **plough 25 cm (unchanged since 1965),**
2. chisel plough 25 cm (plough 25-35 cm until 1990),
3. plough 15 cm (unchanged since 1965),
4. **chisel plough 15 cm (unchanged since 1965),**
5. chisel harrow 10 cm (plough 25 cm to sugar-beet or potatoes and chisel plough to 10 cm) for small grains.
6. **no-tillage (until 1990 plough to 25 cm and subsoiling to 45 cm either before sugar-beet or potatoes).**

The results presented herein are based on the treatments 1, 4 and 6, because those treatments represent the relevant tillage in practical farming. Soil samples for the soil biological measurements were taken at the 23.4.2002 in following six soil layers: 0-5, 5-10, 10-15, 15-20, 20-30 and 30-40 cm. The methods applied are as follows:

- organic carbon content (DIN ISO 10694),
- Determination of earthworms in eight areas in each treatment (DIN ISO 11268-3),
- ß-glucosidase activity (Hoffmann & Dedeken, 1965, mod. Tischer & Altermann, 1992),
- Arginine-ammonification (Schinner et al., 1993) and
- Catalase (Beck, 1971).

The soil physical characteristics were determined using cores with a volume of 250 cm^3. The sampling took place at the 15.4.2001. Six samples were taken from the soil depth 0-6, 6-12, 18-24, 24-30 and 32- 38 cm, respectively. The methods applied are as follows:

- dry bulk density, d_B (Blake & Hartge, 1986a),
- particle density (Blake & Hartge, 1986b),
- water content at 6.3 and 31.6 kPa (according to Richards described by Klute, 1986),
- water content at 1.500 kPa (Klute, 1986) and
- Saturated hydraulic conductivity, k_S (Klute & Dirksen, 1986).

We consider a water content of 6.3 kPa as field capacity. The statistical analysis was done using the SAS program package (SAS Institute, 1999).

Results and Discussion

Organic carbon content

The different tillage treatments caused changes in the carbon content in the uppermost soil layer (Fig. 1). Especially the vertical distribution of the organic carbon content was affected by the differences in the long term tillage treatments. In the "plough" treatment, the organic carbon distribution was fairly similar down to 30 cm. This effect was caused by the typical mixing of manure and plant residues in the uppermost 30 cm of the profile. In contrast, the long term use of conservation tillage with a chisel plough or the no-till system lead to a higher organic carbon content in the soil layers 0-5 and 5-10 cm. Due to the limited input in the lower soil layers in the conservation and no-till systems, a lower organic carbon content occurred.

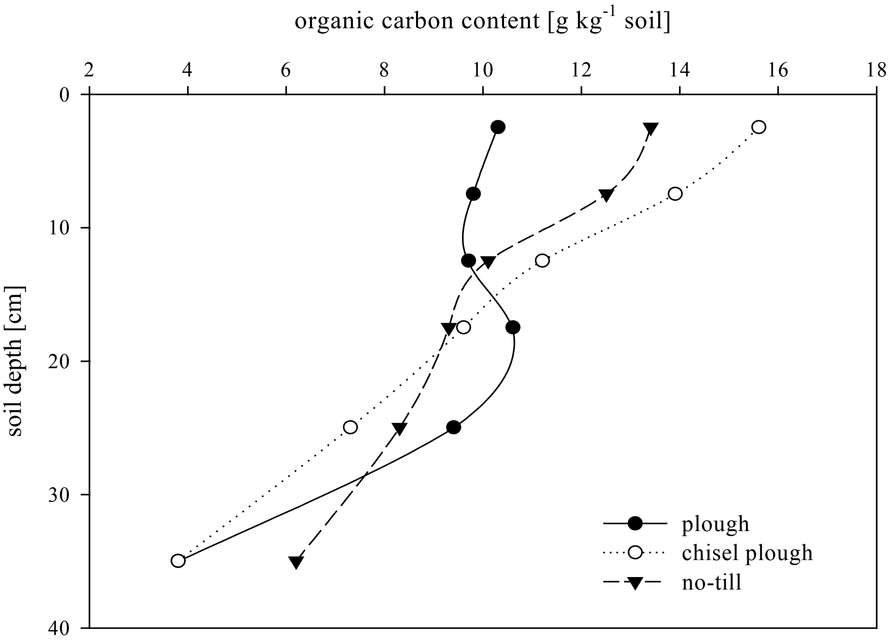

Fig.1: Influence of tillage on organic carbon concentration

CONTENTS

Earthworms

The earthworm population was strongly affected by the different soil tillage treatments (Fig. 2). Highest figures of earthworms were measured in the treatment with the chisel plough.

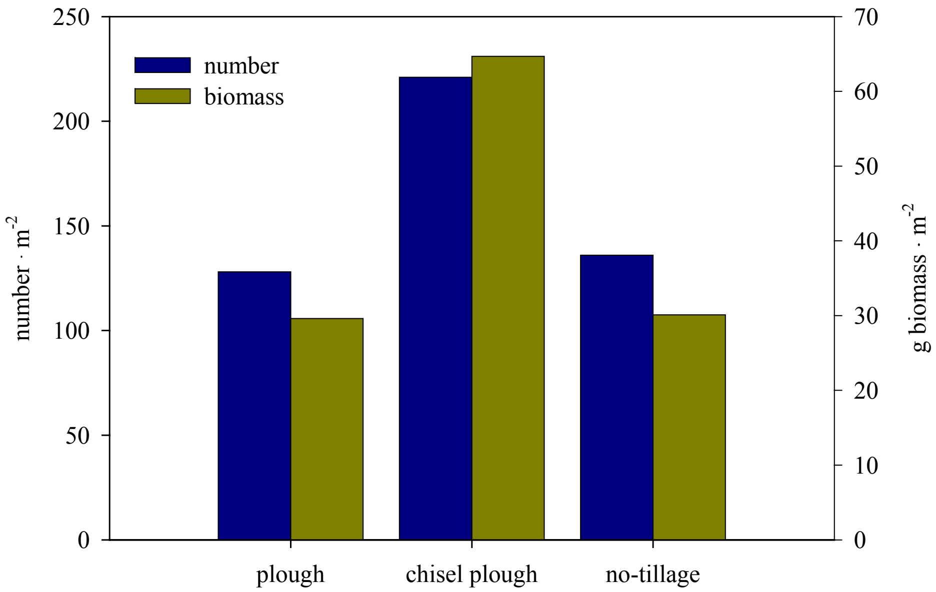

Fig.2: Number and biomass of earthworms

The highest number of adult individuals was found in the no-till system, although the total numbers and biomass was on a comparable level with the figures in the "plough" treatment. With a figure of five, the highest number of earthworm species was observed in the "plough" treatment, whereas in the chisel plough and no-till system only three species were counted. Directly after ploughing, a high number of injured and dead earthworms were observed, which concurs with results of Bostum (1995), Emmerling (2001) und Chan (2001). The authors consistently describe the harmful effects of intensive soil tillage on earthworm populations. In our experiments, *Lumbricus terrestris*, an anecic species, was observed after ploughing or using the chisel plough. A comparison of the juvenile earthworms *(Lumbricus sp.)* based on the eco-morphological traits revealed a high proportion of 33 percent of juveniles after no-till. In contrast, after ploughing, no juveniles of the respective species were observed. In the treatment with the chisel plough 5 percent juveniles occurred.

Enzyme activity

In general, enzyme activities decline with soil depth. The highest enzyme activities were measured in the uppermost 10 cm layer in the "chisel plough" and "no-till" treatment (Tab. 1), whereas in the "plough" treatment the microbial activity was fairly similar in the different soil layers. Almost no differences were recorded in the soil layer 30 to 40 cm. Curci et al. (1997) and Kandeler et al. (1999) have reported similar observations and attribute their finding to the limited oxygen supply under conservation tillage and no-till compared with ploughing.

Tab. 1: Influence of different tillage systems on enzymes activity

variant/depth	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-30 cm	30-40 cm
			Arginine-ammonification			
plough	1.04	0.88	1.12	1.09	1.17	0.02
chisel plough	1.25	1.12	0.59	0.09	0.02	0.02
no-tillage	1.61	0.79	0.49	0.21	0.11	0.04
			ß-glucosidase [µg saligenin·g^{-1} soil]			
plough	23.7	24.9	28.3	23.6	23.1	10.8
chisel plough	92.0	45.9	28.0	20.6	9.6	9.0
no-tillage	54.8	42.3	29.2	23.6	18.6	16.2
			Catalase			
plough	9.2	7.9	8.4	9.9	6.9	2,0
chisel plough	20.9	11.5	7.3	4.7	2.8	1.7
no-tillage	21.7	12.7	7.1	4.6	3.0	2.5

Physical soil properties

Compared with the treatments "plough" and "chisel plough", the highest bulk densities were measured in the "no-till" treatment. The only significant differences, however, in the bulk soil density caused by the different soil tillage treatments, were measured in the soil layer 18 – 24 cm (Tab. 2). Hence the "no-till" treatment showed a 0.15 g cm^{-3} higher bulk density compared with the "plough". The "chisel plough" showed intermediate results. An exception was the soil layer 0-6 cm with almost no differences between the three treatments. Based on a number of field experiments, Tebrügge and Düring (1999) report a higher bulk density in no-till systems right under the soil surface. The fact that such an observation was not confirmed in our results might be due to differences in soil type.

The water content at 6.3 kPa did respond to the soil tillage treatments. Compared with the "plough" and "chisel plough" treatment, the "no-till" treatment showed a higher water content in the two uppermost (0-6 and 6-12 cm) and the two lowest layers (24-36 and 32-38 cm). The "plough" treatment only caused slightly higher water content in the soil layer 18-24 cm. A similar result was observed with the available water content (AWC). With the exception of the soil layer of 32-38 cm, no differences caused by the treatments were measured in the field air capacity (FAC).

Tab. 2: Selected soil water and air parameters (different letters sign a significant difference)

	d_B [g·cm^{-3}]		FC [m^3·m^{-3}]		FAC [m^3·m^{-3}]		AWC [m^3·m^{-3}]		k_s [cm·d^{-1}]	
					0-6 cm					
plough	1.41	a	0.353	b	0.105	a	0.264	b	54	a
chisel plough	1.34	a	0.379	a	0.105	a	0.294	a	122	a
no-tillage	1.40	a	0.356	b	0.106	a	0.268	b	69	a
					6-12 cm					
plough	1.49	a	0.359	a	0.066	a	0.265	a	29	a
chisel plough	1.53	a	0.355	a	0.055	a	0.258	ab	29	a

no-tillage	1.55	a	0.338	b	0.066	a	0.241	b	29	a
18-24 cm										
plough	1.46	b	0.358	a	0.079	a	0.266	a	69	a
chisel plough	1.54	ab	0.330	b	0.079	a	0.233	b	45	ab
no-tillage	1.61	a	0.331	b	0.048	a	0.230	b	18	b
24-30 cm										
plough	1.63	a	0.313	b	0.062	a	0.220	b	11	a
chisel plough	1.61	a	0.329	a	0.053	a	0.238	a	11	a
no-tillage	1.59	a	0.332	a	0.057	a	0.241	a	22	a
32-38 cm										
plough	1.64	a	0.293	c	0.085	a	0.195	b	24	a
chisel plough	1.64	a	0.328	a	0.049	b	0.230	a	11	a
no-tillage	1.70	a	0.312	b	0.043	b	0.210	b	12	a

An effect of the soil tillage treatments on the saturated hydraulic conductivity was only established in the soil layer 18-24 cm with a 58 $cm \cdot d^{-1}$ higher conductivity in the "no-till" treatment.

Conclusions

A tillage system based on a chisel plough or a no-till system compared with traditional ploughing increased the organic carbon in the soil 9 percent (4.1 t/ha). This translates into 15.2 t CO_2 ha^{-1}. In the case of a conversion from no-till to ploughing, a quite rapid mineralization of nitrogen and release of carbon is likely. This increases the likelihood of nitrate leaching with possible consequences for water quality. Strongest microbial activity was observed in the uppermost soil layers, and vice verse. This effect was only small in the "plough" treatment. In contrast, the Arginine-ammonification was higher in the "plough" treatment in a depth of 15-30 cm due to a better aeration in deeper soil layers. Nitrogen mineralization is enhanced by this activity.

The chisel plough treatment showed more favourable conditions as far as the soil water indicators (FC, AWC) are concerned. A positive effect, however, on the saturated hydraulic conductivity of the "chisel plough" and "no-till" treatment compared with the "plough" treatment was not observed.

References

Beck, Th. (1971): Die Messung der Katalaseaktivität von Böden. Z. Pflanzenern. Bodenkd. 130, 68-81.

Blake, G. R. & K. H. Hartge (1986a): Bulk density. In: Klute, A. [Ed.]: Methods of Soil Analysis: Part 1. Physical and Mineralogical Methods. American Society of Agronomy Madison WI, 363-376.

Blake, G. R. & K. H. Hartge (1986b): Particle Density. In: Klute, A. [Ed.]: Methods of Soil Analysis: Part 1. Physical and Mineralogical Methods. American Society of Agronomy Madison WI, 377-382.

Bostum, U. (1995): Earthworm populations (Lumbricidae) in ploughed and undisturbed leys. Soil & Tillage Research 35, 125-133.

Curci M., M. D. R. Pizzigallo, C. Crecchio, R. Mininni & P. Ruggiero (1997): Effects of conventional tillage on biochemical properties of soils. Biology and fertility of soils 25, 1-6.

Chan, K. Y. (2001): An overview of some tillage impacts on earthworm population abundance and diversity – implications for functioning in soils. Soil & Tillage Research 57, 179-191.

Emmerling, C. (2001): Response of earthworm communities to different types of soil tillage. Applied Soil Ecology 17, 91-96.

FAO (1998): World reference base for soil resources, Rome.

Hoffmann, G. & M. Dedeken (1965): Eine Methode zur kolorimetrischen Bestimmung der ß-Glucosidaseaktivität im Boden. Z. Pflanzenern. Bodenkd. 100, 195-201.

Kandeler E., D. Tscherko & H. Spiegel (1999): Long-term monitoring of microbial biomass, N mineralisation and enzyme activities of a Chernozem under different tillage management. Biology and fertility of soils 28, 343-351.

Klute, A. (1986): Water retention: laboratory methods. In: Klute, A. [Ed.]: Methods of Soil Analysis: Part 1. Physical and Mineralogical Methods. American Society of Agronomy Madison WI, 635-662.

Klute, A. & D. Dirksen (1986): Hydraulic conductivity and diffusivity: Laboratory methods. In: Klute, A. [Ed.]: Methods of Soil Analysis: Part 1. Physical and Mineralogical Methods. American Society of Agronomy Madison WI, 687-734.

Statistical Analysis System Institute (1999): SAS user's guide: version 8. SAS Institute Cary NC.

Schinner, F., R. Öhlinger, E. Kandeler & R. Margesin (1993): Bodenbiologische Arbeitsmethoden. Springer-Verlag Berlin.

Tebrügge, F. & R. A. Düring (1999): Reducing tillage intensity – a review of results from a long term study in Germany. Soil & Tillage Research 53, 15-28.

Tischer, S. & M. Altermann (1992): Veränderungen der mikrobiellen Aktivität durch Wechsel der Bodennutzung. Ergebnisse aus dem ehemaligen Grenzstreifen. Vdlufa-Schriftenreihe 35, 559-562

EFFECT OF FERTILIZER ON NUTRIENT BALANCE IN CROP ROTATION

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Abstract

Research was aimed at the investigation of the impact of different nitrogen and phosphorus fertilizer norms on plant nutrient (NPK) balance in crop rotation. Field experiments were carried out (1998 – 2003) on long-term field experimental plots (winter wheat – green manure crop – spring wheat – spring barley – spring barley with under-seeding of clover) of LUA SRF Peterlauki of the Department of Soil Science and Agrochemistry. Soils at the site are sandy clay loam pseudo-gley (GLx). Agrochemical parameters before the experiment were as follows: pH_{KCl} 7.1 – 7.3, organic matter content 29 – 31 g kg^{-1} (17 – 18 g kg^{-1} $C_{org.}$), medium high level of plant available P and high level of K.

Research results indicate that N balance in crop rotation mainly was affected by the applied N mineral fertilizer norm. At the lowest nitrogen fertilizer norm N_{40} nitrogen balance was negative, but already the norm N_{70} provided positive balance 1.9 – 8.9 kg ha^{-1} per year. Incorporated P fertiliser norms had insignificant effect on N balance in soil. P balance in crop rotation was positive and directly proportional to incorporated P fertilizer norm (correlation coefficient r = 0.99). Phosphorus fertilizer norm P_{33} almost fully covered this plant nutrient average removal by yield in crop rotation. Increasing P fertilizer norm to P_{65} resulted in P balance +29.5 kg ha^{-1} on background $N_{40}K_{60}$ but on background $N_{70}K_{60}$ – +31.8 kg ha^{-1} P_2O_5. K balance was positive on both backgrounds of the nitrogen fertilizer norms N_{40} and N_{70} – 2.1 – 5.2 kg ha^{-1} and 1.6 – 3.5 kg ha^{-1} K_2O respectively. The size of P fertilizer norm had insignificant effect on K balance.

Key words: crop rotation, input, removal, NPK balance

Introduction

The integration of environmental concerns into agricultural practices has become a priority during last decades. It requires good management of fertilizer application. An adequate fertilization should compensate plant nutrient amounts removed with crop yield to sustain soil fertility and exclude pollution. However, excessive nitrogen surpluses, the difference between inputs and removals by crops, can cause a threat to the environment, leading to pollution of water, air and soil. On the other hand mining of nutrients from the soil, particularly of phosphorus and potassium, is another problem, causing soil degradation and threatening long-term food production (Oborn et al., 2003; Goodlass et al., 2003; Buciene et al., 2003).
According to EC directives and agricultural policy nutrient balances should be used to promote efficient application of fertilizers; to reduce nutrient losses from agriculture; to reduce inputs of nutrients, and to predict changes in soil nutrient status (OECD, 2001; Parris, 1998). The primary limitations have been settled for nitrogen, but the use of phosphorus is also a live issue. It is stated that the available phosphorus content in arable topsoil should not exceed the requirements of an acceptable crop production. Phosphorus input should be of the

same size as the phosphorus removed. Potassium fertilizer application is not limited, but for an efficient use and setting of potassium rates the balance method is the most appropriate (Jakobsson, 2001; Vos J., Van der Putten, 2000).

Since 1992 fertilizer consumption in Latvia has drastically decreased. According to statistical data only 44 kg N, 11 kg P_2O_5 and 16 kg K_2O were used per hectare of arable land in 2003 (Anon., 2004). Such fertilizer management practice is hazardous for long-lasting agricultural production. It is stressed (Tunney et al., 2003; Sheldrick et al., 2002), that in large number of countries, food production is currently dependent on depleting large quantities of nutrients from soil reserves and this is likely to continue. The world average soil depletion of nutrients in 1996 was estimated to be 12.1 kg ha^{-1} N, 4.5 kg ha^{-1} P, and 20.2 kg ha^{-1} K. The depletion of K is particularly severe and could ultimately lead to a serious loss of crop productivity. Analytical tools, such as the nutrient audit and balance calculation can play an important role in assessing the problem, and in developing sustainable nutrient management policies, strategies, and practices.

The aim of the work was to evaluate the effect of different nitrogen and phosphorus fertilizer rates on NPK input and output relevance and nutrient balance in long-term crop rotation experiment.

Materials and methods

Field experiments were carried out on long-term field experimental plots (winter wheat – green manure crop – spring wheat – spring barley – spring barley with under-seeding of clover) of the Department of Soil Science and Agrochemistry at the Study and Research Farm (SRF) Peterlauki, LUA established in 1997. At present full crop rotation cycle has been completed in the 1st, 5th and 6th fields. In this research we analysed results obtained in the 6th field (1998 –2003). Winter rape at the end of flowering stage was incorporated in soil as green manure. Straw of cereal crops and 2nd cut clover were ploughed into soil as well.

The field experiment was carried out on sandy clay loam pseudo-gley soil (Stagni-Gleyic Luvisol – PAK[1], 1998) formed on silty clay loam limno-glacial deposits, which at the depth of 30-60 cm are covered by Baltic Ice lake sediments. Agrochemical parameters before the experiment were as follows: pH_{KCl} 6.9-7.4, organic matter content 29-31 g kg^{-1} (Tyurin′s method), plant available level of P (P_2O_5 – 170 mg kg^{-1}) and K (K_2O – 264 mg kg^{-1}) (high PK sufficiency level) (Egner-Riehm DL method). Experimental scheme included no-fertilizer control and 8 fertilizer treatments with a constant potassium norm, four phosphorus and three different nitrogen norms, which were differentiated according to requirements of the grown crops (Table 1). Additional dressing for wheat was applied in spring after vegetation was renewed and in stem elongation stage. The experiment was established in 4 replications according to common replication method in two rows. Mineral fertilizers in the form of ammonium nitrate, single superphosphate and potassium chloride were pre-plant applied. Plant total nitrogen content was determined by Kjeldahl procedure, phosphorus – photo-colorimetrically and potassium by flame photometer in ash extraction.

[1] PAK – World Reference Base

Table 1

Fertilizer rates applied during crop rotation, kg ha^{-1}

Treat-ment	Winter wheat			Winter rape, barley+clover			Spring wheat			Spring barley		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1	0	0	0	0	0	0	0	0	0	0	0	0
2	60	0	90	30	0	60	60	0	90	60	0	60
3	60	60	90	30	30	60	60	45	90	60	30	60
4	60	90	90	30	45	60	60	60	90	60	45	60
5	60	120	90	30	60	60	60	90	90	60	60	60
6	120	0	90	60	0	60	90	0	90	90	0	60
7	120	60	90	60	30	60	90	45	90	90	30	60
8	120	90	90	60	45	60	90	60	90	90	45	60
9	120	120	90	60	60	60	90	90	90	90	60	60

N, P and K balances were calculated as difference between NPK input and removal. Input was formed by plant nutrient amount in soil supplied with mineral fertilizers as well as by nitrogen biologically fixed by clover, but removal – by plant nutrient amount, which was fixed in yield and removed from the field: only grain for winter and spring wheat and barley, and 1st cut hay for clover. Removal was calculated considering the size of the corresponding cultivated plant yield and NPK content in it. Obtained data were mathematically processed by one-factorial dispersion method (Arhipova, Bāliņa, 1999).

Results and discussion

An important factor affecting plant nutrient balance is crop yield, which is to a great extent affected both by fertilizer and climatic conditions. It should be noted that meteorological conditions in Latvia are quite variable between particular years. The average yield data from which amount of plant nutrient removal is dependent are presented in Table 2. It follows that N and P fertilizer application contributed to increase of winter wheat grain yield, however significant yield increase on $N_{60}K_{90}$[2] fertilizer background was ensured by the phosphorus fertilizer norms P_{90} and P_{120} respectively 0.45 and 0.49 t ha^{-1}. In 1999, the crop rotation field was under winter rape and yield of the produced herbage in fertilized treatments was in the range of 71 – 102 t ha^{-1}. In the year 2000 meteorological conditions were favourable for spring wheat growth, therefore fertilizer use efficiency and obtained yields were high. All N and P fertilizer norms applied provided significant yield increase. Particularly high yield increase (0.6 – 1.3 t ha^{-1}) was observed with the increase of P fertilizer norms on both fertilizer backgrounds ($N_{60}K_{90}$ and $N_{90}K_{90}$). Spring barley yields in 2001 were not high, but the increase of N fertilizer norms from N_{60} to N_{90} provided significant yield increase (0.44 t ha^{-1}). Application of P fertilizer norms P_{45} and P_{60} on fertilizer background $N_{60}K_{60}$ provided significant increase in yield, but increasing of nitrogen fertilizer to N_{90} resulted in the decrease of P fertilizer use efficiency. As indicated by the obtained data, barley grown in crop rotation with clover as intercrop produced higher grain yields than growing barley without intercrop using lower N fertilizer norms. This tendency was as well observed in the year 2002 because crop yields were high enough and in fertilized treatments were in the range of 5.1 – 5.5 t ha^{-1}. However it should be emphasized at once that the increase of N and P fertilizer norms did not provide significant yield increase. Highest clover hay yield was obtained in non-fertilized

[2] Designations $N_{60}K_{90}$, P_{45} (and similar) means 60 kg ha^{-1} N, 90 kg ha^{-1} K_2O, 45 kg ha^{-1} P_2O_5

treatment – 9 t ha^{-1}. Significant differences were not observed between fertilized treatments and hay yield was by 1 – 2 t ha^{-1} lower. It follows that even small N fertilizer norms in spring barley with clover intercrop had a negative effect on both quality of sward and yield of hay as well.

Table 2

Yields obtained during crop rotation (1998 – 2003)

Treatment	Winter wheat, t ha^{-1}	Spring wheat, t ha^{-1}	Spring barley, t ha^{-1}	Barley + clover, t ha^{-1}	Clover, 1st harvest, t ha^{-1}
1	4.45	3.94	3.02	3.56	9.03
2	4.90	5.26	3.30	5.13	7.61
3	5.23	5.86	3.47	5.47	7.64
4	5.35	6.24	3.56	5.35	7.62
5	5.39	6.58	3.56	5.38	7.58
6	5.32	5.66	3.74	5.26	7.20
7	5.56	6.37	3.84	5.33	7.29
8	5.64	6.64	3.91	5.45	7.22
9	5.63	6.94	3.90	5.50	7.13
$RS_{0.05}$	0.44	0.18	0.24	0.32	0.53

Table 3 presents summarized data on plant nutrient input in crop rotation. Amount of biologically fixed nitrogen accounting for 214 – 258 kg ha^{-1} in experimental treatments was included in N input. Increasing P fertilizer norm resulted in the tendency of increased removal on both N fertilizer backgrounds respectively by 33.1 – 47.1 and 32.5 – 42.0 kg ha^{-1}. The increase of N fertilizer norms increased N removal by 50.7 kg. Regarding P removal, it follows that the increase of N fertilizer norms resulted in the increase of P removal by 11.4 kg, but the increase of P fertilizer norms on lowest N fertilizer background resulted in the increase of P removal by 13.1 – 25.5 kg, but on highest N fertilizer background by 14.8 – 27.5 kg. With increasing N and P fertilizer norms there were observed insignificant tendencies of K removal increase.

Table 3

Total NPK input and output in crop rotation (1998 – 2003)

Treatment	Input with fertilizers and N fixation, kg ha^{-1}			Output with removed crop yields, kg ha^{-1}		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1	258	0	0	487.4	159.1	379.5
2	454	0	360	530.2	173.8	329.0
3	454	195	360	563.3	186.9	335.5
4	454	285	360	572.2	191.8	338.0
5	454	390	360	577.3	199.3	347.2
6	634	0	360	580.9	185.2	338.8
7	634	195	360	613.4	200.0	346.5
8	634	285	360	618.8	207.2	348.6
9	634	390	360	622.9	212.7	350.1

NPK balance in experimental treatments is presented in Figure 1. As shown, highest N, P and K deficit was forming in treatment with no-mineral fertilizers applied. Most of all from soil there were used K resources averagely accounting for 63.2 kg ha^{-1} K_2O per year. N deficit in this treatment was lower than that of K – only 38.3 kg ha^{-1} N, because amount of biologically fixed N was considered in input. P balance was negative as well (- 26.5 kg ha^{-1} P_2O_5) and roughly corresponded to annual average P removal by crop yield. Excluding the use of P mineral fertilizer with N and K fertilizers in fertilized treatments resulted in even greater P deficit due to insignificant increase of its removal by crop yields.

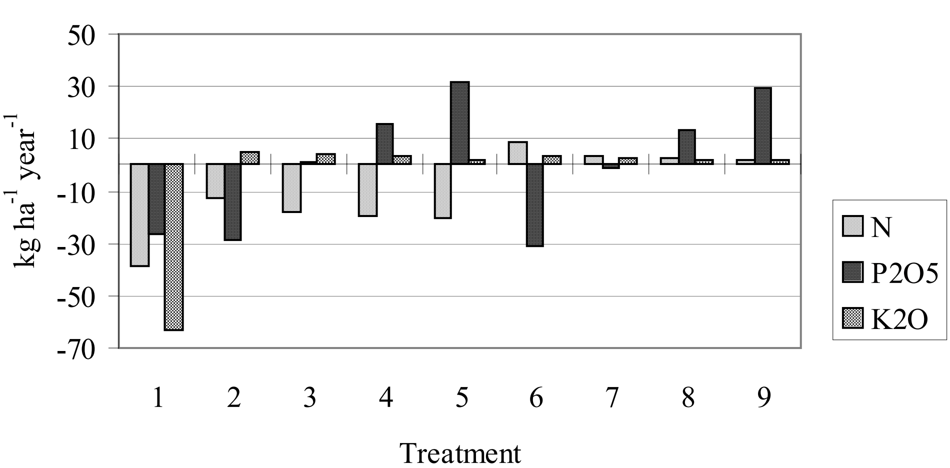

Fig. 1. Average NPK balance in crop rotation (1998-2003)

Effect of P fertilizer norms on N, P and K balances at similar K supply but on backgrounds with different N fertilizer norms is shown in Figure 2. N balance in crop rotation was mainly affected by the applied N mineral fertilizer rate. At N fertilizer norm N_{40} the nitrogen balance was negative but already norm N_{70} in crop rotation provided positive balance 1.9 – 8.9 kg ha^{-1} per year, besides such N surplus did not leave negative effect on the environment. Only in the treatment P_0 nitrogen removal was smaller, and with this, balance was more positive.

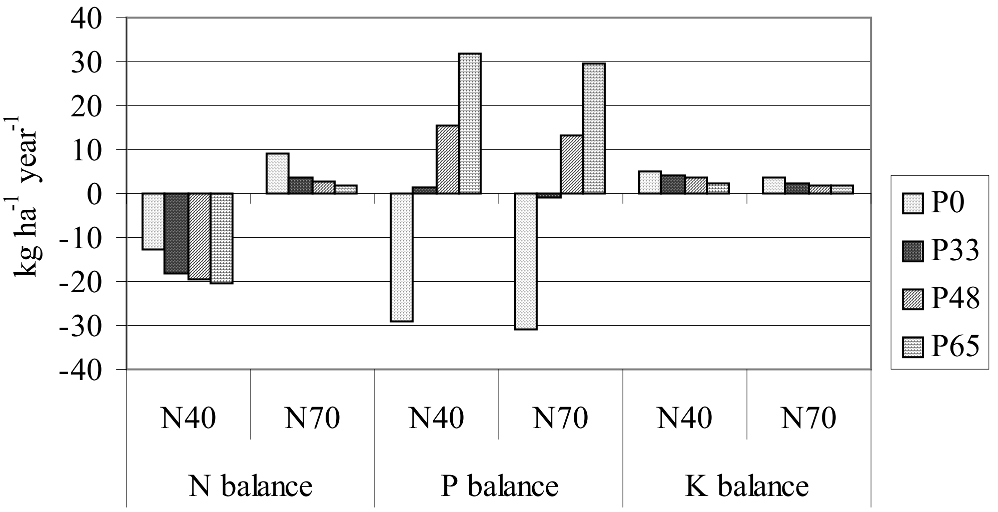

Fig. 2. Effect of average phosphorus norms on NPK balance in crop rotation

P balance in crop rotation was positive and directly proportional to incorporated P fertilizer norm (correlation coefficient r = 0.99). P fertilizer norm P_{33} almost fully covered the average removal of this plant nutrient by crop yield in crop rotation. Increasing P fertilizer norm to P_{65}, balance on the fertilizer background $N_{40}K_{60}$ was reaching +29.5 kg ha^{-1}, but on fertilizer background $N_{70}K_{60}$ - +31.8 kg ha^{-1} P_2O_5. Judging from obtained balance parameters and considering high plant available P content in soil, its maintenance in such a level would suffice with P fertilizer norms corresponding to removal by crop yield and in crop rotation would account for about 40 kg ha^{-1}on average.
K input in soil and removal by crop yield in the experiment was balanced not considering that averagely only 60 kg ha^{-1} K_2O were annually incorporated in crop rotation. It could be explained with K amount, which was accumulated in the basic product forming removal from soil. Most of K removed by by-products (straw, 2nd cut clover and rape herbage) was returned back to soil. K balance was positive on both N fertilizer backgrounds N_{40} and N_{70} – 2.1 – 5.2 kg ha^{-1} and 1.6 – 3.5 kg ha^{-1} K_2O respectively. The size of P fertilizer norm had insignificant effect on K balance as the removal of K by crop yield somewhat decreased in treatments with no-P fertilizer use.

Conclusions

Obtained results indicate that in our investigated crop rotation with cereals being dominating crop NPK fertilizer norms were balanced and mineral fertilizer use efficiency was high enough avoiding environmental pollution risks. However lowest norms of N fertilizer used for cultivated plants could be revised and increased due to negative N balance obtained on this background.

References

Anon. (2004) Agricultural Farms in Latvia: statistical bulletin / Central Statistical Bureau of Latvia. Riga, 81 p.

Arhipova I., Bāliņa S. (1999) Statistika ar Microsoft Excel ikvienam. Datorzinību centrs, 163 lpp.

Buciene A., Svedas A., Antanaitis S. (2003) Balances of the major nutrients N, P and K at the farm and field level and some possibilities to improve comparisons between actual and estimated crop yields. European Journal of Agronomy. 20(1), p. 53-62.

Goodlass G., Halberg N. and Verschuur G. (2003) Input output accounting systems in the European community—an appraisal of their usefulness in raising awareness of environmental problems. European Journal of Agronomy. 20(1-2), p. 17 - 24.

Jakobsson, C. (2001) Agenda 21 for the Baltic Sea Region – Baltic 21. Ecologically Improved Agriculture – Strategy for Sustainability. K. Skogs–o. Lantbr.akad. Tidskr., 140(6), p.33 – 42.

Oborn I., Edwards A. C., Witter E., Oenema O., Ivarsson K., Withers P. J. A., Nilsson S. I. and Richert Stinzing A. (2003) Element balances as a tool for sustainable nutrient management: a critical appraisal of their merits and limitations within an agronomic and environmental context. European Journal of Agronomy**.** 20(1-2), p. 211-225.

OECD National Soil Surface Nutrient Balances: Explanatory notes. March, 2001, OECD secretary. – 19 p.

Parris K. (1998) Agricultural nutrient balances as agri–environmental indicators: an OECD perspective. Environmental Pollution, 102 (Suppl 1), p. 219 – 225.

Sheldrick W.F., Syers J. K., Lingard J. (2002) A conceptual model for conducting nutrient audits at national, regional, and global scales. Nutrient Cycling in Agroecosystems. 62(1). – p. 61-72.

Tunney H., Csath P., Ehlert P. (2003) Approaches to calculating P balance at the field-scale in Europe. Journal of Plant Nutrition and Soil Science. 166(4), p. 438 – 446.

Vos J., Van der Putten P.E.L. (2000) Nutrient cycling in a cropping system with potato, spring wheat, sugar beet, oats and nitrogen catch crops. I. Input and offtake of nitrogen, phosphorus and potassium. Nutrient Cycling in Agroecosystems. 56(2). – p.87 – 97.

EFFECT OF DIFFERENT SOIL-CLIMATIC CONDITIONS ON THE QUALITY OF TABLE POTATOES

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In the Czech Republic the part of areas, on which table potatoes were cultivated, was displaced from traditional potato regions (higher altitudes above 400 m above sea with stony soils) to lower altitudes with more fertile soils without stones. This spontaneous displacement was connected with excessive mechanical damage of tubers during the harvest on stony soils in potato region. In this connection the quality of potato tubers from this region attracts the attention because the soil-climatic conditions could affect it.
Content of dry matter in cool, cloudy years rich in rainfall is usually less (Nowacki et al., 2000), on contrary in warm sunny years and in longer vegetation periods is higher (Míča, Vokál, 1995). Potatoes react differently to rain fall periods and water stress regarding growth and development of above ground mass (Storey, Davies, 1992). Zgórska and Frydecka-Mazurczyk (2000) determined in their experiments high correlation between meteorological conditions of the last 10 days before the harvest and dry matter content and reducing sugars. Higher sum of precipitation and lower average temperatures in this period have as a consequence lesser dry matter and starch content, but higher reducing sugar content.
Mechanical damage resistance (pendulum index) is positively affected by tuber maturity (Storey, Davies, 1992; Sowa-Niedzialkowska, 2000; Nowacki et al., 2000). Effect of rainfall and temperature distribution during the growing season on the degree of mechanical damage to potato tubers was recently studied in Poland. The index of mechanical damage was positively correlated with rainfall in May - September, particularly that during August - September and negatively correlated with the heat sum in May - September, particularly that during ripening (Marks et al., 1993).
Shock et al. (1994) estimated that the content of *reducing sugars* in potatoes is strongly affected by varietal properties, climatic conditions of growing locality, maturity of tubers during the harvest, but above all by temperature and the time of tubers storage. Putz (1995) concluded that with increasing degree of tubers maturity the decrease of reducing sugar content could be estimated.
Qualified estimations presume as high as 85% share on total content variability of *nitrates* in plants (Prugar, 1992). Frydecka-Mazurczyk and Zgórska (2000) described significant effect of nitrogen fertilization, effect of genotype and also effect of climatic conditions during growing vegetation. Especially absence of precipitation and high temperature during vegetation caused the increase of nitrates content. From the point of view of soil conditions potatoes accumulate more nitrates on the more fertile soils with higher biological effectiveness (Prugar, 1992).

Polyphenol content is affected above all with variety, year and stress factors as mechanical damage of potato tubers, attack with pathogens or effect of light on tubers are. About the light effect it is not in the literature enough evidence (Friedman, 1997).

In literature prevails the opinion that high *glycoalkaloid content* is connected with dry stress and high temperatures during vegetation (Zrůst et al., 2000; Frydecka-Mazurczyk and Zgórska, 1995). But some authors did not agree with this conclusion (Přichystalová–Fialková, 1999).
Definite research knowledge about the differences in inner quality of potatoes cultivated in different soil and climatic conditions in lowlands and higher altitudes of Czech Republic were lacking and this is the reason why we oriented our research to this problematic. We focused on these qualitative parameters: tubers resistance to mechanical damage, dry matter content, reducing sugars content, nitrates, polyphenol and glycoalkaloid content.

Material and methods

Potato samples: The varieties Impala, Karin, Agria, Korela, Rosella, Santé and Ornella were cultivated in field trials according unique farming techniques on the twelve localities in Czech Republic in the years from 1995 to 1997. Six of the twelve localities were situated in lower, warmer and drier regions (average above sea level 244 m, average temperatures and precipitation see in Table 1) with fertile predominantly loam soils (prevail Orthic Luvisol and black Luvic Chernozem) and in this contribution they are indicated with common term ”lower regions”. Other localities were situated in higher (average above sea level 531 m), cooler and more humid regions with less fertile predominantly sandy loam soils (prevails Cambisol) and they represent traditional potato growing regions in the Czech Republic. In our contribution we have indicated them as “higher regions”. The mean main weather parameters in the tested period are concentrated in Table 1. The tubers of the mentioned varieties were manually harvested and healed three weeks at 15 ^{o}C and 95 % humidity.

Chemical analysis: Tubers resistance to mechanical damage was determined on the electronic pendulum MIDAS 88 PP, dry matter content by gravimetric method reducing sugar content after Luff – Schoorl, nitrates content with ion-selective electrode, polyphenol content spectrophotometrically with Folin-Ciocalteu´ reagent a glycoalkaloid content (only in cv. Karin) with HPLC method.

Results and discussion

Tuber resistance to mechanical damage
Obtained results convincingly describe significant effect of different ecological conditions of higher and lower regions of the Czech Republic on tuber resistance to mechanical damage. In potatoes grown in lower situated regions were in all experimental years significantly higher pendulum index values determined as compared with potatoes from higher regions (Tab. 2). Because we have not found objective cause in chemical composition of tubers, we assume that this result is connected with the level of tuber maturity – with firmness of their skin, or if need be with the structure of cell walls and the size of cells in tuber flesh (Blahovec, 1996; Sowa-Niedzialkowska, 2000). Long year experience shows that in higher altitudes of CR we often meet worse tuber maturity, because higher above sea level and lower temperature in these regions cause the extension of the vegetation period of potatoes. This fact evidently appeared regarding tuber maturity in our experiments. In higher situated regions we recorded in all years apparently lower temperature averages and higher sum of precipitation during vegetation period and in September and October, when potatoes maturated (exception was only moderately higher sum of precipitation in lower regions at the end of the vegetation period in the year 1997, which was however in both regions extraordinary dry). Experiments proved that lower situated, warmer and more fertile regions of Czech Republic have basic

prerequisites for the production of table potatoes with higher tuber resistance to mechanical damage in comparison with higher situated regions.

Dry matter content (DM)
Locality did not affected significantly in our experiments dry matter of tubers. From tab. 2 it is evident that difference in DM content among tubers from lower and higher altitudes was in three-year average minimal (0.2 %) and it did not accessed the level of statistical significance. The same result was found for the experimental 1995. Though in the years 1996 and 1997 were the differences in DM content of tubers among localities significant, but the results were contradictory; whereas in the year 1996 they indicate values in favour of lower altitudes (by 1.7 % higher DM of tubers in comparison with higher altitudes), in the year 1997 on contrary the results were contradictory (DM content in lower altitudes was by 1.3 % lesser).

Opposite results from the years 1996 and 1997 are apparently in connection with weather course at the end of vegetation period of these years. The year 1996 distinguished in both localities by cool weather with rich precipitation at the end of August and in the first half of September, which already did not so much hit the potato plants in lower altitudes (earlier varieties have already finished their vegetation), whereas in higher altitudes this course of weather led to apparent yield increase, in some cases to worse maturity, to rejuvenescence of tubers and negatively affected DM content. Moreover the mentioned weather course at the end of vegetation in the year 1996 was in lower altitudes less apparent with less temperature and precipitation differences in comparison with long period average in higher altitudes. In the year 1997 the weather course at the end of vegetation period was on contrary very warm and dry and as a consequence significant yield decrease and contemporary DM increase in tubers in higher altitudes compared to lower altitudes was observed (plants in lower altitudes were hit by dryness less regarding the earlier vegetation with sooner term of potato maturity).

Total three-year resultants did not confirm presume of higher dry DM content in lower altitudes, which could be deduced from drier, warmer weather course with longer duration of sunshine (Míča, Vokál, 1995; Nowacki et al., 2000). It is evidently connecting with the fact that DM content is apparently affected by the weather course at the end of vegetation period (Zgórska, Frydecka-Mazurczyk, 2000), which was in two from three years of the period of our experiments extreme (with significant temperature and precipitation deviations from long period average).

Reducing sugar content (RC)
Potatoes cultivated in lower altitudes contained in all experimental years less RC than potatoes from higher altitudes, and at the same time difference in RC content in potatoes from both regions was statistically significant in the years 1995, 1996 and in three-year average (Tab. 2). Our results showed that in cooler and more humid climatic conditions of higher altitudes potatoes accumulate more RC in tubers. It is generally known that higher altitude above the sea and lower temperature cause the proliferation of vegetation period in potatoes, and this is why we are often in higher situated localities of CR meeting worse tuber maturity at the harvest period compared to the same varieties from lower situated localities. This fact appeared also in our experiments, when we recorded in lower altitudes in all years significantly higher temperature averages and lower sums of precipitation during vegetation period and in August and October, when potatoes are maturing, in comparison with higher altitudes. Exception was moderately higher sum of precipitation in lower altitudes at the end of vegetation period of the 1997, which was however in both regions extraordinary dry. About the lower average tuber maturity from higher altitudes confirms also their lower resistance to

mechanical damage. With lower tuber maturity is connected also higher RC content; Burton et al. (1992) and Putz (1995) confirmed this fact.

Nitrate content

Potatoes grown in lower altitudes contained in all three years more nitrates than potatoes from higher regions (Tab. 2). Decisive effect on higher nitrate content in potatoes from lower regions have evidently lesser sum of precipitation and higher average temperatures in vegetation period, especially in periods critical for the plant and tuber development, in this region against higher altitudes, when dry stresses disturbed the process of photosynthesis and restricted nitrogen use by a plant (sum of precipitation in vegetation period in the years 1995, 1996 and 1997 reached in lower regions 83.3 %, 94.4 % and 80.4 % of the value of higher regions). So our results confirm knowledge published by Cieślik, 1994, Frydecka-Mazurczyk, Zgórska, 2000, Hamouz et al., 1999 and Míča et al., 1991. Higher nitrate content in lower regions could hang in certain deal together with soil conditions. On brown and chernozem soils with higher soil fertility and biological activity with the connection with higher average temperatures in lower altitudes evidently accumulate more nitrates in consequence of mineralization (higher offer in soil solution affects their accumulation by plants) than on the soils of higher regions. To similar result came also Prugar (1992), who states that the higher soil fertility causes higher potential ability of plant to accumulate nitrates.

Table 1 Main weather characteristics of the regions in 1995-1997

Year	Region	Average temperature (^oC)			Sum of precipitation (mm)		
		August	September	April-Sept.	August	September	April-Sept.
1995	LR	18.92	13.57	15.63	90.6	82.4	439.9
	HR	16.15	11.80	13.42	100.2	113.0	527.7
	Aver.	17.53	12.68	14.53	95.4	97.7	483.8
1996	LR	18.23	11.10	14.57	73.3	53.1	463.5
	HR	16.12	9.02	12.40	97.1	69.0	490.9
	Aver.	17.18	10.06	13.48	85.2	61.1	477.2
1997	LR	19.90	13.98	15.02	46.9	29.3	391.8
	HR	18.02	12.70	13.12	33.6	25.6	487.9
	Aver.	18.96	13.34	14.07	40.2	27.3	439.8
Long-term average	LR	18.03	14.28	15.15	71.5	45.4	360.1
	HR	15.83	11.23	12.73	83.2	52.2	424.7
	$\bar{x}$	16.93	12.76	13.94	77.3	48.8	392.4

LR - lower regions (average of 6 localities), HR - higher regions (average of 6 localities), $\bar{x}$ – average of 12 localities

Polyphenol content

Potatoes cultivated in warmer and drier conditions in the localities with lower above sea level altitudes with mainly fertile predominantly loam soils (prevail Orthic Luvisol and black Luvic Chernozem) contained in all three years less polyphenolic compounds than potatoes from cooler and more humid localities of traditional potato growing regions with mainly sandy loam soils (prevails Cambisol). Difference between regions in three-year average was statistically significant (Tab. 2). During more detail evaluation of individual years we determined significant difference between regions only in the year 1995, in two next years identical trend was recorded. Our experiments show that more severe conditions in higher altitudes caused moderate increase of total polyphenol content. To similar conclusions we came also in our former work (Hamouz et al., 1999). In literature we have found only information (Mapson et al., 1963) that in some cases direct dependence of tyrosine content in potatoes on precipitation in the given locality was recorded. It corresponds to our results obtained for total polyphenol, but it is not necessary in full agreement between tyrosine and total polyphenol contents.

Glycoalkaloid content (GA)

In three year average of results was not in Karin variety demonstrated effect of soil climatic conditions of regions on GA content in tubers (Table 2). Differences in GA content in tubers between regions were minimal in the year 1996, in the year 1997 was evident definite trend of GA higher content in lower altitudes, but in the year 1995 significantly higher content of these compounds in tubers from higher altitudes with cooler and more humid climate was determined. Our knowledge goes along with the results of Přichystalová-Fialková (1999), but contradicts results obtained by Zrůst (2000).

Table 2 Influence of locality conditions of growing region on qualitative potato properties

Growing region	Year			
(Significance)	1995	1996	1997	Average
Pendulum index (% undamaged tubers)				
Lower altitudes	91.6	61.2	69.1	74.0
Higher altitudes	82.4	45.1	58.5	61.3
$D_{min(p0.05)}$/signif.	5.1/*	6.8/*	5.6/*	3.4/*
Dry matter content (%)				
Lower altitudes	21.6	21.5	22.3	21.8
Higher altitudes	21.4	19.8	23.6	21.6
$D_{min(p0.05)}$/signif.	2.24/ns	0.71/*	0.70/*	0.45/ns
Reducing sugar content (%)				
Lower altitudes	0.41	0.72	0.18	0.44
Higher altitudes	0.52	0.89	0.26	0.56
$D_{min(p0.05)}$/signif.	0.09/*	0.16/*	0.09/ns	0.07/*
Nitrate content (mg NO_3^-.kg^{-1})				
Lower altitudes	197.8	115.0	122.4	145.1
Higher altitudes	144.7	97.6	100.8	114.4
$D_{min(p0.05)}$/signif.	25.16/*	18.32/ns	15.78/*	11.37/*
Polyphenol content (mg.$100g^{-1}$)				
Lower altitudes	42.8	44.3	43.5	43.5
Higher altitudes	25.6	48.9	44.2	46.2
$D_{min(p0.05)}$/signif.	2.75/*	5.63/ns	4.14/ns	2.63/*
Glycoalkaloid content in cv. Karin (mg.kg^{-1})				
Lower altitudes	89.1	62.1	67.5	72.9
Higher altitudes	155.0	63.3	60.4	92.9
$D_{min(p0.05)}$/signif.	43.2/*	10.1/ns	18.9/ns	29.5/ns

*Statistically significant difference (α=0.05), ns non-significant difference

References

Blahovec J. (1996): Fyzikální a strukturální základy mechanického poškození brambor. Sborník ze semináře Kvalita konzumních brambor, VÚB, VŠCHT, Havl. Brod, 6.11.1996: 60-67.

Burton W. G., van Es A., Hartmans K. J. (1992): The physics and physiology of storage. In: Harris, P. M.: The Potato Crop. The Scientific Basis for Improvement, London, Chapman and Hall: 608-709.

Cieślik E. (1994): The effect of weather conditions in the level of nitrates in tuber of some potato varieties. Polish J. Food Nutr. Sci., 45: 11-13.

Friedman M. (1997): Chemistry, biochemistry, and dietary role of potato polyphenols. A Review. J. Agric. Food Chem., 45: 1523-1540.

Frydecka-Mazurczyk A., Zgórska K. (1995): Nitrates and glycoalkaloids concentration in potato tubers during the vegetation and storage period. Join Meeting Eur. Assoc. Pot. Res., Vila Real, Portugal, 24.-30.6.1995: 50-51.

Frydecka-Mazurczyk A., Zgórska K. (2000): Zawartość azotanów w bulwach ziemniaka w zalezności od odmiany, miejsca uprawy i terminu zbioru. Zywność, 4(25), Supl.: 46-51.

Hamouz K., Čepl J., Vokál B., Lachman J. (1999): Influence of locality and way of cultivation on the nitrate and glycoalkaloid content in potato tubers. Rostl. Výr., 45(11): 495-01.

Hamouz K., Blahovec J. (2001): Role of environment in mechanical damage of potatoes. Proc. Conf. „Physical Method in Agriculture“. CUA in Prague 27.- 30.8.2001:106-111.

Hamouz K., Lachman J., Vokál B., Pivec V. (1999): Influence of environmental conditions and way of cultivation on the polyphenol and ascorbic acid content in potato tubers. Rostl. Výr., 45(7): 299-303.

Mapson L. W., Swain T., Tomalin A. W. (1963): Influence of variety, cultural conditions and temperature of storage on enzymic browning of potato tubers. J. Sci. Food. Agric., 14: 673-684.

Marks N., Baran P., Sobol Z. (1993): Effect of rainfall and temperature distribution during the growing season on the degree of mechanical damage to potato tubers. Proc. Conf. Sci. and Technol. Progress in Polish Agriculture. Zesz. Probl. Post. Nauk. Roln., 408: 319-338.

Míča B., Vokál B., Penk J. (1991): Dusičnany v bramborách a možnost snížení jejich obsahu. Praha, MZe ČR: 75 s.

Míča B., Vokál B. (1995): Bramborový škrob, jeho význam a podmínky tvorby v hlízách. Bramborářství, 3(4): 11-14.

Nowacki W., Gluska A., Gruczek T., Lis B., Lutomirska B., Roztropowicz S., Zarzynska K. (2000): Uprawa ziemniaków a wartosc konsumpcyjna i technologiczna bulw. Konf. Nauk., Akad. Rol. we Wroclawiu - Polanica Zdrój, 8.-11.5.2000: 23-32.

Prugar J. (1992): Agroekologické faktory ve vztahu k hromadění dusičnanů v zelenině a bramborách. Rostl. Výr., 38(9-10): 875-881.

Přichystalová-Fialková V., Zrůst J., Hlušek J., Jůzl M. (1999): Obsah α-chaconinu a α-solaninu v hlízách velmi raných odrůd bramboru (*Solanum tuberosum* L.). Vědecké práce VÚB - 13, Havlíčkův Brod: 91-102.

Putz B. (1995): Importance of the physiology of the [potato] tuber, as expressed by maturity, for reducing sugar at harvest and in storage. Veroeff. Arbeitsgem. Kartoffelforsch., 16: 18-25.

Shock C. C., Stieber T. D., Zalewski J. C., Eldredge E. P., Lewis M. D. (1994): Potato tuber stem-end fry color determination. American Potato Journal, 71: 77-88.

Sowa-Niedzialkowska G. (2000): Wplyw warunków wzrostu roślin i magazynowania bulw odmian jadalnych ziemniaka na ich trwalość do przrechowalnicza. Biul. IHAR Jadwisin, 213: 225-232.

Storey R. M. J., Davies H. V. (1992): Tuber quality. In: Harris P. M. (ed.): The potato crop. London, Chapman & Hall: 507-552.

Zgórska K., Frydecka-Mazurczyk A. (2000): Wplyw warunków w czasie wegetacji oraz temperatury przechowywania na cechy jakości ziemniaków przeznaczonych do przetwórstwa. Biul. Inst. Hodowli i Aklimatyzacji Roślin. Jadwisin (NR 213): 239-251.

Zrůst J., Horáčková V., Přichystalová V., Rejlková M. (2000): Content of alpha-chaconine and alpha-solanine in groups of potato varieties listed in the national book of varieties of the Czech Republic. Rostl. Výr., 46(11): 481-486.

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ENTOMOPATHOGENIC FUNGI IN SOIL – NATURAL COMPONENTS OF BIOINTENSIVE IPM

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Abstract

Total of 113 soil samples was collected evenly throughout the South Bohemia region from various cereals' fields. Entomopathogenic fungi were discovered in 108 samples and 197 strains of entomopathogenic fungi representing 3 genera and 5 species of mitosporic fungi recorded. Among all, *Paecilomyces lilacinus* with 104 isolated strains was the most frequently detected species followed with *Metarhizium anisopliae*, *Beauveria bassiana*, *Paecilomyces carneus* and *Paecilomyces fumosoroseus*. When monitored with GBM, *M. anisopliae* with 46 strains and *B. bassiana* (14 strains) were the most frequently discovered species. Contrary, *P. lilacinus* and *P. carneus* were the only species which presence in soil was proved only with selective PDA-dodine medium. All other species of entomopathogenic fungi were detected with both selective techniques. Also, augmentative release of *B. bassiana* strain M062 was tested to verify its potential to colonize soil niche. It was found, that this strain became dominant component in soil when assessed 6 weeks after introduction. Furthermore, introduction if *B. bassiana* – M062 did not influenced diversity of other naturally occurring entomopathogenic fungi, because all other species (e.g. *M. anisopliae* and *P. lilacinus* were still detected even 6 weeks after strain M062 was introduced. Comparison of partial DNA profiles (PCR-RAPD) proved the identity of all *B. bassiana* strains that were isolated after introduction of M062, including identity with introduced strain.

Key words: entomopathogenic fungi, *Beauveria bassiana*, arable soils, augmentative release

Introduction

The concept of „*Biointensive Integrated Pest Management*" constitutes new interpretation of an IPM. An important difference between conventional and biointensive IPM is that the emphasis of the latter is on proactive measures to redesign the agricultural ecosystem to the disadvantage of a pest and to the advantage of its pathogen, parasite and predator complex (Dufour 2001). Among proactive measures, the intentional support of naturally occurring beneficials is one of the most important strategies, which unambiguously meet the criteria of biointensive IPM.

Entomopathogenic fungi are frequently recorded as important components in arable soils. Particularly, *Metarhizium anisopliae*, *Beauveria bassiana*, *Paecilomyces lilacinus* and *P. fumosoroseus* are regularly detected in various soil niches (Mietkiewski, Mietkiewska 1993, Bidochka *et al.* 1998, Landa et al, 2002). Different methods are used to detect entomopathogenic fungi in soil. Particularly, larvae of great wax moth *Galleria mellonella* (Zimmermann 1986, Mietkiewski *et al.* 1997, Landa et al. 2002) are routinely used as bait insects. Furthermore, different selective artificial media are also used to discover entomopathogenic fungi from soil (Goettel, Inglis 1997), including selective media with a.i.

dodine, which is preferably used to detect presence of *Metarhizium anisopliae* and *Beauveria bassiana* (Chase *et al.* 1986; Pereira, Roberts 1991). Very little is known about abundance and importance of entomopathogenic fungi in cultivated soils and about theirs capability to colonize soil niche after their augmentative introduction (biological control practices intended to increase the number or effectiveness of existing natural enemies). This project was therefore aimed to monitor the occurrence of entomogenous fungi in arable soils, with special attention to compare diversity of mitosporic entomopathogenic fungi in soils collected from fields with various cereals. Also, the capability of particular strain of the entomopathogenic fungus *Beauveria bassiana* to establish in soil system after augmentative release was tested, including verification of standard procedures aimed to determine *B. bassiana* on strain specific level.

Materials and methods

Fungal strains

Strain M062 was used to study capability of *B. bassiana* to establish after augmentative release into soil system. Also, *B. bassiana* strains Bba-01 (reisolate from commercial biopreparation Botanigard®) and strain Bba-02 (isolated from soil substrate sampled at greenhouses of IFAS, UF, MFRC Apopka, Florida, USA) were used to demonstrate variability of partial RAPD pattern among different *B. bassiana* isolates.

Production and application of Beauveria bassiana

Conidiospores of *B. bassiana* – strain M062 were obtained from 14 days old cultures grown on sterile natural substrate (peeled barley) in Erlenmeyer flasks (25±1°C, photoperiod 16/8). Submerged cultures were used to produce blastospores for augmentative release or biomass for DNA extraction. Sterile Erlenmeyer flasks (250 ml) filled with 100 ml of PDB (potato-dextrose-broth, SIGMA) were inoculated with 10 ml of blastospore suspension adjusted to 1.0 x 10^7 blastospores /1 ml and shaken continuously on orbital shaker (200 rpm, amplitude 5, 25±1°C) for 5 days. Both, blastospores or conidiospores of *B. bassiana* were applied as suspensions with 0.05% Tween 80. Suspensions were adjusted on titer 1.0 x 10^7 per 1 ml and applied with back sprayer on soil surface (approx. 100 ml/1 m^2). Fungus was applied 30 – 45 min before soil surface cultivation. Soil samples were collected before application and 6 weeks after augmentative release of strain M062.

Monitoring of the occurrence of entomopathogenic fungi in soil samples

A modified "G*alleria baits method*" (GBM) (Zimmermann 1986; Landa *et al.* 2002) and selective artificial medium (Chase *et al*. 1986; Landa *et al.* 2002) were used to monitor presence of entomogenous fungi in soil. First, homogenized soil samples were placed into sterile plastic Petri dishes (diameter 90 mm, 40 ml of soil/1 dish, 2 replicates per sample), moistened with sterile distilled water and 3rd instar larvae of *G. mellonella* (10 larvae/1 dish) were added and incubated for 14 days at 25±1°C. All samples were evaluated on day 7, 10 and 14. When external growth of fungi was visible anywhere on the integument of the insect bait, cadavers were removed and placed into new sterile Petri dish and incubated for next 3-5 days at 25°C, before fungus was isolated and purified. After 14 days of exposure, all remaining larvae were removed from soil, immersed for 3 minutes into 1% solution of sodium hypochlorite, washed with sterile distilled water and placed on surface of wet sterile filter paper in Petri dish for further incubation (3-5 days). Secondly, potato-dextrose agar (PDA, Difco) with supplement of fungicide dodine (50 μg/1 ml) and antibiotic (chloramphenicol – 50 μm/1 ml) was used as a selective media. When analyzed, 20g of soil sample were soaked into 100 ml of sterile 0.05% Tween 80 solution, homogenized on orbital laboratory shaker (15 minutes, 200 rpm, amplitude 5), filtered through sterile cloth and after diluted with sterile 0.05% Tween 80 (1:10 - v/v) 0.5 ml of adjusted suspension was spread over the surface of selective media in Petri dish (90 mm diameter, 5 replicates/1 soil sample) and incubated at 25°C for 14 days. Presence of entomopathogenic fungi was recorded on day 7, 10 and 14 (Chase *et al.* 1986; Liu *et al.* 1993). Soil samples were classified as negative if entomopathogenic fungi were detected neither with *G. mellonella* baiting nor with PDA-dodine selective medium. When growth of fungus was observed on cadavers or selective medium, the fungus were transferred with a sterile needle on PDA plates and purified isolates were identified after seven days of incubation on thin layer of PDA on surface of microscopic glass (25°C, photoperiod 0/24) (Humber 1997; Samson 1974).

<u>DNA extraction and RAPD analysis</u>

Modified method for DNA extraction and RAPD reactions were used, when capability of *B. bassiana* strain M062 to establish in soil after augmentative release was evaluated (Tigano-Milani *et al*. 1995; Bieliková *et al.* 2002). Approximately, 100 mg of biomass obtained from submerged culture (PDB Difco, orbital shaker) was used for DNA extraction. Fungal biomass was frozen at –20^{o}C for 24 hrs then grounded in 1.5 ml microfuge tube with sterile plastic stick. The homogenized mixture was suspended in 500 µl sterile lysis buffer (50 mM Tris/HCl, 150 mM NaCl, 100 mM EDTA), then 50 µl 10% (w/v) SDS was added, and tubes were shaken gently. After one hour at 37^{o}C, 75 µl 5 M NaCl was added and mixed, 60-µl cetyltrimethylammonium bromide (CTAB) solution (10%, w/v, CTAB in 0.7 M NaCl) was added and mixed again, the suspension was incubated at 65^{o}C for 20 min and centrifuged for 2 min at 8 000 rpm. The supernatant was extracted with an equal volume of chloroform/isoamylalcohol (24:1 v/v), and 0.6 volume of 2-propanol was added to precipitate the nucleic acids. The pellets obtained by centrifugation at 14,000 rpm for 10 min were washed with 70% (v/v) sterile ethanol, dried and resuspended in 100 µl of sterile distilled water. The extracted DNA was assessed on 1% TAE (Tris/Acetic Acid/EDTA) agarose gel stained with etidium bromide (Sambrook *et al.*1989).

The RAPD reactions were performed in a 25 µl volumes of reaction mix: 0.2mM of each dNTPs (Promega), 0.5 µM primer (Operon Technologies), 1U Taq-polymerase (Finnzyme), 1 x polymerase recommended buffer (Finnzyme) and 1µl template DNA, using Termocycler PTC 1160 (MJ-Research). The temperature profile for all reactions was 92 ^{o}C for 3 min in initial step followed by 45 cycles of 92 ^{o}C for 1 min, 35 ^{o}C for 2 min, 72 ^{o}C for 3 min, with a final extension at 72 ^{o}C for 10 min. Reaction products were checked by loading full reaction mixture onto 2% TAE agarose gel with ethidium bromide. Gels were photographed by Polaroid gel camera and pictures were digitized (600 dpi, Adobe Photoshop) and processed using Biprofil 1D ++. Set of primers from kit OPB and OPF (Operon Technologies) was used to demonstrate variations among various strains of fungus *Beauveria bassiana* gained.

Results and discussion

Total of 113 soil samples was collected evenly throughout the South Bohemia region from various cereals' fields. Entomopathogenic fungi were discovered in 108 samples (95.58%) and 197 strains of entomogenous fungi representing 3 genera and 5 species of mitosporic fungi were isolated, purified and immobilized into Na-alginate pellets for long term maintenance. Among all, *Paecilomyces lilacinus* with 104 isolated strains (92.04 % of soil samples, resp. 52.79 % from all strains which were isolated) was the most frequently detected species followed with *Metarhizium anisopliae* (67 strains, 59.29 %, resp. 34.01 %), *Beauveria bassiana* (16 strains, 14.16 % resp. 8.12 %), *Paecilomyces carneus* (6 strains, 5.31 %, resp. 3.05 %) and *Paecilomyces fumosoroseus* (4 strains, 3.54 %, resp. 2.03 %). When monitored with GBM, *M. anisopliae* with 46 strains (40.71 % of soil samples) and *B. bassiana* (14 strains, 12.39 % of soil samples) were the most frequently discovered species. On the contrary, *P. lilacinus* (104 strains, 92.04 % of soil samples) and *P. carneus* (6, 5.31 %) were the only species which presence in soil was proved solely when selective medium was used for analysis. All other species of entomopathogenic fungi were detected with both selective techniques.

Tab. 1. Occurrence of entomopathogenic fungi in soils collected from winter barley fields

Fungal species	Total no. of soil samples	Soil samples with fungi		*Galleria* bait method [i]		PDA with dodine [ii]	
		No.	%	No.	%	No.	%
P. lilacinus	20	19	95,0	0	0,0	19	95,0
M. anisopliae	20	15	75,0	10	50,0	10	50,0
B. bassiana	20	2	10,0	2	10,0	0	0,0
P. carneus	20	2	10,0	0	0,0	2	10,0
P. fumosoroseus	20	0	0,0	0	0,0	0	0,0

[i] Presence of entomopathogenic fungi monitored with "*Galleria bait method*"
[ii] Presence of entomopathogenic fungi monitored with selective "*dodine*" medium

Tab. 2. Occurrence of entomopathogenic fungi in soils collected from spring barley fields

Fungal species	Total no. of soil samples	Soil samples with fungi		*Galleria* bait method		PDA with dodine	
		No.	%	No.	%	No.	%
P. lilacinus	14	11	78,57	0	0,00	11	78,57
M. anisopliae	14	9	64,29	5	35,71	8	57,14
B. bassiana	14	2	14,29	2	14,29	0	0,00
P. carneus	14	1	7,14	0	0,00	1	7,14
P. fumosoroseus	14	1	7,14	1	7,14	0	0,00

Tab. 3. Occurrence of entomopathogenic fungi in soils collected from winter wheat fields

Fungal species	Total no. of soil samples	Soil samples with fungi		*Galleria* bait method		PDA with dodine	
		No.	%	No.	%	No.	%
P. lilacinus	46	43	93,48	0	0,00	43	93,48
M. anisopliae	46	21	45,65	11	23,91	17	36,96
B. bassiana	46	6	13,04	6	13,04	2	4,35
P. carneus	46	1	2,17	0	0,00	1	2,17
P. fumosoroseus	46	1	2,17	0	0,00	1	2,17

Tab. 4. Occurrence of entomopathogenic fungi in soils collected from rye fields

Fungal species	Total no. of soil samples	Soil samples with fungi		*Galleria* bait method		PDA with dodine	
		No.	%	No.	%	No.	%
P. lilacinus	15	14	93,33	0	0,00	14	93,33
M. anisopliae	15	9	60,00	9	60,00	7	46,67
B. bassiana	15	2	13,33	1	6,67	1	6,67
P. carneus	15	1	6,67	0	0,00	1	6,67
P. fumosoroseus	15	2	13,33	2	13,33	0	0,00

Tab. 5. Occurrence of entomopathogenic fungi in soils collected from oat fields

Fungal species	Total no. of soil samples	Soil samples with fungi		*Galleria* bait method		PDA with dodine	
		No.	%	No.	%	No.	%
P. lilacinus	13	12	92,31	0	0,00	12	92,31
M. anisopliae	13	8	61,54	7	53,85	5	38,46
B. bassiana	13	3	23,08	2	15,38	2	15,38
P. carneus	13	1	7,69	0	0,00	1	7,69
P. fumosoroseus	13	0	0,00	0	0,00	0	0,00

Tab. 6. Occurrence of entomopathogenic fungi in soils collected from other crop fields. [iii]

Fungal species	Total no. of soil samples	Soil samples with fungi		*Galleria* bait method		PDA with dodine	
		No.	%	No.	%	No.	%
P. lilacinus	5	5	100,00	0	0,00	5	100,00
M. anisopliae	5	5	100,00	4	80,00	3	60,00
B. bassiana	5	1	20,00	1	20,00	0	0,00
P. carneus	5	0	0,00	0	0,00	0	0,00
P. fumosoroseus	5	0	0,00	0	0,00	0	0,00

[iii] e.g. oat under seeded with clover, barley under seeded with clover, rye with winter wheat ...etc.

Tab. 7. Frequency of the occurrence of entomopathogenic fungi in soils collected from fields with different cereals

Crop	Soil samples with entomopathogenic fungi (%)				
	P. lilacinus	*M. anisopliae*	*B. bassiana*	*P. carneus*	*P. fumosoroseus*
winter barely	95,00	75,00	10,00	10,00	0
spring barley	78,57	64,29	14,19	7,14	7,14
winter wheat	93,48	45,65	13,04	2,17	2,17
rye	93,33	60,00	13,33	6,67	13,33
oak	92,31	61,54	23,08	7,69	0
other crops	100	100	20,00	0	0
Mean (%)	92,12	67,75	15,62	5,61	3,78
±STDV	± 6,5486	±16,7908	± 4,4725	± 3,4243	± 4,9669

Within a study of augmentative release of *B. bassiana,* soil samples were collected from experimental plots (8) and analyzed twice, 1) immediately before and 2) 6 weeks after strain M062 was introduced. When analyzed with GBM before introduction of *B. bassiana* M062, the occurrence of *B. bassiana* was detected in 5 from 8 soil samples, but none naturally occurring isolate of *B. bassiana* was discovered when soil samples were assessed with selective PDA-dodine medium. On the contrary, the presence of *B. bassiana* was recorded in all samples (GBM) and in 7 soil samples when analyzed with selective PDA-dodine medium 6 weeks after augmentative release of *B. bassiana* M062.

Tab. 8. Occurrence of entomopathogenic fungi in soil monitored with "*Galleria* bait method" before and after introduction of *Beauveria bassiana* – strain M 062 (Žabčice, 2004)

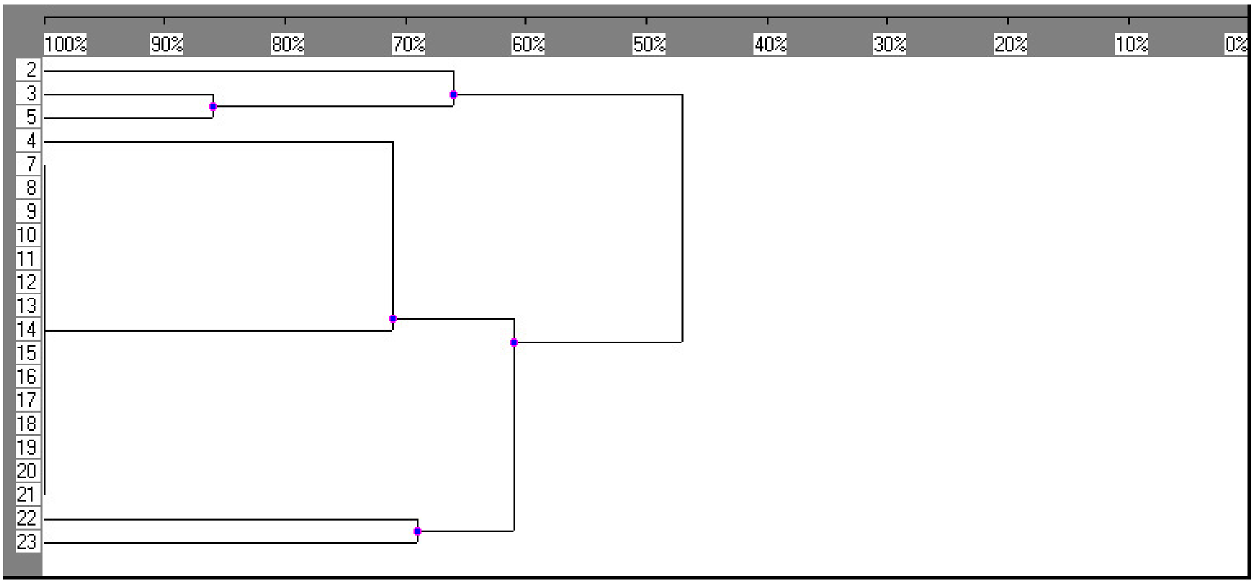
Site No.	Isolated fungal species		Introduction of *B. bassiana* – M062
	before M062 introduction	after M062 introduction	
Ao3-I	*M. anisopliae*	*M. anisopliae, B. bassiana*	blastospores
Ao3-II	-	*M. anisopliae, B. bassiana*	blastospores
Ao3-I	*M. anisopliae, B. bassiana P. fumosoroseus*	*B. bassiana*	conidiospores
Ao3-II	*M. anisopliae, B. bassiana*	*B. bassiana*	conidiospores
Ao4-I	*M. anisopliae, B. bassiana*	*M. anisopliae, B. bassiana*	blastospores
Ao4-II	*M. anisopliae, B. bassiana*	*M. anisopliae, B. bassiana*	blastospores
Ao4-I	*M. anisopliae*	*B. bassiana*	conidiospores
Ao4-II	*M. anisopliae, B. bassiana*	*M. anisopliae, B. bassiana*	conidiospores

Tab. 9. Occurrence of entomopathogenic fungi in soil monitored with selective PDA-dodine medium before and after introduction of *Beauveria bassiana* – strain M 062 (Žabčice, 2004)

Site No.	Isolated fungal species		Introduction of *B. bassiana*-M062
	before M062 introduction	after M062 introduction	
Ao3-I	*M. anisopliae, P. lilacinus*	*M. anisopliae, B. bassiana, P. carneus, P. lilacinus*	blastospores
Ao3-II	*M. anisopliae, P. lilacinus*	*M. anisopliae, B. bassiana, P. carneus, P. lilacinus*	blastospores
Ao3-I	*M. anisopliae, P. lilacinus*	*M. anisopliae*, *B. bassiana P. lilacinus*	conidiospores
Ao3-II	*M. anisopliae, P. lilacinus*	*M. anisopliae, B. bassiana P. carneus, P. lilacinus*	conidiospores
Ao4-I	*M. anisopliae, P. lilacinus*	*M. anisopliae, P. lilacinus*	blastospores
Ao4-II	*M. anisopliae, P. lilacinus*	*M. anisopliae, B. bassiana P. lilacinus*	blastospores
Ao4-I	*M. anisopliae, P. lilacinus*	*M. anisopliae, B. bassiana P. lilacinus,*	conidiospores
Ao4-II	*M. anisopliae, P. lilacinus*	*M. anisopliae, B. bassiana P. lilacinus*	conidiospores

Comparison of partial DNA profiles (PCR-RAPD) proved the identity of all *B. bassiana* strains that were isolated after introduction of M062. Furthermore, RAPD analysis demonstrate also identity between introduced strain M062 and all *B. bassiana* strains which were reisolated from soil after introduction of this strain. Besides, comparison of cultures grown on PDA (size, shape, horizontal profile, color...etc.) confirm similarity between isolates of *B. bassiana* which were isolated after introduction of M062 and simultaneously showed up differences of those strains when compared either with reference strains of US origin (strains No. 22 and 23), and *B. bassiana* isolates which were discovered within first evaluation (strains No. 2-5). Those results indicate capability of *B. bassiana* M062 colonize soil niche and became dominant component in soil after augmentative introduction. Furthermore, introduction of *B. bassiana* did not influenced diversity of other naturally occurring entomopathogenic fungi, because all other species (e.g. *M. anisopliae* and *P. lilacinus*) were still detected even 6 weeks after strain M062 of *B. bassiana* was introduced.

Fig. Similarity matrix and dendrogram of *Baeuveria bassiana* isolates gained by analysis of partial RAPD profiles (*B. bassiana* isolates obtained after introduction of *B. bassiana* - M062)



2-5:	Strains of *B. bassiana* isolated with GBM before introduction of *B. bassiana* - M062
7:	*B. bassiana* – strain M062
8-21:	*B. bassiana* strains isolated by GBM or selective PDA-dodine medium 6 weeks after augmentative introduction of M062
22-23:	*B. bassiana* – strains of US origin (Botanigard® - 22, MFRC Apopka - 23)

All fungi, which have been detected within this study, represent polyphagous species recognized as beneficial components of soils worldwide (Goettel, Inglis 1997). Particularly, *M. anisopliae*, *B. bassiana* and *P. fumosoroseus* are already used as the components of commercially available mycoinsecticides which are used in biological control against many insect pests (Mann, Hall 1999), and *P. lilacinus* is known also as nematophagous fungus (Kiewnick, Sikora 2004). The frequency of natural occurrence of this fungi and capability of *B. bassiana* to colonize soil niche after augmentative release, as it was demonstrated in this study, indicates importance of native strains of entomopathogenic fungi and possibility to enhance their role either by support or by augmentative release.

Literature

Bidochka M.J., Kasperski J.E., Wild A.M., 1998: Occurrence of the entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria bassiana* in soils from temperate and near-northern habitats. Canadian Journal of Botany, 76: 1198-1204.

Chase A.R., Osborne L.S., Ferguson V.M., 1986: Selective isolation of the entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* from an artificial potting medium. Florida Entomologist, 69: 285-292.

Dufour R., 2001: Biointensive integrated pest management (IPM). Attra, [cit. 2005-05-13], available on http://attra.ncat.org/attra-pub/PDF/ipm.pdf

Goettel M.S. & Inglis G.D., 1997: Fungi – Hyphomycetes. *In:* LACEY L.A. (Ed.): Manual of techniques in insect pathology. Academic Press, Chapter V.: 213-249.

Humber, R. A., 1997: Fungi-Identification. *In*: LACEY, L. A. (Ed.): Manual of Techniques in Insect Pathology, Academic Press, Chapter III.: 153-185.

Kiewnick S., Sikora R.A., 2004: Optimizing the efficacy of Paecilomyces lilacinus (strain 251) for the control of root-knot nematodes. Communications in Agricultural and Applied Biological Sciences, 69, 3: 373-380.

Landa Z., Horňák P., Osborne L.S., Nováková A., and Bursová E., 2001a: Entomogenous fungi associated with spruce bark beetle *Ips typographus* L. (Coleoptera, Scolytidae) at National Park sites of the Bohemian Forest. Silva Gabreta, 6:259-272.

Landa Z., Bieliková L., Osborne L.S., and Bobková P., 2001b: Assessment of isolates of entomogenous fungi collected from spruce bark beetle *Ips typographus* L. (Coleoptera, Scolytidae) at National Park sites in the Bohemian Forest. *Silva Gabreta, 6:273-286*

Landa, Z., Horňák, P., Charvátová, H., Osborne, L.S., 2002: Distribution, occurrence and potential use of entomopathogenic fungi in arable soils in Czech Republic. In: Proceedings of International Conference ISTRO "Current Trends in the Research of Soil Environment", held in Brno, CR, October 2-5th2002, pp. 195-201

Liu, Z.Y., Milner, R.J., McRae, C.F., Lutton, G.G., 1993: The use of dodine in selective media for isolation of Metarhizium spp. from soil. Journal of Invertebrate Pathology, 62, 248-251.

Menn J.J., Hall F.R., 1999: Biopesticides - Present status and future prospects. *In*: Methods in biotechnology, Vol. 5: Biopesticides – Use and delivery. Hall F.R. & Menn J.J. (Eds.) Humana Press Inc., Totowa, NJ, chapter 1: 1– 10.

Mietkiewski R., Mietkiewska Z., 1993: Occurrence of entomopathogenic fungi in arable soils. Acta Mycologica, 28, 1:77-82.

Pereira R. M. & Roberts D.W., 1991: Alginate and cornstarch mycelial formulations of entomopathogenic fungi, *Beauveria bassiana* and *Metarhizium anisopliae*. Journal of Economic Entomology, 84, (6): 1657-1661.

Sambrook, J.; Fritsch, E. F.; Maniatis, T., 1989: Molecular cloning: a laboratory manual, 2nd ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York

Samson R.A., 1974: *Paecilomyces* and some allied Hyphomycetes. Studies in Mycology, 6: 1-119.

Tigano-Milani M.S., Samson R.A., Martins I., Sobral B.W.S. (1995): DNA Markers for Differentiating Isolates of *Paecilomyces lilacinus*. Microbiology, 141: 239-245.

Vanninen I., Husberg G.B., Hokkanen M.T., 1989: The occurrence of entomopathogenic fungi and entomoparasitic nematodes in cultivated soils in Finland. Acta Entomologica Fennica, 53: 65-71.

Zimmermann G., 1986: The "Galleria bait method" for detection of entomopathogenic fungi in soil. Journal of Applied Entomology, 102: 213-215.

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THE EFFECT OF SOME AGRONOMICAL PRACTICES ON INCIDENCE OF SOME PATHOHENS OF WINTER WHEAT IN THE YEAR 2004

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Abstract

The effect of some agronomical practices on incidence of wheat eyespot (*Pseudocercosporella herpotrichoides*) and wheat leaf blotch (*Septoria tritici*) was studied in small plot experiments in the year 2004. The factors studied were: foregoing crop, tillage and straw management. We have found that only factor of foregoing crop influenced incidence of *Pseudocercosporella herpotrichoides* and *Septoria tritici* on winter wheat. The stands of this crop were much more damaged if wheat preceded in comparison with safflower. We did not find any interaction between studied factors on the incidence of these pathogens.

Keywords: wheat, pathogens, crop rotation, tillage, straw management

Introduction

Many plant pathogens survive between growing seasons on plant debris in so called saprophytic phase. That is why different cultural practices and systems of plant production can influence the incidence of these pathogens. In the Czech Republic new cultural practices (e.g. tillage with reduced operations and some new practices of straw management) are implemented. Wheat eyespot caused by pathogen *Pseudocercosporella herpotrichoides* and *Septoria tritici* leaf blotch are the common diseases in this region. The influence of various tillage and straw management systems on incidence of these pathogens was studied by many authors, but the information are contradictory in many cases. For instance Colbach and Sauer (1998) did not prove any difference between plough-in and removal of straw on the incidence of *Pseudocercosporella herpotrichoides*, conversely Jenkyn et al. (2001) brief, that straw incorporation in the soil decrease the incidence of this pathogen. Many authors did not prove the influence of different tillage on the incidence of eyespot (Bistrichanov et al., 1995; Kelly a Dube, 2000). Colbach et al. (1999), Blecharczyk et al. (1999) a Brautigam a Tebrugge (1994) determined, that reduced tillage increase the infection of wheat by *Pseudocercosporella herpotrichoides*. On the contrary Herman et al. (1992), Garbe (1994) and Pratley (1995) detected the decrease of wheat infection by this pathogen in variants with reduced tillage. The effect of various agronomical practices can be influenced by conditions of stands, that is why we decided to determine wheat infection by *Pseudocercosporela herpotrichoides* and *Septoria tritici* under conditions of different soil tillage and straw management in the dry and warm region of the Czech Republic. This work was funded by Ministry of Agriculture of the Czech Republic, project No. 1G46055.

Material and methods

The effect of some factors on the incidence of *Pseudocercosporella herpotrichoides* and *Septoria tritici* in winter wheat was determined in small plot experiments on the locality Žabčice (maize growing region) in the year 2004. These factors were:

A. foregoing crop – wheat, safflower
B. soil tillage
    I. unreduced – skimming and plough
    II. reduced – only skimming
C. straw treatment – straw was incorporated in the soil after treatment by:
    a. Beta-liq
    b. DAM
    c. Unifert
    d. untreated control

The incidence of *Pseudocercosporella herpotrichoides* was determined on wheat stalk bases in growing stages BBCH 69-71 and 85. The incidence of disease were evaluated by five grade scale (1 – unifected, 5 – the stalk base totally destroyed). The incidence of *Septoria tritici* was determined on wheat leaves in the growth stages BBCH 69-71 and was evaluated by nine grade scale (1 – unifected, 9 - leaf area totally covered by spots of *Septoria* infection). The influence of particular factors on the incidence of above mentioned pathogens were statistically treated by multi component analysis of variance (computer programme UNISTAT).

Results

Pseudocercosporella herpotrichoides

The infection of wheat by this pathogen was very low in the first term of evaluation, but it increased till the second term. In both terms of evaluation we have found, that only factor of foregoing crop influenced incidence of eyespot disease on winter wheat. The stands of this crop were much more damaged if wheat preceded in comparison with safflower (Table 1). We did not find any interaction between studied factors on the incidence of *Pseudocercosporella herpotrichoides.*

Table 1 - The grade of winter wheat infection by *Pseudocercosporella herpotrichoides*

Tukey HSD

Factor	22.6.2004	20.7.2004
Foregoing crop		
Safflower	1,065[b]	1,573[b]
Wheat	1,334[a]	2,104[a]
Tillage		
I	1,086[a]	1,817[a]
II	1,113[a]	1,861[a]
Straw treatment		
a	1,093[a]	1,848[a]
b	1,108[a]	1,731[a]
c	1,109[a]	1,813[a]
d	1,088[a]	1,962[a]

ANOVA – 22.6.2004

Source of variability	df	MS	F
Foregoing crop (FC)	1	0,076	15,378
Tillage (T)	1	0,012	2,460
Straw treatment (ST)	3	0,020	0,367
FCxT	1	0,009	1,835
FCxST	3	0,005	1,094
TxST	3	0,005	0,994
FCxTxST	3	0,005	1,014

ANOVA – 20.7.2004

Source of variability	df	MS	F
Foregoing crop (FC)	1	4,521	165,922
Tillage (T)	1	0,031	1,140
Straw treatment (ST)	3	0,146	5,375
FCxT	1	0,000	0,001
FCxST	3	0,058	2,123
TxST	3	0,014	0,500
FCxTxST	3	0,025	0,906

Septoria tritici

In the term of evaluation, the incidence of *Septoria* leaf blotch was also influenced only by factor of foregoing crop. Variants in which winter wheat preceded were much more damaged by this pathogen in comparison with variant where safflower was foregoing crop (Table 2). We did not also find any interaction between factors on the incidence of *Septoria tritici.*

Table 2 - The grade of winter wheat infection by *Septoria tritici*

Tukey HSD

Factor	22.6.2004
Foregoing crop	
Safflower	2,661[b]
Wheat	3,325[a]
Tillage	
I	3,098[a]
II	2,888[a]
Straw management	
A	2,916[a]
B	2,888[a]
C	2,922[a]
D	3,247[a]

ANOVA

Source of variability	df	MS	F
Foregoing crop (FC)	1	7,056	71,857
Tillage (T)	1	0,712	7,250
Straw treatment (ST)	3	0,462	4,705
FCxT	1	4,28	43,586
FCxST	3	1,119	11,395
TxST	3	0,433	4,413
FCxTxST	3	0,04	0,412

From our results we can conclude, that the foregoing crop can be very important factor of wheat infection by serious stalk bases and leaf pathogens. These results are only preliminary, because the effect of many factors on infection by pathogens can be also influenced by weather condition in different years. These experiments will be carried out also in next years.

References

Bistrichanov,S. - Christov,I. - Petrov,P.: Effect of some agricultural factors on the basic rot (Pseudocercosporella herpotrichoides, Fron.). Infection and wheat yield. Rasteniev"dni Nauki 32, 5: 97-99, 1995.

Blecharczyk,A. - Skrzypczak,G. - Malecka,I. - Piechota,T.: Effect of differentiated soil tillage on physical soil properties and yield of winter wheat and pea. Conference: Soil tillage systems: 171-179, 1999.

Brautigam,V. -Tebrugge,F.: Effect of long term plough-less soil cultivation systems on Pseudocercosporella herpotrichoides (Fron) Deighton; Fusarium spp. and Gaeumannomyces graminis (Sacc.) Arx et Olivier. 46th International symposium on crop protection, Gent, Belgium: 1009-1015, 1994.

Colbach,N. - Meynard,J.M. - Duby,C. - Huet,P.: A dynamic model of the influence of rotation and crop management on the disease development of eyespot. Proposal of cropping systems with low disease risk. Crop Protection 18, 7: 451-461, 1999.

Colbach,N. - Saur,L.: Influence of crop management on eyespot development and infection cycles of winter wheat. Eur. J. Plant Pathol. 104, 1: 37-48, 1998.

Garbe,V.: Reduced tillage: few plant protection problems. PSP-Pflanzenschutz-Praxis. 2: 25-28, 1994.

Herman,M. - Dovrtel,J. - Suskevic,M.: The effect of soil cultivation and forecrop on reduction of winter wheat yield by foot and root rot diseases.Rostl.Vyr. 38, 7: 595-602, 1992.

Kelly,D.J. - Dube,A.J.: Management of Rhizoctonia bare patch in the South Australian mallee using a modified direct drilling system, deep-banded urea, and sowing time in relation to the break in the season. Austr.J.Exp.Agr., 1: 57-67, 2000.

Jenkyn,J.F. - Christian,D.G. - Bacon,E.T.G. - Gutteridge,R.J. - Todd,A.D.: Effects of incorporating different amounts of straw on growth, diseases and yield of consecutive crops of winter wheat grown on contrasting soil types. J. Agr. Sci. 136, 1: 1-14, 2001.

Pratley,J.E.: Long term investigations of the effect of tillage practices on crop production at Wagga Wagga, New South Wales. Austr. J. Exp. Agr. 35, 7: 885-892, 1995.

EFFECT OF SOIL BIOTA ON SOIL AND CROP HEALTH

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Abstract
Interactions of AM fungi with plants (lettuce, barley) and soil microflora were studied in pot experiments under the stress conditions (high content of As and ^{137}Cs in the soil). Inoculation of plants with AM Glomus mosseae BEG 25 significantly restricted the uptake of contaminants from soil to plants. At the same time, transfer of contaminants from roots to above-ground biomass was limited in inoculated plants. The presence of AM fungi modified populations of N-transforming soil microorganisms.

Key words: AM fungi, soil microflora, lettuce, barley, As, ^{137}Cs.

Soil health is defined as the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments and maintain plant, animal and human health (Doran et Safley, 1997). Soil microorganisms play an important role in soil as well as in plant health. They decompose organic debrice, synthetize humus, mobilize plant nutrients and participate in soil aggregate formation. A key component of soil microbial communnities are arbuscullar mycorrhizal (AM) fungi which increase the absorptive surface area of plant root systems, provide an increased area for interactions with other soil microorganisms and represent an important pathway for the transformation of energy-rich plant assimilates to the soil (Johansson et al 2004). A better understanding of the interactions among soil microorganisms, AM fungi and plants is crucial above all for low-input cropping systems as soil biota may improve supply of nutrients for plants, contribute to the biocontrol of pathogens and remove pollutants thus maintaining crop and soil health.
The purpose of this study was to describe and explain the interactions among soil microorganisms, AM fungi and plants under the stress conditions (high concentration of As and ^{137}Cs in the soil).

Material and Methods

In the pot experiments, the lettuce (*Lactuca sativa L., var. Jupiter*) and barley (*Hordeum vulgare L.*) were used. Plants were preincubated in growth chambers for 3 weeks (barley) or 6 weeks (lettuce) and inoculated with *Glomus mosseae* BEG 25.

<u>Experiment No1</u>
Lettuce seedlings were cultivated in arable soil taken from an experimental field plots three weeks after the application of different rates of arsenic: 0.0 (control), 4.5, 60.0 and 120.0 mg As per kg of dry soil. The experiment consisted of eight variants representing four levels of As combined both with/and without the inoculated AM fungus.Glomus mosseae Each variant was replicated 12 times. The dry matter of above- and underground plant biomass, root

colonization by AM fungi (Giovanneti et Mosse, 1980), As in plants (wet combustion and dissolution of ash substances in 10 M HNO_3 ASS Philips PU 7200) and microbiological properties of soils (plate-counts) were estimated after seven weeks of cultivation of lettuce in greenhouse.

Experiment No2

The transfer of radiocesium (^{137}Cs) from soil to barley plants were followed. Pots with plants inoculated and /or non-inoculated with AM fungus and arable soil enriched by nutrients were placed in phytotron for a period of five weeks. From the beginning of experiment, soil was contaminated with $^{137}CsCl$ aqueous solution gradually with five small doses (l KBq every 2nd day). Dry matter of above – and underground plant biomass, ^{137}Cs in plants (HPGe detector), and colonization of roots by AM fungi were analyzed (for details see Experiment No 1).
Results have been statistically evaluated (Statgraphic, ANOVA $P \leq 0.05$).

Results and Discussion

Inoculation of lettuce plants with mycorhizal fungus Glomus mosseae BEG 25 increased colonization of roots and led to significant plant yields increase (Tab. 1, Fig.1). Lettuce plants growing in unpolluted soil showed 61% AM root colonization while those in soil polluted by arsenic (4.5,60.0,120mg per kg of dry soil) exhibited weak colonization (27%, 14% and 7%, respectively).

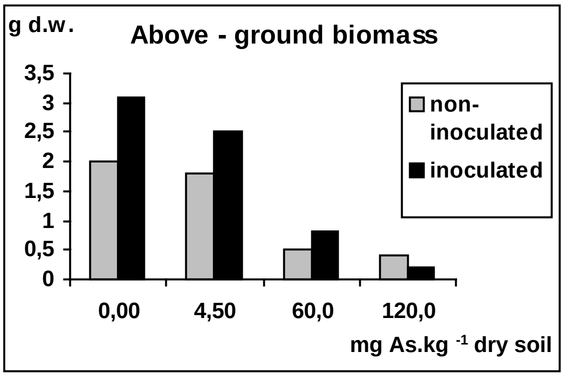
AM root colonization substantionally restricted As input from roots to the above-ground biomass. Content of As in the above-ground biomass of inoculated lettuce plants growing in polluted soils was substantionally lower, than that of non-inoculated plants (Fig.l).
Results of experiments with barley confirmed that presence of AM fungus G.mosseae significantly restricted the uptake of ^{137}Cs by plants. Transfer of ^{137}Cs from soil to barley was lower in shoots in comparison with roots and was independent on the inoculation with AM fungi (Tab.2).

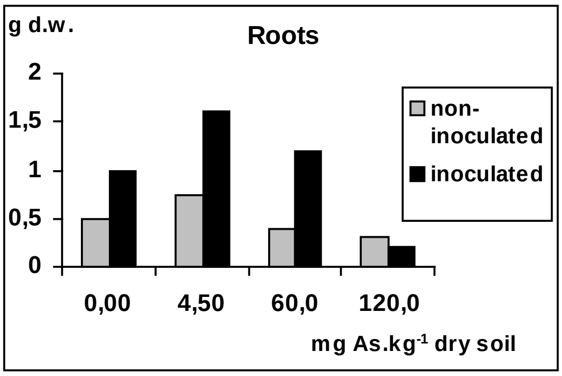
Tab.1 Effect of inoculation with Glomus mosseae BEG 25 (AM) on the colonization of roots (%) and content of As in plant biomass ($mg.kg^{-1}$ dry matter) under the different As contend in the soil.

As in the soil (mg.kg dry soil)	Colonization of roots (%) n=12	As content in plant biomass (n=3)	
		above-ground	roots
Control (0)	39.09^{f}	0.02^{a}	0.05^{a}
(AM)	60.90^{g}	0.02a	0.08^{a}
4.50 As (0)	20.00^{d}	0.22^{b}	0.55^{b}
(AM)	26.66^{e}	0.21^{b}	0.69^{b}
60.00 As (0)	10.00^{bc}	0.65^{c}	0.62^{b}
(AM)	13.70^{c}	0.29^{b}	0.85^{c}
120.0 As (0)	0.01^{a}	1.41^{e}	1.20^{d}
(AM)	6.41^{b}	0.92^{d}	1.85^{e}

Values in columns marked by the different letters are statistically different.

Fig. 1 Effect of inoculation of lattuce with *Glomus mosseae* on the biomass production under the increasing content of As in the soil





Tab. 2 The transfer of radiocesium (^{137}Cs) from soil to barley plants inoculated and/or non-inoculated with Glomus mosseae BEG 25 (n=11)

	non-inoculated	inoculated
Biomass (g d.w)		
shoots	0.7^a	0.7^a
roots	0.3^a	0.3^a
^{137}Cs activity (cps.kg^{-1})		
shoots	133.3^b	96.7^a
roots	884.0^b	753.0^a
Transfer coefficient (TR)		
shoots	0.38^a	0.30^a
roots	2.54^b	2.33^b

Values in lines marked by different letters are statisttically different.

Colonization of roots by AM fungi affects not only plants but can induce structural and functional changes in soil microbial communities (Ames et al., 1984). However, the mechaníisms of the interactions are still poorly understoed (Amara-Lazcano et al., 1998). In our experiments, a simple dilution plate technique was used for comparison of soil microflora accomanying mycorrhizal and non-mycorrhizal plants. The occurence of free-living nitrogen-fixing bacteria as well as ammonitging microorganisms in pot cultures of lettuce colonized by AM Glomus mosseae was significantly higher than in non-mycorrhizal plants, whereas counts of fungi significantly decreased (Tab.3).

Tab.3 Changes in soil microbial communities accompanying mycorrhizal and non-mycorrhizal lettuce. Data in CFU per 1 g of dry soil. For details see Tab.1

	CFU		
	Bacterie		Fungi
	Ammonifieyrs x10^6	Azotobacter x10^3	x10^4
Control (0)	88.7^e	9.62^c	48.61^e
Control (AM)	122.6^f	16.30^d	29.12^d
4.50 AS (0)	62.8^d	5.62^b	31.16^d
(AM)	93.8^e	10.13^c	18.00^c
60.00 AS (0)	15.8^c	0.20^a	29.46^d
(AM)	56.2^d	2.60^a	10.41^c
120.0 A (0)	0.36^a	0.09^a	3.14^b
(AM)	8.62^b	0.16^a	0.48^a

Values in columns marked by the different letters are statistically different

Evidently, the presence of AM fungi can modify populations of N-transforming microorganisms and these interactions may affect nutrient availability in soil (Amore-Lazcano et al. 1998). A better understanding of the interactions of soil microorganisms with AM fungi and with plants is therefore crucial for the development of sustainable management of soil and erop health.

Acknowledgements

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Literature

Ames,R.N., Reid,C.P.P, Ingham, E.R.: Rhizosphere bacterisl population responses to root colonization by a vesicular-arbuscular mycorrhizal fungus. New Phytologist, 96 (1984), 555-563

Amora-Lazcano,E.,Vasquez,M.M.,Azcon,R.: Response of nitrogen-transforming microorganisms to arbuscular mycorrhizal fungi. Biology and Fertility of Soils 27 (1998), 65-70

Doran ,J.W.,Safley,M.: Defining and assessing soil health and sustainable productivity. In: Panhkurst,C.E., Doube,B,M., Gupta,V.V.S.R. (eds): Biologica Indicators of Soil Health. Wallingford, CAB International (1997), 1-28

Giovannetti,M., Mosse,B.: An evaluation of techniques for measuring vesicular-arbuscular infection in roots. New Phytologist 84 (1980), 489-500

Johansson,J.F., L.R.Paul, R.D.Finlay: Microbial interactions in the mycorhizosphere and their significance for sustainable agriculture. FEMS Microbiology Ecology 48 (2004), 1-13.

WEED INFESTATION AND WEED MANAGEMENT IN THE INTEGRATED AND ECOLOGICAL FARMING SYSTEMS

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Abstract

The development of actual weed infestation in spring barley and winter wheat stand was investigated during the 2001-2004 period in small plot field experiments at the experimental base of FAFR SAU Nitra, Dolná Malanta. The investigation methods of weed infestation monitoring were the EWRS (European weed research society) standard methods – the number of weeds and their weight per square meter. In field condition of the experiment the weed infestation achieved different values according to different variants from low to very high level. In the ecological farming system the occurrence of different weed species was significantly higher and similarly in this system the weight of weed dry matter was much higher than in the integrated one. Higher weed occurrence was recorded in the fertilized variant within the framework of different fertilization level variants. On the other hand the spectrum of weed species was wider in the non-fertilized variant. In the integrated farming system the dominant weed species in the cereal crop coverage were according to the level of infestation: *Cirsium arvense, Stellaria media, Medicago sativa, Cardaria draba, Tripleurospermum perforatum, Chenopodium album, Convolvulus arvensis, Thlaspi arvense, Capsella bursa pastoris, Lamium purpureum, Avena fatua, Persicaria maculosa and Amaranthus retroflexus*. In the ecological system the dominant weed species were: *Tripleurospermum perforatum, Chenopodium album, Cardaria draba, Capsella bursa pastoris, Cirsium arvense, Lamium amplexicaule, Lamium purpureum, Thlaspi arvense, Medicago sativa, Stellaria media, Galium aparine and Polygonum aviculare*.

Key words: weeds, farming systems, cereals, ecological and integrated farming systems

Introduction

The weed species in the individual farming years and in various stand conditions are very variable. It is mainly *Galium aparine* which requires a lot of our attention and this is because of its negative impact and the difficulty of limiting it. This weed spreads easily due to the mild winters, high ratio of winter plants (summer wheat the winter form and a white mustard), removal of competing weeds and insufficient action of herbicides. There is a considerable occurrence of *Anthemis arvensis* and other botanically related varieties in higher altitudes in densely sown cereal plots. The other various variety of *Tripleurospermum spp*. are occurring more in southern areas. In recent years the *Cirsium arvense* started to spread out of control; this one does not grow only amongst the cereals densely sown but also amongst some legumes and other plants sown in wide inter-rows as for example sugar beet, sunflowers and corn (Fabri, Brunclik, 1999 and Smatana, 2003). The authors also mention that alongside this variety there is a higher occurrence of other permanent weeds specifically *Convolvulus arvensis* amongst the cereals and this is mainly due to the lower ratio of fodder plants and insufficient regulation measures to eliminate mainly annual weeds.

The weeds compete with the cultivated plants by considerably reducing the crop. In order to be able to regulate the weeds it is necessary to understand perfectly the biology of weed plants, the ways of their regulation. In future, there will be always an interest in limiting the impact of all negative factors and great attention is going to be devoted to the study of weeds (Wallinga, 1998; Soukup, 2003; Kohout – Holec - Fišerová, 2003; Týr, 2003). We observed the development of cereals plots and the occurrence and development of different weeds within the plots in two different systems with a tendency of change after several years.

Materials and methods

The task was solved in field small plot experiments in the framework of six crop sequences on the basis of experiment base of Faculty of Agro biology and Food Resources of the Slovak Agricultural University, Nitra. The allotments are situated on the grounds of SBER Dolna Malanta.
The task was being solved in during the years 2001- 2004 in the framework of the project VEGA 1/9083/02.

I. The farming system

A: THE INTEGRATED FARMING SYSTEM
- Negative impact protection on the basis of prognosis localisation marking rationally.
- Fertilisation by means of industrial fertilisers and manure in order to achieve the planned crop yields.

B: THE ECOLOGICAL FARMING SYSTEM
- Mechanical weeding of the whole crop, physical weed regulation in crops with wider rows.
- Only manure fertilisation by means of balance method.

II. Observation of actual weed infestation

1. Crop and weed inspection in spring before using the herbicides – numerical method (integrated system) and before the mechanical input (ecological system).
2. Crop and weed inspection after herbicide usage – numerical method (integrated system) and after the mechanical input (ecological system).
3. Crop and weed inspection before the harvest – numeric and weighing method.

III. Crop rotation

Table 1

Crop rotation							
Year	**Farming system**	**I.**	**II.**	**V.**	**VI.**	**VII.**	**VIII.**
2001	A	Alfalfa	Winter wheat	Common peas	Winter wheat	Spring barley	Corn for silage
	B	Bean+ Alfalfa	Winter wheat	Spring barley	Common peas	Corn for silage	Alfalfa
2002	A	Winter wheat Sunflower	Corn for silage	Winter wheat White mustard	Common peas	Bean+ Alfalfa	Spring barley

	B	Alfalfa	Common peas White mustard	Bean + Alfalfa	Corn for silage	Spring barley	Winter wheat Sunflower
2003	A	Common peas	Spring barley	Corn for silage	Winter wheat White mustard	Alfalfa	Winter wheat Sunflower
	B	Winter wheat Sunflower	Corn for silage	Alfalfa	Spring barley Sunflower	Bean + Alfalfa	Common peas White mustard
2004	A	Winter wheat White mustard	Bean + Alfalfa	Spring barley	Corn for silage	Alfalfa	Common peas
	B	Common peas White mustard	Spring barley Sunflower	Winter wheat Sunflower	Bean + Alfalfa	Alfalfa	Corn for silage

Note: Sunflower and White mustard are intercrops

IV. Additional factors

- Number of experimental plots: 4.
- Experimental plots: 60 m$^{2.}$
- Number of repetition: 4 (r1, r2, r3, r4).
- Plots of experimental variant: 1 m^2
- Observed crop: spring barley and summer wheat winter variety.

Characteristics of the experiment

- **Climatic and meteorological conditions**
  The experiment was realised in the framework of agro-climatic areas in the territory with the following features:
- ***Macro area:*** warm with temperature t > 10 ^oC in a range of 3100 – 2400 ^oC.
- ***Area:*** predominantly warm with temperature t > 10 ^oC in a range of 3000 – 2800 ^oC.
- ***Sub area:*** very dry with climatic humidity factor for the months June -August K $_{VI-VII}$ = 150 mm.
- ***ward:*** predominantly mild winter with an average of absolute minimum of T_{min} = -18 to -21^oC.

The altitude is 172,5 m above sea level. The average long- term annual precipitation (1951 – 1980) is 532,5 mm, for the vegetation period 309,4 mm.
The average long- term annual temperature is (1951 – 1980) and for the vegetation period is 16,4 ^oC.

- **Soil characteristics**

Soil type: brown soil. Proportional soil weight: 2,60 – 2,61 t.m^{-3}. The contents of humus in arable soil/top soil: 2,16 % in average (mean value). Soil reaction: 5,03 – 5,69 (acidic almost mild acidic). The experimental stand was created at the proluvial sediments. The soil profile of brown soil has three genetic horizons (Ap, Bt, c), and their stratography is following; Humus (Ap) horizon with depth 0,31 m underneath which is the main diagnostical luvisolic Horizon 9Bt0 and this one was as a result of alluvial accumulation of translocated colloids. Its depth is up to 0,66 m then there is a transitional horizon (Bt/C) with a depth up to 0,95 m and follows continually into the soil forming substrate up to the depth of 1,5m. The studied brown soil is clayey in its sub layer and in its topsoil is mildly firm. Humus is of a humo-phulvate type (Hanes and others, 1993).

The soil preparation was realised at the experimental plots in the years of 2001 –2004 in order to create the suitable conditions for sowing and the following growth of the cultured crop in our case of spring barley and summer wheat after the crop appeared the number of grown plants was done at the surface of 1 m^2 according to the variants and repetitions in both farming systems. The state of the crop and weeds was described. In the farming system „A“ the integrated one the crop were rationally treated by means of herbicides. The efficiency of herbicides was evaluated according to the international scale of EWRS. In the farming system „B„ the ecological one the weeds were removed mechanically (*Cirsium arvense, Avena fatua*) manually by means of a sickle. It was before the blossom. By this we prevented further generative multiplication of these weeds

- The crop was evaluated according to Hosnedl and others (1979) (in Týr, 1997).
- Weed infestation of crop was evaluated according to Hosnedl and others. (1979). The author introduces the weed infestation grades S_1 – S_6, during the implementation of the experiments we used the adapted scale S_1 – S_4, taking into consideration its efficiency (in Týr, 1997).
- During the harvest of crop the weeds in the observed plants were pulled out from the efficient surface of 1 m^2 of each variant and analysed according to different species by means of numeric and weighing method. (Týr, 1997).

Results and discussion

The climatic conditions in 2001 were unfavourable for Spring Barley and this was due to the serious drought and insufficient precipitation followed by very warm weather. The precipitation conditions in 2002 and 2003 were considerably better even there was again considerable drought during the spring of 2003. The crop of cereal in 2001 was semi-densely and in a good condition. We noticed the differences in weed infestation in the integrated and ecological farming systems. The crop coverage over the four years in the integrated farming system was between 80- 90 % in average 85 % in the ecological farming system the crop coverage was in a range of 80 –95 % in average 90,00 %. Weed infestation in spring in the integrated farming system was 110,39 weeds per m^2. The weed coverage was 3,91 % in this system of farming. The most frequent varieties in the integrated system for a period of 4 years were: *Amaranthus retroflexus, Chenopodium spp., Cirsium arvense, Convolvulus arvensis, Persicaria maculosa, Tithymalus helioscopia, Fallopia convolvulus* (table 2). We observed 61,16 weeds per m^2in the ecological farming system for a period of four years in average. This is almost 45 % less than in the integrated farming system. The average weed infestation coverage for a period of four years was 4.33 %. The most frequent species in the ecological farming system were *Chenopodium spp., Amaranthus retroflexus, Tripleurospermum perforatum, Fallopia convolvulus, Persicaria maculosa, Cirsium arvense, Convolvulus arvensis, Stellaria media, Avena fatua* (table 2). During the harvest of spring barley for a period of three years the weed infestation in the integrated farming system was smaller than in the ecological one. The number of weeds in the integrated farming system achieved for a period of three years in average 2,36 weed per m2. The weight of weed dry matter was 25,02 $g.m^{-2}$. Over the period of three years the species the most represented were the following: *Convolvulus arvensis, Avena fatua, Cirsium arvense, Polygonum aviculare, Chenopodium spp., Plantago lanceolata, Cardaria draba* (table 3). The number of weeds before the harvest for a period of three years was in average 9,59 per m^2 in the ecological farming system .The weight of dry matter achieved a value of 151,07 $g.m^{-2}$. The most frequently represented species in average for a period of three years were *Cirsium arvense, Convolvulus arvensis, Amaranthus retroflexus, Chenopodium spp., Avena fatua, Cardaria draba, Plantago lanceolata* (table 3). There was not only much higher proportion of weeds per m^2, 45 % in the integrated farming system than in the ecological one but the weed coverage was also higher by 9,7 % in the ecological farming system. Before the harvest of cereal the ecological farming system was better than the integrated one and the percentage of weeds was 60 % higher in the ecological system (graph 1). The weed dry matter weight was higher in the ecological farming system in total by 86,48 %. (Graph 2).

Table 2 Weed infestation and state of densely sown cereal coverage in spring for a period of four years (2001 – 2004)

Year	Farming system on soil	In spring			
		Coverage in %		Weeds per m^2	The most frequent varieties
		Plants	Weeds		
x 2001 - 2004	x A	83,33	3,91	110,39	AMARE, CHEXX, CIRAR, CONAR, POLPE, EPHHE, POLCO
	x B	83,86	4,33	61,16	CHEXX, AMARE, MATIN, POLCO, POLPE, CIRAR, CONAR, STEME, AVEFA
	x AB	83,6	4,12	87,28	AMARE, CHEXX, CIRAR, CONAR, POLPE, EPHHE, POLCO, AVEFA, MATIN

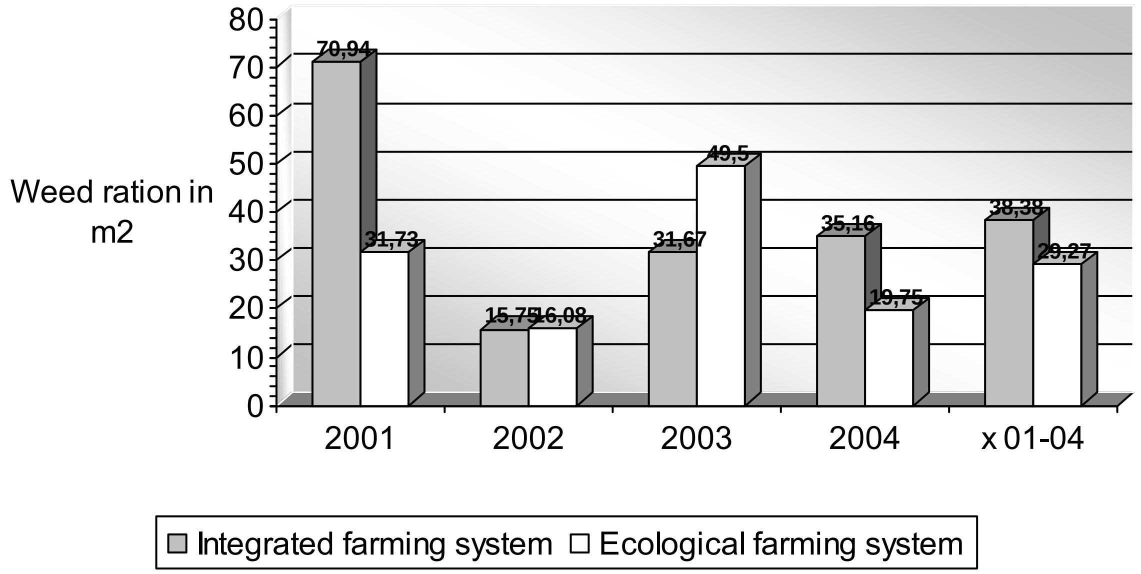
Table 3 Weed infestation and state of densely sown cereals coverage before harvest for a period of four years (2001 – 2004)

Year	Farming system on soil	Before harvest		
		Weed ratio per m^2	Weight of dried weeds in $g.m^{-2}$	The most frequent varieties
x 2001 - 2004	x A	2,36	6,93	CONAR, AVEFA, CIRAR, POLAV, CHEXX, PLALA, CARDR
	x B	9,59	51,24	CIRAR, CONAR, AMARE, CHEXX, AVEFA, CARDR, PLALA
	x AB	5,98	29,09	CHEXX, AVEFA, CIRAR, AMARE, CONAR, POLAV, CARDR, PLALA

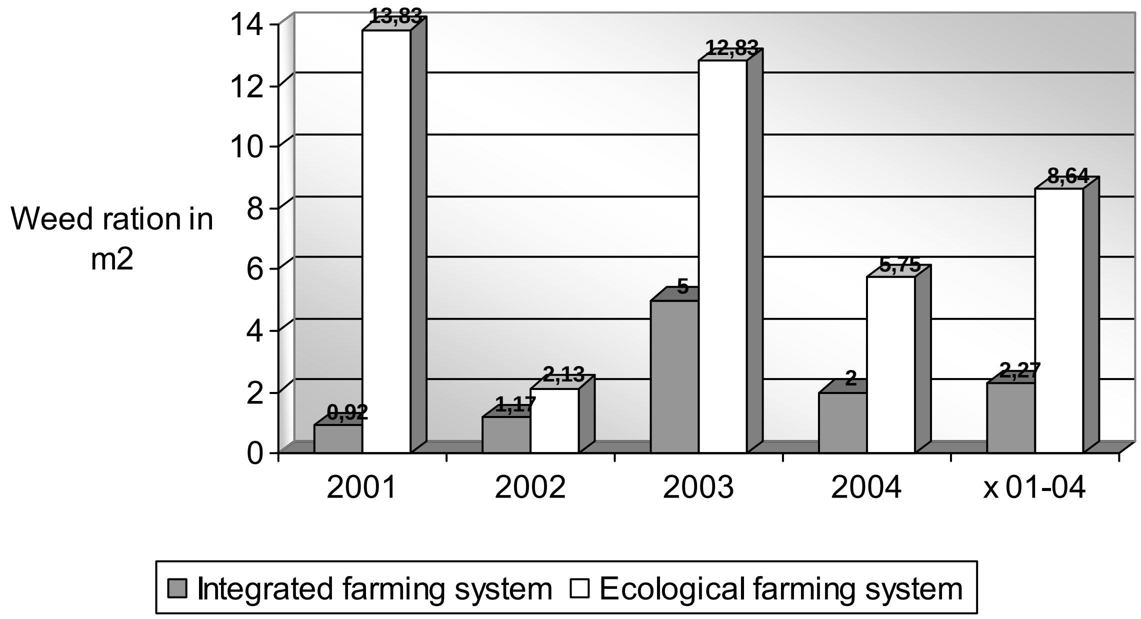
Legend: A – Integrated farming system, B – Ecological farming system, AMARE, CHEXX, and so on. –abbreviations of weeds according to the EWRS. „X“- average.

In the crop coverage of spring barley there were mainly *spring early* weed species as for example *Avena fatua, Fallopia convolvulus, Polygonum aviculare* . The results confirmed the Černuško and others (1994) data, that there is an occurrence of spring early weed species in spring cereal crops. They germinate at lower temperatures around 1 to 3 ^{o}C. Some varieties germinate and come out during the whole vegetation period. There were also some weeds from late spring types as for example: C*henopodium album, Amaranthus retroflexus,* *Tithymalus helioscopia, Persicaria maculosa.* We agree with Líška and others (2002) findings that late spring weeds come after the sowing of spring crop and sometimes even the winter crop. This group favours the coverage of thinned spring and winter plants. They germinate at the soil temperature of 6 to 10 ^{o}C. The highest weed infestation was in 2001.The most represented types were *Chenopodium spp.* and *Amaranthus retroflexus*. These weeds belong to a group of aggressive weed species and mainly the aggressive weed types are found in the manure used to fertilise the pre- plant. Similarly as Málek (1986) (quot. Líška and others 2002) confirms our results when he writes that there was 38 % more weeds in the topsoil on the plots fertilised by manure in comparison to the plots not fertilised. Apart other weed varieties the species as *Cirsium arvense, Avena fatua, and Sonchus oleraceus* were considerably represented. The variety of *Cirsium arvense* represents a big problem during the farming of cereals. Our observation is also confirmed by Šipek (1997), who considers this weed as a stubborn one and very adaptable to the environment and the plot. We agree with Škeřík (1999), who denominates this weed as one of the biggest problem in the agriculture. He proposes to destroy the creeping thistle mechanically before it blossoms. We agree with Petr and others (1983), in their belief that weed regulation should consist of weed species and weed infestation resources identification. It is also necessary to understand the important biological properties of weeds and it is also important to establish the weed infestation records of the plots and to prepare the weed infestation prognosis of the crop. The contemporary plant farming could be hardly realised without absolute use of herbicides and therefore it is necessary to apply them rationally and on the basis of weed infestation diagnosis and prognosis. We can unanimously say on the basis of our results that various farming systems do have various impacts on the weed infestation of cereal crop coverage. We also agree with the opinion of Černuško and others (1994), to use indirect methods in order to protect the cereal crops from the negative impact of weeds and this is from the economical and ecological point of view. It is necessary to prepare the soil in order to establish well the crop coverage and to protect the crops from the weed impact especially in the first stages of the crop growth. We can conclude on the basis of our research that the weed infestation reduced by means of herbicides application in average by 92,69 % in 2001 –2004 in the integrated farming system; whilst the reduction in the ecological farming system was 76,83 % without using the herbicides. The cereal crop coverage has to be able to compete and suppress the weeds as Černuško and others (2000) mention. Our findings confirm that the crop coverage establishment has to be efficient, the seedlings sown in the optimal time and in a required density.

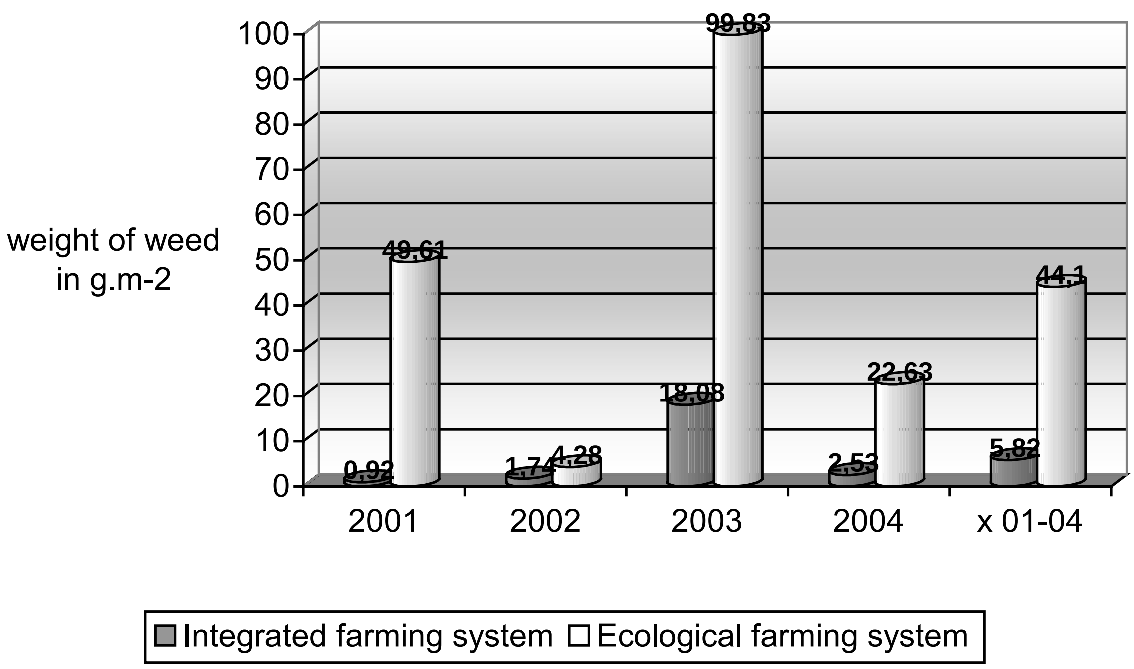
Graph 1 Weeds in crop coverage in spring in years 2001 - 2004 (number per m^{-2})



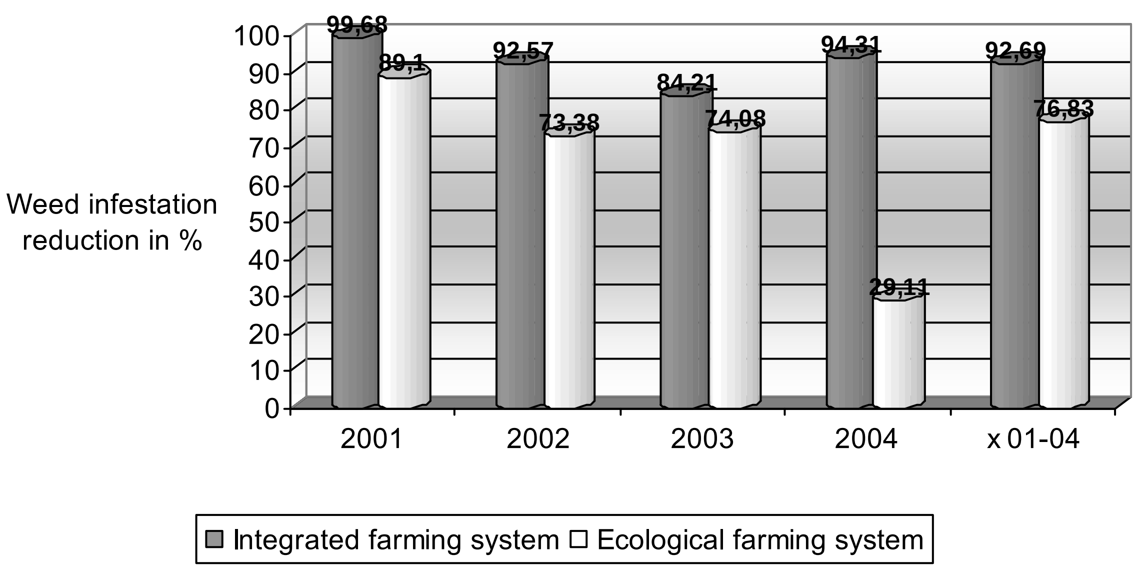
Graph 2 Weeds in crop coverage before harvest in years 2001 - 2004 (number per m^{-2})



Graph 3 Weight of dried weeds in crop coverage before harvest in years 2001 - 2004 (gramm per m^{-2})



Graph 4 Influence of farming systems for weed infestation in years 2001 - 2004 (%)



Conclusion

We observed the influence of two farming systems (integrated and ecological) on the state of weed infestation of cereals crop in the field small plot experiments of FAFR SPU, Nitra – Dolná Malanta during a period of years 2001 – 2004. We can conclude on the basis of researched literature and evaluated achieved results the following:

1. The soil and climatic conditions for the growth of cereal crop coverage were adequate. The crop coverage grew completely and this created very good competitiveness with weeds. The number of individual cereal plants was from 329 to 385 per m^2.
2. The types of individual farming systems influenced considerably the weed infestation of cereal plots in springtime.
3. The weed infestation of cereal crop was heavily influenced by the fact of using the manure as a fertiliser. The highest weed infestation was recorded during the first year in both farming systems. In this year the weed infestation was 126,94 – 283,75 per m^2. Later both systems differed in the proportion of weed infestation and the species e.g. *Cirsium arvense, Amaranthus retroflexus, Chenopodium album and Convolvulus arvensis* spread in the ecological farming system.
4. The differences between the two systems of farming were also in the number of species before the harvesting. Whilst we had in the integrated system the representation of the individual species from 1 to 10 varieties there was much wider weed species representation from 5 to 10 varieties in the ecological farming system.
5. The herbicides considerably reduced the occurrence of weeds by using in the integrated farming system. Some weed species still remained but the herbicide usage considerably limited their growth and spreading. Amongst them there are: *Cirsium arvense, Chenopodium album, Convolvulus arvensis* and *Avena fatua.*
6. There was more considerable reduction of weeds during the harvest in comparison with weed occurrence in springtime in the integrated farming system. The weed infestation reduced by 92,69 %. The highest weed infestation reduction was by 99,68 % in year 2001.
7. The weed infestation reduction in the ecological farming system from springtime till harvest was 78,85 %. The highest reduction was in 2001 by 89,1 %.
8. We can conclude from the results that during the complete coverage under good conditions of densely sown cereal crop it is possible to farm them in the ecological farming system but we cannot have the occurrence of durable weed species with higher weed infestation proportion on the field plot.

References

ČERNUŠKO, K. – LÍŠKA, E. – BORECKÝ, V. 1994. Buriny a ochrana proti nim. 1. vyd. Nitra : ÚVTIP, 1994, 102 s., ISBN 80-5330-17-2.

ČERNUŠKO, K. a i. 2000. Buriny v semenárskej praxi. 1. vyd. Nitra : VES SPU, 2000, 95 s., ISBN 80-7137-778-3.

FÁBRI, A. – BRUNCLÍK, P. 1999. Možnosti regulácie zaburinenosti hustosiatych obilnín s dôrazom na jačmeň jarný. In: Naše pole, roč. 3, 1999, č. 5, s. 10.

HANES, J. and others 1993. Charakteristika hnedozemnej pôdy na výskumno-experimentálnej báze AF VŠP Dolná Malanta. 1. vyd. Nitra: VES VŠP, 1993, 29 s., ISBN 80-7137-097.

KOHAUT, P. 1999. Spôsoby herbicídnej ochrany obilnín vzhľadom na zmenu spektra zaburinenosti v SR. In: Nové trendy v ošetrovaní obilnín proti škodlivým činiteľom.1999, č.1.

KOHOUT, V. – HOLEC, J. - FIŠEROVÁ, J. 2003. Zaplevelující rostliny jako limitující faktor osevních postupů. In: Udržateľné poľnohospodárstvo a rozvoj vidieka. Nitra: SPU v Nitre, 2003, s. 253-255.

SMATANA, J 2003: Aktuálna zaburinenosť slnečnice ročnej na Slovensku a jej ovplyvnenie predplodinou. In: Udržateľné poľnohospodárstvo a rozvoj vidieka. Nitra: SPU v Nitre, 2003, s. 276-278. ISBN 80-8069-246-7

SOUKUP, J. 2003. Vývoj v herbologii a ochraně proti plevelům z pohledu udržitelného rozvoje. In: Udržateľné poľnohospodárstvo a rozvoj vidieka. Nitra: SPU v Nitre, 2003, s. 234. ISBN 80-8069-246-7

ŠIPEK, J. 1997. Pichliač roľný – hospodársky významná burina v obilninách. In: Roľnícke novinky, roč. 7, 1997, č. 17, s. 23.

ŠKEŘÍK, J. 1999. Možnosť regulace pcháče osetu v ekologickém zemědělství. In: Bulletin ekologického zemědělství, 1999, č. 15. s. 5-9.

TÝR, Š. 2003. Systémy hospodárenia a ich vplyv na zaburinenosť kukurice siatej. In: Udržateľné poľnohospodárstvo a rozvoj vidieka. Nitra: SPU v Nitre, 2003, s. 237-240. ISBN 80-8069-246-7

TÝR, Š. 1997. Vplyv sústav hospodárenia na zaburinenosť porastov poľných plodín. Doktorandská dizertačná práca. Nitra: AF SPU 186 s., 1997.

WALLINGA, J. 1998. Dynamic of weed populations. 1. vyd.Wageningen :
Landbouwuniversiteit, 1998, 99 s., ISBN 90-5485-934-2.

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EFFECT OF ECOLOGICAL WAY OF POTATO CULTIVATION ON THE YIELD AND QUALITY OF POTATO TUBERS

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Some of the EU countries increase a portion of ecologically cultivated areas. Proportion of ecologically managed areas in the Czech Republic has increased since 90th. Absence of herbicides, fungicides, insecticides and industrial fertilizers in potato growing has a consequence in yield reduction by 30 % and more (Prugar, 2000). Ecologically cultivated potatoes are supposed by some authors to have lower content of contaminants, better taste qualities, reduced mechanical damage and improved storage stability. On the other hand according to other authors (e.g. Rayburn et al., 1995; van Gelder, 1991; Maga, 1994) plants cultivated without chemicals sometimes protect themselves against diseases and pests by increasing concentration of some harmful substances (e.g. glycoalkaloids - GA). Knowledge about differences in quality of conventionally and ecologically cultivated potatoes is not sufficient and therefore we have focused our research on this issue dealing with selected quality indicators.

Materials and methods

In the years 1995-1997 precise field trials on two sites in Czech Republic were performed. On experimental station of Czech University of Agriculture in Prague in Uhříněves and on working area of Research Potato Institute Havlíčkův Brod in Valečov seven varieties of potatoes (Impala, Karin, Agria, Korela, Rosella, Santé, Ornella) were cultivated conventionally and ecologically. In Uhříněves ecologically cultivated potatoes were incorporated into model sowing plan according to principles of IFOAM farming, conventional potatoes were grown in common sowing plan on adjacent plot. In Valečov site both variants were incorporated into common sowing plan on the same plot. Winter wheat was in all cases preceding crop. Differences in growing technology relate to fertilization and use of pesticides. Conventional technology came out from the methodology of state varietal experiments of Central Institute for Supervising and Testing in Agriculture. Ecological technology differed by omission of chemical protection against potato blight (with the exception of two applications of cupric oxychloride fungicide on the site Valečov), potato beetle and by deletion of the fertilization with industrial fertilizers. Organic fertilization was the same in ecological and conventional variants: autumn ploughing in of dung manure 35 $t.ha^{-1}$ (Valečov) and 30 $t.ha^{-1}$ (Uhříněves). Mineral fertilization was used only in conventional option: on both sites 100 $kg.ha^{-1}$ N, in Valečov 40 $kg.ha^{-1}$ P and 81 $kg.ha^{-1}$ K, in Uhříněves 31 $kg.ha^{-1}$ P and 73 $kg.ha^{-1}$ K. Herbicides used in conventional option: Topogard 50 WP (terbutryn + terbuthylazine) 2.5 $kg.ha^{-1}$ - preemergent application. Insecticides against potato beetle in conventional option: Cymbush 10 DP (cypermethrin) 0.25 $kg.ha^{-1}$. Fungicides against potato blight: in conventional option in individual years in different succession preparations Ridomil MZ (metalaxyl + mancozeb) 2.5 $kg.ha^{-1}$, Sandofan M 8 (oxadixyl + mancozeb) 2.5 $kg.ha^{-1}$, Ripost M (cymoxanil + oxadixyl + mancozeb) 2.5 $kg.ha^{-1}$, Altima 500 SC (fluazinam) 0.4

l.ha^{-1} - number of treatment in 1995-1997: Uhříněves 4; 6; 6, Valečov: 5; 6; 7. In ecological option in Uhříněves any fungicide was not used, in Valečov two treatments with preparation Kuprikol 50 (cupric oxychloride) in the dosage 5 kg.ha^{-1} (4.7. and 16.8.1995; 24.7. and 7.8.1996; 24.7. and 6.8.1997). After the harvest and three weeks´ healing period the samples were delivered to the laboratories of Research Potato Institute in Havlíčkův Brod and Department of Chemistry of Czech Agricultural University in Prague for analyses. Tubers resistance against mechanical damage was determined on the electronic pendulum MIDAS 88 PP, dry matter content by gravimetric method, table value by tasting test according to Czech State Normative ČSN 462211, reducing sugar content after Luff-Schoorl, nitrate content by ion-selective electrode, polyphenol content spectrophotometrically with Folin-Ciocalteu´s reagent, glycoalkaloid content by HPLC method.

Results and discussion

Tubers resistance to mechanical damage

Three-year trials with seven cultivars did not prove any influence of ecological cultivation on this tubers quality indicator. Differences in values of pendulum index (percentage of non-damaged tubers at rebound pendulum) between ecological and conventional option have not reached in any year a value of minimum confirmative difference (Table 1). In our experiments using fertilizer rate of 100 kgN.ha^{-1} we have not confirmed a hypothesis that nitrogen fertilization should decrease well ripeness of tubers and their resistance against mechanical damage (Sowa-Niedzialkowska, 2000). Our results could be explained by Nowacki et al. (2000) according to whom relatively high fertilizer rates of nitrogen (in dependence on cultivar) have adverse effect on tubers resistance to damage. According to Diviš and Štěrba (1997) neither fertilizer rate of 120 kgN.ha^{-1} has increased a level of mechanical damage.

Cooking quality

Cultivation method has not influenced significantly a quality of table potatoes; only in the year 1995 has been found a tendency (non significant difference) to higher quality of table potatoes from ecological growing (Table 1). We have not found quite comparable results in scientific and professional literature. Tendency to higher quality of table potatoes in the year 1995 from ecological growing could be connected with their unusually small tuber size in Uhříněves in this year (the lowest tubers yield of all experimental years was 13.12 t.ha^{-1} due to considerable weed infestation, potato haulm damage by Colorado beetle and consequently very dry weather in July) (Hamouz et al., 2004) tuber size influences a pulp strength and cooking strength of tubers. In experiments of Bárta and Diviš (2000) tubers overgrowth resulted in „deterioration of cooking type“ of existing cultivar.

Dry matter content

Our results have not proved influence of ecological growing on dry matter content in tubers (Table 1). Our expectation that nitrogen and potassium applied in conventional variant should decrease dry matter content was not confirmed. This could be because of common rates of nitrogen and potassium fertilizers, which we have applied in our experiments. The changes in dry matter contents´ were small (Nowacki et al., 2000) and on the other hand shorter period of ecological variant assimilatory apparatus existence (as a consequence of its damage by Colorado beetle or *Phytophthora infestans*) could result in dry matter decrease in this variant (Diviš and Čurn, 1996). This explains our result from the year 1997 (lower dry matter content in ecological variant - Table 1) when potato haulm has been prematurely damaged by *Phytophthora infestans*. Our findings are in accordance with results of Prugar (2000) who has found during the four years trials a higher content of dry matter in tubers in 47 % of cases from conventional variant and in 41 % of cases from ecological variant; 12 % of cases have been found without difference.

Reducing sugar content

During three years of experiments with ecologically cultivated potatoes a trend (inconclusive difference) to lower content of reducing sugars in tubers was only discovered as compared to conventional option (Fig. 2). Diviš (1996) found similar results whereas results of Hajšlová et al. (1998) had opposite character. Above-mentioned trend could be related to the absence of nitrogen fertilization in ecological option because it is known that the application of nitrogen fertilizers could participate in prolongation of growing season and in delay of potato vegetation physiological maturity (Zgórska, Frydecka-Mazurczyk, 1982). According to Diviš (1996) it is possible only to assume physiological relationship between cultivation method and reducing sugars formation, but different nitrogen and potassium nutrition and different period of functionality of assimilatory organs play an important role, too.

Nitrate content

Experiments did not prove any influence of cultivation on nitrates content, but during all years ecologically cultivated potatoes had significantly lower nitrate content (Table 1). This trend is consistent with published research e.g. (Prugar et al., 2000; Woese, 1995). We have discovered an important difference in nitrate content of different cultivation methods (close to detection limit) in our experiments in the year 1995, but during next two years the differences were much lower. It was probably connected with premature termination of vegetation due to *Phytophthora* fungus in ecological option, which has happened during the years 1996 and 1997 when tubers were juvenile and nitrates were partially built into other compounds.

Glycoalkaloid content

Regarding high expenses the sample analyses have been performed only for cultivar Karin. Ecologically cultivated potatoes had higher GA content during all years compared to conventional cultivation, but this was only a trend, which was significant only in the year 1995 (Table 1). Our results correspond with other authors´ research (influence on GA content not proved), which published their studies (Prugar, 2000; Hajšlová et al., 1998).

Polyphenol content

Ecologically cultivated potatoes had higher content of total polyphenols (Table 1). Similar results, though not always significant, were confirmed also by other authors (Hajšlová et al., 1998). Results can be connected with response of potatoes, which were not chemically treated to various stress factors (in our case Colorado beetle feeding and *Phytophthora* fungus).

Yield

Potatoes cultivated by ecological method have had - as was expected (Prugar, 2000) - lower yield as compared to conventional method (Fig. 1). During the three year average decrease has come to 35.9 %, which confirms data found by Bőhm (1999). Ecologically cultivated potatoes significantly lagged behind potatoes from conventional cultivation in yield (by 36 %). We consider insufficient nutrient reserve in soil and especially inadequate level of diseases and pests regulation as a cause of significantly lower yields in ecologically cultivated potatoes. Different intensity of experimental stands infestation by Colorado beetle and *Phytophtora* fungus during last years resulted in reduction or premature removal of assimilation apparatus and in yield decrease of ecological option.

Table 1. Influence of Cultivation on Qualitative Parameters and Potato Yield

Way of growing (Significance)	Year			
	1995	1996	1997	Average
Pendulum Index (percentage of undamaged tubers)				
Conventional	80.6	42.1	60.8	61.2
Ecological	77.8	43.3	53.1	59.7
LSD/signif.	10.34/ns	21.18/ns	14.20/ns	8.54/ns
Polyphenol Content ($mg.100g^{-1}$)				
Conventional	33.4	47.8	48.5	43.2
Ecological	40.5	51.1	51.4	47.6
LSD/signif.	7.00/*	8.90/ns	5.19/ns	4.17/ns
Nitrate Content ($mgNO_3^-.kg^{-1}$)				
Conventional	215.2	105.1	140.8	153.7
Ecological	182.5	98.2	129.5	136.7
LSD/signif.	37.65/ns	27.30/ns	29.43/ns	27.37/ns
Glycoalkaloid Content in Cultivar Karin ($mg.kg^{-1}$)				
Conventional	112.6	53.1	65.4	77.0
Ecological	157.0	59.2	77.5	97.9
LSD/signif.	47.0/ns	35.8/ns	27.6/ns	36.9/ns
Dry Matter Content (%)				
Conventional	20.74	19.61	22.98	21.11
Ecological	20.43	20.07	21.12	20.54
LSD/signif.	0.89/ns	0.82/ns	1.58/*	0.62/ns
Cooking Quality (number of point)				
Conventional	56.0	63.2	61.9	60.4
Ecological	59.7	63.4	62.8	62.0
LSD/signif.	4.13/ns	8.30/ns	5.71/ns	3.32/ns

* Statistically significant difference (LSD = 5 %), ns – non-significant difference

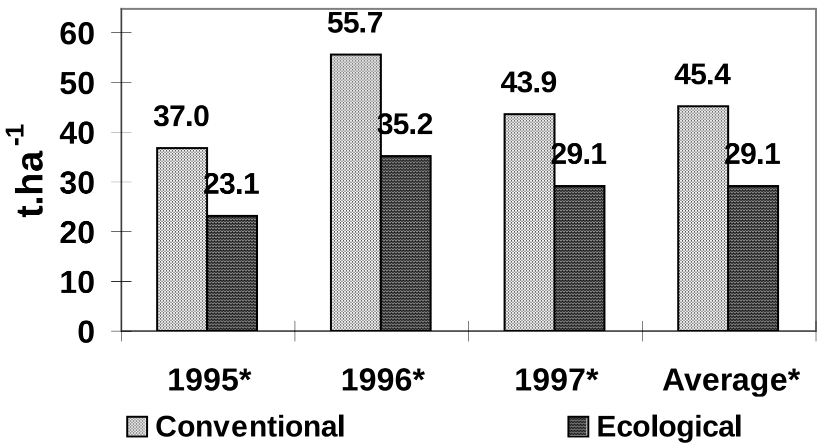

Figure 1. Effect of the way of growing on the yield (average of 6 varieties from 2 localities). $LSD_{0.05}$ = 10.23 (1995); 8.41 (1996); 4.67 (1997) and 4.36 (average). * significant difference between ways of growing for P = 0.05

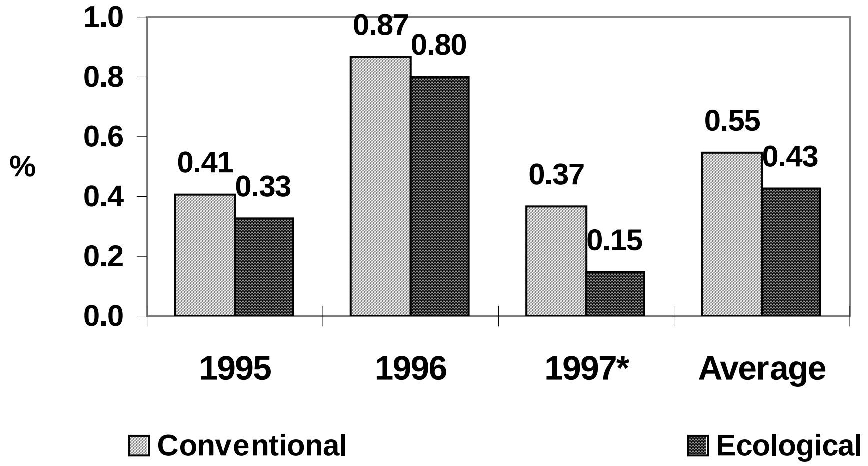

Figure 2. Reducing sugar content in % of tubers´ fresh matter affected by the way of growing (average of 4 varieties from 2 localities). $LSD_{0.05}$ = 0.14 (1995); 0.12 (1996); 0.21 (1997); 0.13 (average). * significant difference between ways of growing for P = 0.05

Conclusion

Polyphenols could play two roles in potatoes. Negative role of polyphenols could be described by their oxidation, when dark coloured organic substances are formed; polyphenols in this process cause enzymatic browning and after cooking blackening of flesh. On contrary - positive role of polyphenols lies in the fact that polyphenols are important efficient antioxidants with favourable effect in nutrition on human health. Qualitative parameters of ecologically cultivated potatoes (compared to conventionally cultivated potatoes) had these significant and desirable trends: lower reducing sugar content, lower nitrate content. Furthermore ecological option was proved to have: higher total polyphenols content (undesirable in regard to colour changes of pulp and desirable in nutrition as natural antioxidants). Cultivation did not influence tuber resistance to mechanical damage, cooking quality and GA content. Experiments demonstrated that differences of qualitative parameters between ecologically and conventionally cultivated potatoes depend largely on year conditions in relation to *Phytophthora* fungus and Colorado beetle (this determines duration of assimilation area of ecologically cultivated potatoes) and also in relation to weather conditions (influences utilization of nutrients from fertilizers).

References

Bárta J., Diviš J. (2000): Pěstitelské podmínky a stolní hodnota brambor. Bramborářství, 8(5): 9-10.

Bőhm H. (1999): Effect of manure on yield and quality of potatoes in organic agriculture. Abstr. 14th Trien. Conf. EAPR, Sorrento: 622-623.

Diviš J., Čurn V. (1996): Kvalita hlíz konzumních brambor z biofarmy a konvenčního pěstování. Bramborářství, 4(5): 11-12.

Diviš J. (1996): Kvalita konzumních brambor z biofarmy a z konvenčního pěstování. Sborník ze semináře Kvalita konzumních brambor, VÚB, VŠCHT, Havl. Brod, 6.11. 1996: 49-54.

Hajšlová J., Schulzová V., Guziur J., Voldřich M., Parkányiová L. (1998): Assessment of the quality of potatoes and other crops from organic farming. Zpráva o řešení projektu COST, VŠCHT Praha: 25pp.

Hamouz, K., Pazdera, J., Dvořák, P. (2004) Differences in the quality of potatoes cultivated conventionally and ecologically. Proc. of the 39th Croatian Symp. on Agric., Opatija, 17.-22.2. 2004, 69-70.

Maga J. A. (1994): Glycoalkaloids in *Solanaceae*. Food Rev. Intern., 10(4): 385-418.

Nowacki W., Gluska A., Gruczek T., Lis B., Lutomirska B., Roztropowicz S., Zarzynska, K. (2000): Uprawa ziemniaków a wartosc konsumpcyjna i technologiczna bulw. Konf. Nauk., Akad. Rol. we Wroclawiu - Polanica Zdrój, 8.-11.5. 2000: 23-32.

Prugar J. (2000): Kvalita rostlinných produktů ekologického zemědělství. Plant Prod., Stud. infor., 5/99: 79 pp.

Rayburn J. R., Friedman M., Bantle J. A. (1995): Synergistic interaction of glycoalkaloids α-chaconine and *α*-solanine on developmental toxicity in *Xenopus* embryos. Food Chem. Toxicol., 33(12): 1013-1019.

Woese K., Lange D., Boess C., Bőgl K. W. (1995): Őkologisch und konventionell erzeugte Lebensmittel im Vergleich. Eine Literaturstudie. Teil I u. II. BgVv-Hefte, 04 and 05.

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THE INFLUENCE OF SHORT-TERM FALLOW ON THE CHANGE OF WEED SEEDBANK

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Introduction

The main objective of short-term fallow in Europe is the effort to stop increase of agricultural production and to decrease negative impact on the environment. There are very important aims of this disposal: to decrease problems with nitrogen leaching, degradation of soil fertility, soil erosion etc. Fallow can constitute potential risks for spreading of aggressive weed species.

Material and methods

A field experiment with different variants of short-term fallow was conducted in locality Postoupky (near Kromeriz, Central Moravia). In spring 2002 were sowed the next three variants of cover crops:

1 - Poa pratensis 5 kg.ha^{-1}, Festuca rubra 6,3 kg.ha^{-1}, Trifolium repens 5 kg.ha^{-1}
2 - Poa pratensis 5 kg.ha^{-1}, Festuca rubra 6,3 kg.ha^{-1}, Medicago lupulina 8,3 kg.ha^{-1}
3 - Lolium perenne 12,5 kg.ha^{-1}, Trifolium pratense 12,5 kg.ha^{-1}

Three methods of cover crops maintenance were applied by all variants of cover crops during whole vegetation period were applied: a) 1x mulching, b) 2x mulching and c) 1x chemical retardation with low doses of herbicides (250 g.ha^{-1} MCPA a 240 g.h^{-1} glyphosate-IPA).
The two years long impact of different cover crops and applied methods of maintenance on the change of weed seedbank in soil was observed in this experiment.
The soil samples (diameter 0.08 m, depth 0.15 m) were taken with soil sampler of the EIJKELKAMP firm for purpose of assessment number of weed seeds in soil. Soil samples were analysed with the elutriation method using ANALYSETTE device (Fritsch firm). The sieves with diameter 200 mm, height 50 mm and opening size 0.25 mm were used (SMUTNÝ, KŘEN, 2002). The number of health seeds (assessed by pressure analyses of preparation needle) was re-count to the area of 1 m^2 using coefficient C (DEČKOV, 1975):

$$C = \frac{10000 \cdot h \cdot O_v}{g}$$

h = depth of taking samples (cm)
O_v = bulk density (g.cm^{-3})
g = weight of a soil sample (g)

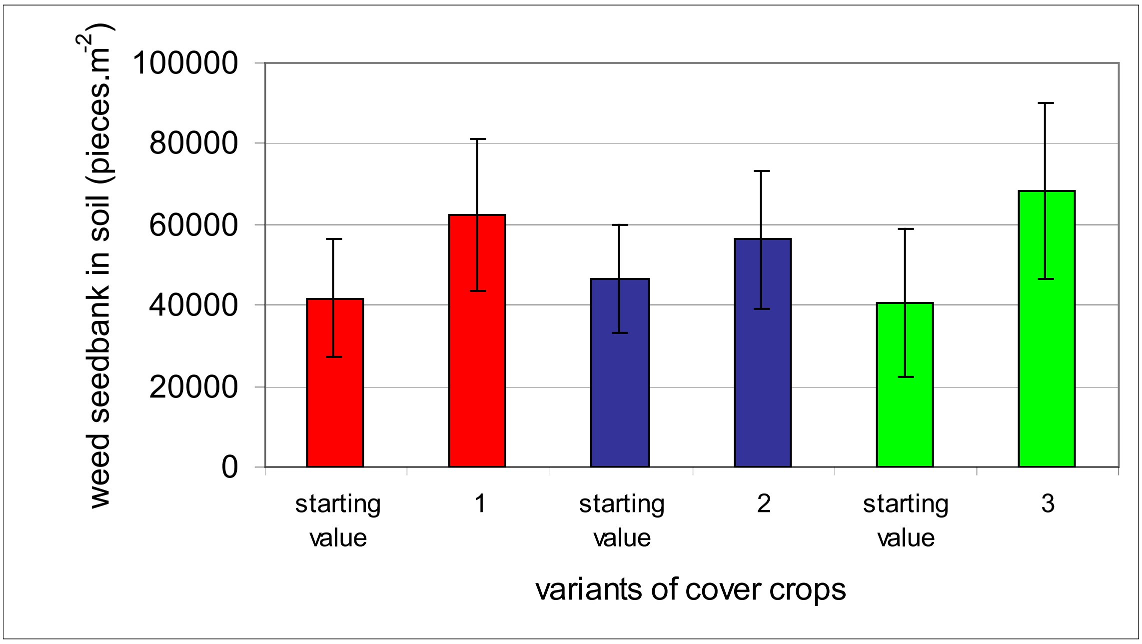
Bulk density was assessed by Kopecky physical cylinders (volume 100 cm^3). Assessed numbers of seeds were evaluated by analysis of variance (ANOVA) with consequent test of differences in average values using least significant difference (LSD).

Results and discussion

The impact of different variants of cover crops

Statistically evaluated results showed increase of weed seedbank in soil (layer 0-0.15 m) in all variants of used cover crops. From Graph 1 is visible that the highest increase was found on variant 3 (*Lolium perenne* and *Trifolium pratense*). The increase was 27738 weed seeds, as represents relative increase 69 % comparison with starting value. On variant 1 (*Poa pratensis*, *Festuca rubra* and *Trifolium repens)* the increase was 20697 pieces (+ 50 %). The lowest increase number of seeds in soil seedbank was on variant 2 *(Poa pratensis, Festuca rubra* and *Medicago lupulina).* The increase was 9723 pieces, as represents relative increase 21 % comparison with starting value.

Graph 1 The impact of different cover crops on the change of weed seedbank



1 - Poa pratensis 5 kg.ha^{-1}, Festuca rubra 6,3 kg.ha^{-1}, Trifolium repens 5 kg.ha^{-1}
2 - Poa pratensis 5 kg.ha^{-1}, Festuca rubra 6,3 kg.ha^{-1}, Medicago lupulina 8,3 kg.ha^{-1}
3 - Lolium perenne 12,5 kg.ha^{-1}, Trifolium pratense 12,5 kg.ha^{-1}

In Table 1 are quantified changes in number of seeds in soil by weed species with regular occurrence.

Table 1 Relative change of weed seedbank (weed species with regular occurrence)

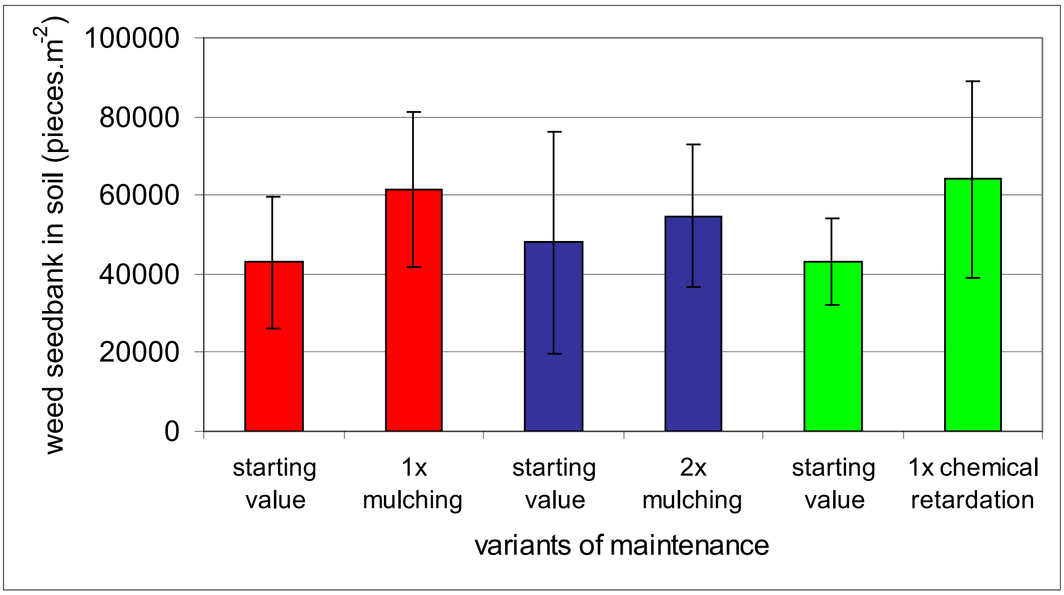
Weed species	variant 1	variant 2	variant 3
Chenopodium album	+ 14 %	- 22 %	+ 18 %
Echinochloa crus-galli	+ 249 %	+ 721 %	+ 768 %
Fallopia convolvulus	- 32 %	+ 27 %	+ 133 %
Tripleurospermum inodorum	+ 55 %	- 11 %	- 32 %
Lactuca serriola	- 61 %	+ 69 %	- 4 %
Setaria glauca	+ 29 %	- 70 %	+ 8 %

Variant 2 - *Poa pratensis*, *Festuca rubra* and *Medicago lupulina* showed the best results according to changes of weed seedbank level. There was found reduction number of seeds of *Chenopodium album, Tripleurospermum inodorum* and *Setaria glauca.* Very big increase was recorded by *Echinochloa crus-galli* on all variants. On variant 1 was found reduction number of seeds in soil seedbank by *Fallopia convolvulus* (- 32 %) and *Lactuca serriola* (- 61 %). In opposite of these results was reduced number of seeds by *Tripleurospermum inodorum* on variant 3 (- 32 %). In general the highest increase of seeds was on variant 3, especially by *Echinochloa crus-galli* and *Fallopia convolvulus*. The obtained results showed that variants of cover crops influenced weed seedbank dynamic of individual weed species by different way.

The impact of different maintenance methods

The Graph 2 shows that in all variants of maintenance were increased weed seedbank by comparison second term of soil sampling with starting value. The highest increase number of seeds was obtained by variant 3 (1x chemical retardation). There was found 20845 (+ 48 %) more weed seeds than by starting value. By variant 1 (1x mulching) was increase 18403 pieces, what means 43 % and by variant 2 (2x mulching) 6791 pieces, + 14 %.

Graph 2 The impact of different maintenance method on the change of weed seedbank



In Table 2 are quantified changes in number of seeds in soil by weed species with regular occurrence.

Table 2 Relative change of weed seedbank (weed species with regular occurrence)

Weed species	1x mulching	2x mulching	1x chemical retardation
Chenopodium album	+ 35 %	- 4 %	+ 3 %
Echinochloa crus-galli	+ 116 %	+ 185 %	+ 376 %
Fallopia convolvulus	+ 73 %	+ 18 %	- 4 %
Tripleurospermum inodorum	+ 7 %	- 65 %	+ 110 %
Lactuca serriola	- 19 %	- 38 %	+ 123 %
Setaria glauca	+ 35 %	+ 7 %	- 40 %

From Table 2 is clear that variant with 2x mulching was the most effective in reduction of weed seedbank by most weed species. The decrease was by seeds of *Lactuca serriola, Tripleurospermum inodorum* and a little by *Chenopodium album*. Only *Echinochloa crus-galli* has increasing trend in all methods of maintenance. This monocotyledonous weed (Family *Poaceae*) is very competitive in cover crop stand. The biggest development of this weed was on variant 3, where chemical retardation was not efficient and most of weed plants could bring new seeds. Similar reaction was by *Lactuca serriola* and *Tripleurospermum inodorum.*

Conclusion

For reduction of weed seedbank in soil is important to stop production of new seeds. The method of maintenance and sowing of cover crops are important disposals what can be effective by weed management strategies. The best results were found by variant with 2x mulching. But also this method was leading to increase weed seeds in soil. By comparison competitiveness different mixture of cover crops were the best results obtained by *Poa pratensis*, *Festuca rubra* and *Medicago lupulina.*

The obtained results showed on risks whose can come by use of fallow. Situation on short-term fallow is suitable for annual weed species. The seeds of these weeds can be still important as a source of weed infestation in next period of cultivated soil and by growing annual crops.

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References

Dečkov, Z. (1975): Weed seeds in the soil of some regions in the central part of the Danubian plain. Rast. Nauki, (12): 148-157.

Smutný, V., Křen, J. (2002): Improvement of an elutriation method for estimation of weed seedbank in the soil. Rostlinná výroba, 6 (48), s. 271-278.

THE EFFECT OF SELECTED BIOPREPARATION ON THE DEVELOPMENT OF ARBUSCULAR MYCORRHIZA IN WINTER WHEAT (*Triticum aestivum*)

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Introduction

Arbuscular mycorrhiza (AM) is one of several types of mycorrhizal symbiosis which are formed between plant roots and the soil fungi. Methods of how to support the formation of AM have been studied for a rather long time, particularly with respect to the importance of AM for nutrition and enhanced resistance to adverse factors of plants. The soil represents a natural source of arbuscular-mycorrhizal fungi propagules (spores, soil mycelium, infected root parts) which are of importance for the origin of mycorrhizal infection. However, the supply of propagules in soil and the ability to form the symbiosis can be influenced by a number of factors including, besides others, biological preparations used in agriculture (biofertilizers, plant stimulators, means of biological plant protection). It is assumed that their use in crop production can restrict the hygienical and environmental risks accompanying the excessive soil inputs of chemical substances in traditional agriculture (VÁZQUEZ et al., 2002). Thus, biological preparations can be considered as one of probable possibilities how to promote the formation of functional symbiotic relationship between the fungus and the plant.
The present work´s goal was to evaluate the effects of biological preparation BETA-LIQ along with the forecrop features on the store of spores of arbuscular-mycorrhizal fungi (AM fungi) in soil as well as on the development of mycorrhizal symbiosis with winter wheat (*Triticum aestivum*).

Material and methods

Ojects of the present study were experimental plots which are components of a field experiment conducted by the Research Institute for Fodder Crops at Troubsko. The research area is located in the region of the so called Troubsko-Střelická Kotlina basin, 10 km to SW from the town of Brno, at 270 m a.s.l.. It belongs into a district of sugar beet productiont. The average air temperature corresponds here to 8.4 °C (average temperature of growth period 14.8 °C), yearly mean of precipitation amount to 547 mm (total precipitation for the growing season 344 mm). The Troubsko locality is characterized from the pedological point of view as albic Luvisols, loamy, soil reaction neutral, humus content of arable land 2.00 %, good contents of available phosphorus and potassium.
The Troubsko field experiment established in 1996 studies different methods of soil cultivation and the use of straw. Individual variants of soil cultivation and straw husbandry are shown in Tab. 1. The monitoring is taking place within the frame of a six years crop rotation: field peas - winter wheat - spring barley - winter rape - winter wheat - winter wheat.

Tab. 1: Variants of soil treatment and straw husbandry in the field experiment at Troubsko

Variant	Soil treatment and straw husbandry
1	Crushed straw worked into the soil by means of soil cultivator to 0.12 – 0.15 m, ploughing to 0.22 m, sowing by means of a sowing set
2	Crushed straw worked into the soil by means of soil cultivator to 0.12 – 0.15 m, sowing by means of a sowing set
3	Crushed straw worked into the soil by means of soil cultivator to 0.12 – 0.15 m, sowing by means of a precision drill
4	Straw harvested, soil cultivated to 0.12 – 0.15 m, sowing by means of a sowing set
5	Straw burned, soil cultivation to 0.12 – 0.15 m, sowing by means of a sowing set
6	Crushed straw sprayed with the preparation BETA-LIQ, soil cultivation to 0.12 – 0.15 m, sowing by means of a sowing set

The application of mineral nutrients followed the Complex Methods of Plant Nutrition. The compensatory dosis of nitrogen corresponded to 0.8 kg per 100 kg of straw and to 0.6 kg per 100 kg of winter rape straw. A correction for nutrient contents in the preparation BETA-LIQ is taken when the preparation is applied.
The preparation BETA-LIQ is an organomineral liquid fertilizer from processed foot of sugar beet molasses with enhanced contents of remaining sugar. It is a product by the company REDAM s.r.o., Smržice. Nutrient contents of BETA-LIQ is given in Tab 2.

Tab. 2: Nutrient contents in the preparation BETA-LIQ

Dry Matter (%)	Organ. comp. (%)	Organ. N (%)	NH_4^+ (%)	K_2O (%)	P_2O_5 (%)	Ca^{2+} (%)	Mg^{2+} (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)
50-60	26	2-3	0.5	5-6	0.06	2.2	0.2	150	50	40	25

Scheme 1 shows the condition of field experiment in 2003. As the crop of interest was chosen winter wheat (*Triticum aestivum*, variety Nela) grown on three plots after different forecrops (winter wheat, winter rape and field peas). Of the six variants with diverse soil treatments and straw husbandry were chosen variants 2 (no BETA-LIQ application) and 6 (BETA-LIQ application). Each variant was represented by four replicates.
Soil samples were collected from all experimental plots closely before harvest (August 2003) for estimating the spore supply of AM fungi and root samples for appreciating their mycorrhizal colonization. Soil samples were taken from 0 - 15 cm soil depth. In the laboratory were sieved through the 2 mm mesh sieve. The samples of both roots and soil were kept till to the further processing in a fridge at 4 – 6° C.

Scheme 1: Scheme of the field experiment at Troubsko in 2003 with variants of soil treatments and straw husbandry. Shading indicates plots serving as objects of study.

Winter wheat after winter wheat						Winter wheat after winter rape						Winter rape					
1	2	4	5	6	3	3	6	4	5	2	1	1	2	4	5	6	3

Field peas						Winter wheat after field peas						Spring barley					
1	2	4	5	6	3	3	6	4	5	2	1	1	2	4	5	6	3

Spores of AM fungi were extracted from 10 g of dry soil by the method of wet sieving and centrifugation in 2.5 M saccharose solution (GERDEMANN et NICOLSON, 1963). The extracted spores were counted on a Petri dish under magnifying glass (magnification 40) and separated into live and dead ones by means of pinsette (Sigma T4537, style # 5, 110 mm). Spores filled by lipidic constituents, which were released when the spores had burst, were evaluated as living. Empty and damaged spores were evaluated as dead. Resulting data were recalculated per 1 g of dry soil. Spores were extracted in all cases from two replicates of each soil sample.

Plant roots were stored before processing proper in the fixative solution FAA (ethanol 50 %, acetic acid, formaldehyde). Staining of roots by 0.05% trypan blue in lactoglycerol (KOSKE et GEMMA, 1989) was used for the evaluation of mycorrhizal infection, and the percentage of root colonization by AM fungi was estimated microscopically by means of a modified slide method (GIOVANNETI et MOSSE, 1980). Mycorrhizal colonization of roots was evaluated in all cases in two replicas from each soil sample.

Data on winter wheat yields in 2003 were provided by the Research Institute for Fodder Crops at Troubsko.

Research data were processed statistically by means of the program STATGRAPHIC (ANOVA, Multiple Range Test, $P < 0.05$).

Results and discussion

Data on the spore counts of AM fungi in soil are very scarce in literature. One of such rare informations provides WERNER (1987). The spore counts of AM fungi range according to him within the limits of 10 to 20 spores per g of dry soil; the spore counts are higher in arable soils than in those of meadows or agriculturally unexploited ones. Similar results have been presented by KORHOŇ (2003) and FIALOVÁ (2003). The spore counts vary according to these authors in the range of 6 to 24, respectively 7 to 12 , per g of dry soil.

The total spore counts of AM fungi ranged in our samples from 29 to 172 per g of dry soil; corresponding values were 2 – 31 for live spores and 26 – 145 for the dead ones. The presence of both live and dead spores expressed in percent is shown for individual variants in Graph 1.

The overall highest spore counts of AM fungi were found in samples collected from plots with winter wheat after winter wheat, and this namely in both BETA-LIQ treated and not

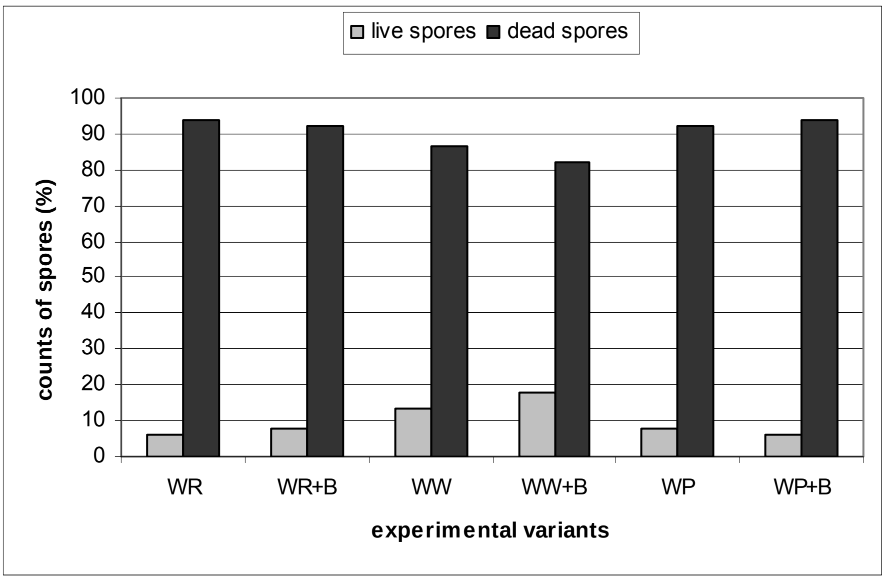
treated variants. On the other side, the lowest spore count were found in samples obtained from plots where winter wheat was grown subsequent to field peas.
It is possible to say in general that the ratio of live to dead spores was 1 : 8.6. Quite different data have been given by KORHOŇ (2003). The ratio of live to dead spores was according to him 2.3 : 1.
The application of BETA-LIQ preparation had no statistically significant influence on spore counts of AM fungi in soil. Only in winter wheat after winter wheat have been found significantly lower counts of dead spores in the variants treated with BETA-LIQ preparation than in the BETA-LIQ untreated variant.
Spore counts of AM fungi in soil were more affected by the forecrop than by the BETA-LIQ preparation. The character of forecrop was statistically most pronounced in the counts of live spores in soil. A statistically higher supply of live spores in soil was found after winter wheat as forecrop (irrespective whether BETA-LIQ had been applied or not) than after winter rape and field peas. Winter wheat and field peas were among the forecrops statistically most distinctly marked by the total and dead spore counts. Significantly lower total and dead spore counts in soil were found after field peas than after winter wheat (Tab. 3).

Tab. 3: Average spore counts of AM fungi in soil.

Variant	Counts of live spores per 1 g of dry soil	Counts of dead spores per 1 g of dry soil	Total counts of spores per 1 g of dry soil
WR	4.75 (± 1.09) a	69.88 (± 9.03) ab	74.63 (± 9.91) ab
WR+B	6.00 (± 2.18) a	68.88 (± 14.56) ab	74.88 (± 16.50) ab
WW	13.13 (± 8.15) b	86.75 (± 29.34) b	99.88 (± 36.76) b
WW+B	14.00 (± 9.68) b	64.63 (± 24.85) a	78.63 (± 32.63) ab
WP	4.75 (± 2.22) a	54.50 (± 21.72) a	59.25 (± 23.69) a
WP+B	3.88 (± 0.93) a	56.63 (± 11.62) a	60.50 (± 11.54) a

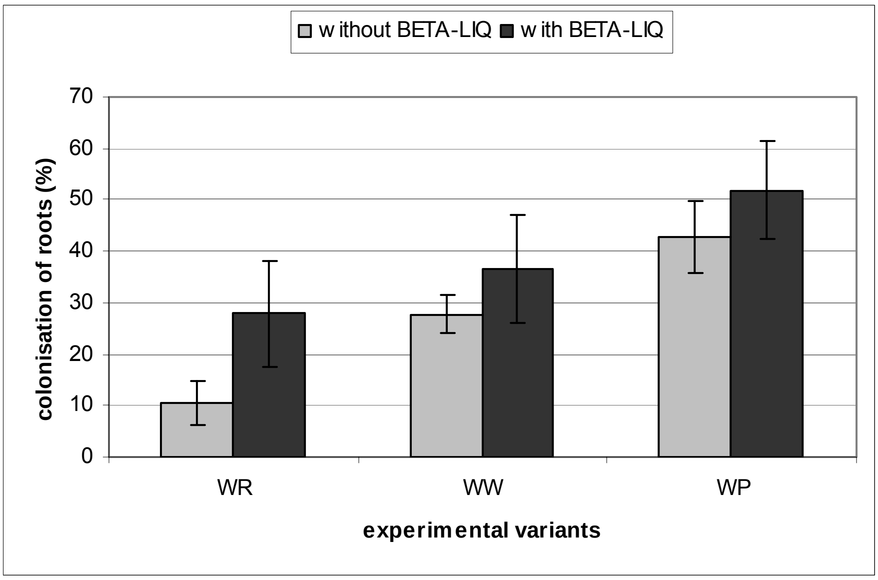
The table gives average values of 8 replicates of each variant (± standard deviation). Values marked by different letters in column are statistically different ($P < 0.05$).
(WR – winter wheat after winter rape, WW – winter wheat after winter wheat, WP – winter wheat after field peas, +B - treated with BETA-LIQ preparation).

Graph 1: Percentage of live and dead spores in total spore counts of AM fungi in soil (n = 8; WR – winter wheat after winter rape, WW – winter wheat after winter wheat, WP – winter wheat after field peas, +B - treated with BETA-LIQ preparation).



CONTENTS

Graph 2: Colonization of winter wheat roots by AM fungi in soil, both with and without application of BETA-LIQ preparation
(significant differences indicated by vertical bars, n = 8; WR – winter wheat after winter rape, WW – winter wheat after winter wheat, WP – winter wheat after field peas, +B - treated with BETA-LIQ preparation).



The colonization of winter wheat roots by AM fungi varied within limits of 6 – 73 %. The highest percentage of colonization was found in wheat following field peas. The colonization of roots attained 51.88 % in the variant treated with BETA-LIQ and 42.75 % in the untreated variant.

The colonization of winter wheat subsequent to winter wheat was 36.63 % in the variant treated with BETA-LIQ and 27.75 % in the untreated one.

The lowest percentage of root colonization was found in winter wheat grown after rape. The colonization of roots corresponded to 27.88 % in variant with BETA-LIQ applied and 10.50 % in the untreated variant.

The application of BETA-LIQ showed a statistically significant effect on the colonization of winter wheat roots by AM fungi. The mycorrhizal colonization of roots was statistically significantly enhanced in all variants treated with the BETA-LIQ preparation in contrast to untreated variants (Graph 2). The preparation BETA-LIQ could have activated in this case a greater amount of AM fungi propagules to the formation of mycorrhizal infection within the roots of winter wheat.

The forecrop character also became statistically evident in the colonization of winter wheat roots by the AM fungi. The statistically significantly highest colonization of roots of winter wheat grown after field peas was found in variants treated as well as untreated with BETA-LIQ, while the statistically significantly lowest one was in winter wheat subsequent to winter rape (Tab. 4).

Tab. 4: Colonization of winter wheat roots by AM fungi

Variant	Colonization of roots (%)	
WR	10.50 (± 4.27)	a
WR+B	27.88 (± 10.33)	b
WW	27.75 (± 3.56)	b
WW+B	36.63 (± 10.39)	c
WP	42.75 (± 6.96)	c
WP+B	51.88 (± 9.39)	d

The table gives average values of 8 replicates of each variant (± standard deviation). Values marked by different letters in adjacent column are statistically different ($P < 0.05$).
(WR – winter wheat after winter rape, WW – winter wheat after winter wheat, WP – winter wheat after field peas, +B - BETA-LIQ preparation applied).

The above presented results indicate that the application of the biological preparation BETA-LIQ had no influence on the store of AM fungi in soil, but that it supported the germination of livable spores as well as other propagules of AM fungi. This became subsequently reflected in a higher mycorrhizal colonization of winter wheat roots. The enhanced mycorrhizal colonization of roots was also observed by SIDIBE et TESAŘOVÁ (2001) following the application of the biological preparation AMALGEROL, containing a mixture of vegetable oils and an extract of plants and sea algae, to the banana and apple trees. The germination of spores can be initiated according to WERNER (1987) by some biologically active substances. He also considers as ecologically important the fact that not all spores of AM fungi germinate in the year of their origin. Such spores also represent the "natural inoculum" of AM fungi for the subsequent crop.
The efficiency of mycorrhiza can be altered by different kinds of soil management (PANKHURST et al., 1997). The growing of non-mycorrhizal crops advancing that of mycorrhizal ones can according to FONTENLA et al. (1999) decrease the soil potential to inoculate and, subsequently, even the root colonization by AM fungi. The authors explain this fact by the ability of non-mycorrhizal crops to produce substances decreasing the ability of AM fungi to colonize the plant roots. The same has been corroborated also by our experiments, where the lowest root colonization by AM fungi apeared in winter wheat grown after winter rape, considered to be a non-mycorrhizal crop. On the other hand, the highest colonization of roots by AM fungi was observed in winter wheat grown after field peas. It is stated in literature that the inclusion of legumes into crop rotation can improve the mycorrhizal colonization of the following crop, particularly due to the nodul bacteria contributing nitrogen to the soil (HAMEL, 1996).
The evaluation of all experimental variants (Pearson's correlation coefficient $r = -0.096$) revealed no significant relationship between the counts of live spores of AM fungi in soil and the mycorrhizal colonization of winter wheat roots. This probably may be due to the fact that besides spores of AM fungi even other propagules of AM fungi present in the soil (soil mycelium, infected plant roots) participate on the origin of mycorrhizal infection
A very weak dependence was also found between the mycorrhizal colonization of roots and the yield of winter wheat grain (Pearson's correlation coefficient $r = 0.168$). The reason may be that straw production has not been accounted for in the winter wheat yields.

Conclusion

The total spore counts of arbuscular mycorrhiza fungi varied within the limits of 29 – 172 per g of dry soil, of which about 10 % were live spores. The highest counts of live spores were in the soil with winter wheat grown after winter wheat. The application of BETA-LIQ preparation had no influence on the spore counts of AM fungi in soil. The colonization of winter wheat roots by AM fungi varied within the limits of 6 – 73 %. The highest colonization of roots by AM fungi was found at winter wheat grown after field peas. Winter wheat treated with the BETA-LIQ had a higher colonization of roots by AM fungi than untreated winter wheat. A relationship was evidenced neither between the counts of live spores and mycorrhizal colonization of roots, nor between the mycorrhizal colonization of roots and winter wheat yields.

References

FIALOVÁ, L., 2003: Charakteristika spór endomykorhizních hub ve vybraných orných půdách. Diplomová práce, MZLU Brno, Fakulta agronomická. Ústav půdoznalství a mikrobiologie. In Czech (Characteristic of spores of endomycorrhizal fungi in selected arable soils. Diploma work, Mendel University of Agriculture and Forestry in Brno, Faculty of Agronomy, Institute of Soil Science and Microbiology).

FONTENLA, S., GARCIA-ROMERA, I., OCAMPO, J. A., 1999: Negative influence of non-host plants on the colonization of *Pisum sativum* by the arbuscular mycorrhizal fungus *Glomus mosseae*. Soil Biology & Biochemistry 31: p. 1591-1597.

GERDEMANN, J. W., NICOLSON, T. H., 1963**:** Spores of mycorrhizal Endogone species extracted from soil by wet sieving and decanting. Trans. Br. Mycol. Mem. 5: p. 1-76.

GIOVANNETI, M., MOSSE, B., 1980: An evaluation of techniques for measuring vesicular-arbuscular mycorrhizal infection in roots. New Phytologist 84: p. 489-500.

HAMEL, CH., 1996: Prospects and problems pertaining to the management of arbuscular mycorrhizae in agriculture. Agriculture, Ecosystems and Environment 60: p. 197-210.

KORHOŇ., R., 2003: Prezence endomykorhizních hub jako jeden z biologických indikátorů kvality orných půd. Diplomová práce, MZLU Brno, Fakulta agronomická. Ústav půdoznalství a mikrobiologie. In Czech (The presence of endomycorrhizal fungi as biological indicator of arable soil quality. Diploma work, Mendel University of Agriculture and Forestry in Brno, Faculty of Agronomy, Institute of Soil Science and Microbiology).

KOSKE, R. E., GEMMA, J. N., 1989: A modified procedure for staining roots to detect VA mycorrhizas. Mycological Research 92: p. 486 - 505.

PANKHURST, C. E., DOUBE, B. M., GUPTA, V. V. S. R., 1997: Biological indicators of soil health. CAB International, Wallingford.

SIDIBÉ, A., TESAŘOVÁ, M., 2001: Effect of inoculation with endomycorrhizal fungi on the growth of selected plants. Acta Univ. Mendel. 1: p. 15-20.

VÁZQUEZ, M. M., BAREA, J. M., AZCÓN, R., 2002: Influence of arbuscular mycorrhizae and a genetically modified strain of *Sinorhizobium* on growth, nitrate reductase activity and protein content in shoots and roots of *Medicago sativa* as affected by nitrogen concentrations. Soil Biology & Biochemistry 34: p. 899 - 905.

WERNER D., 1987: Pflanzliche und mikrobielle Symbiosen. Georg Thieme Verlag Stuttgart, New York.

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FARMING SYSTEMS AND INTEGRATED WEED INFESTATION CONTROL

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Abstract

Weeds are much less a problem in multiple cropping systems, especially in intercropping, the idea being to occupy the space normally available to weeds with other crops. The task was solved in field small plot experiments in the framework of six crop sequences on the basis of experimental base of Faculty of Agro biology and Food Resources of the Slovak Agricultural University, Nitra. The soil preparation was realized at the experimental plots in the years 1998 –2004 in order to create the suitable conditions for sowing and the following growth of the cultured crops, in our case, spring barley and summer wheat. At time of crop occurrence, the number of grown plants was counted at the surface of 1 m^2 according to the treatments and replications in both farming systems. In the integrated farming system the crops were rationally treated by using herbicides. The herbicides efficiency was evaluated according to the international scale of EWRS. In the ecological farming system, the weeds were controlled mechanically. Strong weed infestation with dominant species *Cirsium arvense, Stellaria media, Medicago sativa, Cardaria draba, Avena fatua, Tripleurospermum perforatum* have been noted. Herbicides used in common pea markedly reduced number and share of weed species in the integrated farming system during the years 1998-2004. In the integrated farming system the numbers of individual plant weeds were increased.

Key words: weeds, common pea, ecological and integrated farming systems, herbicides.

Introduction

Weeds, on the other hand, present another problem. It has been reported that weeds are much less a problem in multiple cropping systems, especially in intercropping, the idea being to occupy the space normally available to weeds with other crops. The aggressive nature of weeds is well known, but recent work has begun to show that weeds can fill an important ecological role in cropping systems, by capturing unused nutrients, protecting the soil, altering soil fauna and flora, serving as trap plants for pests and disease, and changing the microhabitat to allow for high populations of pest predators and parasites (Leibhardt, Francis, and Sands, 2005). When a piece of land is left fallow, it is soon covered over by annual weeds. If the field is left undisturbed for a second year, briars and brush start to grow. As the fallow period continues, the weed community shifts increasingly toward perennial vegetation. By the fifth year, the field will host large numbers of young trees in a forest region, or perennial grasses in a prairie region. This natural progression of different plant and animal species over time is a cycle known as succession. This weed invasion, in all its stages, can be viewed as nature's means of restoring stability by protecting bare soils and increasing biodiversity.

Under conservation tillage, there was nearly a 25% increase in winter wheat yield after peas compared to after spring wheat, when yields were averaged over weed management levels. The yield response was largely attributed to improved control of soil borne diseases and winter annual grass weeds, and more available soil water after peas. Approximately 10% higher winter wheat yields (averaged over weed management levels) were achieved with direct seeding after peas and spring wheat compared to conventional tillage because of increased soil water storage over winter in dryer years and improved winter survival. In addition, the direct -seeded wheat fields always retained adequate surface residue to meet farm conservation plan requirements while winter wheat under conventional tillage did not. The use of tillage for spring seedbed preparation can also reduce the "green bridge effect" on root diseases for the following spring crop by accelerating the decomposition of roots of volunteer grain and weeds before root pathogen populations can increase. However, Northwest researchers have found that early green bridge control with a non-selective herbicide before direct-seeding of spring cereals without prior tillage has resulted in yields that were as good as and often better than with tillage. Tillage increases soil water loss by evaporation and surface runoff, thus reducing yield potential for spring crops. Spring tillage on wet soils also increases soil compaction problems. If a non-selective herbicide is used ahead of tillage in a minimum tillage system, preliminary research results indicates that it still may be advantageous to spray 2-3 weeks ahead of seeding. More research is needed on the importance of spray timing ahead of seeding spring crops under minimum tillage systems. The important thing to remember is that crop residue is not the primary food source for root pathogens affecting spring crops under conservation tillage -- it is the roots of volunteer grain and weeds growing between crops. In summary, the development and maintenance of successful conservation tillage systems depends on a cropping systems approach to crop health and resource protection. It should involve a combination of available physical, biological and chemical options integrated for maximum overall effect, but with due consideration to ecological and economic limits of the crop and the cropping systems (Veseth, 2005).

On weeds infestation in stand of legumes are contributed species similar as in Europe. As mentioned Schroeder and al. 1993, there are monocotyledons species: *Echinochloa cruss galli, Setaria spp., Elytrigia repens* and dicotyledonous species *Chenopodium album, Amaranthus retroflexus, Solanum nigrum, Convolvulus arvensis, Atriplex patula, Sonchus arvensis, Persicaria maculosa, Polygonum aviculare, Cirsium arvense, Fallopia convolvulus, Capsella bursa pastoris.*

Materials and methods

The task was solved in field small plot experiments in the framework of six crop sequences on the basis of experiment base of Faculty of Agro biology and Food Resources of the Slovak Agricultural University, Nitra. The allotments are situated on the grounds of experimental station of Dolná Malanta.

The task was being solved in during the years 1998- 2004 in the framework of the project VEGA 1/9083/02.

III. The farming system

A: THE INTEGRATED FARMING SYSTEM

- Negative impact protection on the basis of prognosis localisation marking rationally
- Fertilisation by means of industrial fertilisers and manure in order to achieve the planned crop yields.

B: THE ECOLOGICAL FARMING SYSTEM

- Mechanical weeding of the whole crop, physical weed regulation in crops with wider rows
- Only manure fertilisation by means of balance method.
-

IV. Observation of actual weed infestation

4. Crop and weed inspection in spring before using the herbicides – numerical method (integrated system) and before the mechanical input (ecological system)
5. Crop and weed inspection after herbicide usage – numerical method (integrated system) and after the mechanical input (ecological system)
6. Crop and weed inspection before the harvest – numeric and weighing method.

III. Crop rotation

Table 1

Crop rotation							
Year	**Farming system**	**I.**	**II.**	**V.**	**VI.**	**VII.**	**VIII.**
1998	**A**	Spring barley	Alfalfa	Corn	Corn for silage	Common pea	Sugar beet
	B	Winter wheat	Sunflower	Common pea	Bean+ Alfalfa	Alfalfa	Corn for silage
1999	**A**	Bean+ Alfalfa	Winter wheat	Spring barley	Corn for silage	Winter wheat	Common pea
	B	Corn for silage	Bean+ Alfalfa	Corn for silage	Alfalfa	Winter wheat	Spring barley
2000	**A**	Alfalfa	Common pea	Winter wheat	Spring barley	Corn for silage	Winter wheat
	B	Spring barley	Alfalfa	Corn for silage	Winter wheat	Common pea	Bean+ Alfalfa
2001	**A**	Alfalfa	Winter wheat	Common pea	Winter wheat	Spring barley	Corn for silage
	B	Bean+ Alfalfa	Winter wheat	Spring barley	Common pea	Corn for silage	Alfalfa
2002	**A**	Winter wheat Sunflower	Corn for silage	Winter wheat White mustard	Common pea	Bean+ Alfalfa	Spring barley
	B	Alfalfa	Common peas White mustard	Bean + Alfalfa	Corn for silage	Spring barley	Winter wheat Sunflower
2003	**A**	Common pea	Spring barley	Corn for silage	Winter wheat White mustard	Alfalfa	Winter wheat Sunflower
	B	Winter wheat Sunflower	Corn for silage	Alfalfa	Spring barley Sunflower	Bean + Alfalfa	Common pea White mustard
2004	**A**	Winter wheat White mustard	Bean + Alfalfa	Spring barley	Corn for silage	Alfalfa	Common pea
	B	Common pea White mustard	Spring barley Sunflower	Winter wheat Sunflower	Bean + Alfalfa	Alfalfa	Corn for silage

Note: Sunflower and White mustard are intercrops

IV. Additional factors

- Number of experimental plots: 4
- Experimental plots: 60 m^2
- Number of repetition: 4 (r1, r2, r3, r4)
- Plots of experimental variant: 1 m^2
- Observed crop: spring barley and summer wheat winter variety

Characteristics of the experiment

- ❖ **Climatic and meteorological conditions**
  The experiment was realised in the framework of agro-climatic areas in the territory with the following features:
- ***Macro area:*** warm with temperature t > 10 ^{o}C in a range of 3100 – 2400 ^{o}C
- ***Area:*** predominantly warm with temperature t > 10 ^{o}C in a range of 3000 – 2800 ^{o}C
- ***Sub area:*** very dry with climatic humidity factor for the months June -August K $_{VI-VII}$ = 150 mm
- ***ward:*** predominantly mild winter with an average of absolute minimum of T_{min} = -18 to -21^{o}C.

The altitude is 172,5 m above sea level. The average long- term annual precipitation (1951 – 1980) is 532,5 mm, for the vegetation period 309,4 mm.
The average long- term annual temperature is (1951 – 1980) and for the vegetation period is 16,4 ^{o}C.

- ❖ **Soil characteristics**

Soil type: brown soil. Proportional soil weight: 2,60 – 2,61 t.m^{-3}. The contents of humus in arable soil/top soil: 2,16 % in average (mean value). Soil reaction: 5,03 – 5,69 (acidic almost mild acidic). The experimental stand was created at the proluvial sediments. The soil profile of brown soil has three genetic horizons (Ap, Bt, c), and their stratography is following; Humus (Ap) horizon with depth 0,31 m underneath which is the main diagnostical luvisolic Horizon 9Bt0 and this one was as a result of alluvial accumulation of translocated colloids. Its depth is up to 0,66 m then there is a transitional horizon (Bt/C) with a depth up to 0,95 m and follows continually into the soil forming substrate up to the depth of 1,5m. The studied brown soil is clayey in its sub layer and in its topsoil is mildly firm. Humus is of a humo-phulvate type (Hanes and others, 1993).

The soil preparation was realised at the experimental plots in the years of 2001 –2004 in order to create the suitable conditions for sowing and the following growth of the cultured crop in our case of spring barley and summer wheat after the crop appeared the number of grown plants was done at the surface of 1 m^2 according to the variants and repetitions in both farming systems. The state of the crop and weeds was described. In the farming system „A“ the integrated one the crop were rationally treated by means of herbicides. The efficiency of herbicides was evaluated according to the international scale of EWRS. In the farming system „B„ the ecological one the weeds were removed mechanically (*Cirsium arvense, Avena fatua*) manually by means of a sickle. It was before the blossom. By this we prevented further generative multiplication of these weeds

- o The crop was evaluated according to Hosnedl and others (1979) (in Týr, 1997).
- o Weed infestation of crop was evaluated according to Hosnedl and others. (1979). The author introduces the weed infestation grades S_1 – S_6, during the implementation of the experiments we used the adapted scale S_1 – S_4, taking into consideration its efficiency (in Týr, 1997).

- During the harvest of crop the weeds in the observed plants were pulled out from the efficient surface of 1 m^2 of each variant and analysed according to different species by means of numeric and weighing method. (Týr, 1997).

Results and discussion

On the base of the actual weeds infestation results during years 1998-2004 in the table 1. We note that infestation of common pea was very different in the spring.

Table 1 Actual weed infestation of common peas in year 1998-2004

Year	Farming system	Mumber weeds per m^{-2}	The most frequent varieties in spring (skratky burín podľa EWRS- Bayerov kód)
1998	A	6,3	SONAR, CHEAL, ECHCG, TRIPE, a i.
	B	78,0	CIRAR, THLAR, LAMPU, TRIPE, CAPBP, CHEAL, LAMAM, a i.
1999	A	51,5	AMARE, PERMA, CHEAL, ANAAR, TRIPE, STEME, ECHCG, a i.
	B	87,5	AMARE, AVEFA, ECHCG, CARDR, ANAAR, PERMA, VERHE, CHEAL
2000	A	12,5	CAPBP, LAMAM, TRIPE, THLAR, LAMPU, STEME, a i.
	B	19,3	TRIPE, CIRAR, GALAP, THLAR, STEME, LAMAM, a i.
2001	A	29,0	AMARE, CHEAL, PERMA, SONOL, STEME, AVEFA, ECHCG, CONAR
	B	14,5	PERMA, AMARE, CHEAL, CIRAR, THLAR, AVEFA, CONAR, ANAAR
2002	A	29,25	CHEAL, AMARE, PERMA, CARDR, THLAR, VERAR, ANAAR, a i.
	B	39,0	AMARE, CIRAR, VERAR, PERMA, CARDR, CHEHY, ANAAR, THLAR
2003	A	38,25	CAPBP, CIRAR, FALCO, CHEAL, LAMXX, PERLA, VERAG.
	B	71,25	CHEAL, LAMXX, AVEFA, CIRAR, CAPBP, FALCO, PERLA, VERAG.
2004	A	2,50	PLAME, ATRPA, CAPBP, CONAR, CHEAL, ECHCG, PERMA.
	B	34,00	CHEAL, LAMXX, AMARE, AMBAR, ATRPA, CAPBP, CONAR, DATST, FALCO, PERLA.
Average	X A	9,5	AMARE, CHEAL, CIRAR, PERMA, AVEFA, TRIPE, CONAR, THLAR, SONAR, ECHCG,ANAAR, STEME, LAMAM, LAMPU, CARDR, VERAG, ATRPA.
	X B	49,08	AMARE, CHEAL, CAPBP, SONAR, CIRAR, TRIPE, AVEFA, SONAR, FALCO, THLAR, CARDR, CONAR, ANAAR, LAMPU, ECHCG, PERMA, GALAP, STEME, CHEHY, VERAG, DATST, ATRPA.

Table 2 Actual weed infestation of common peas in year 1998-2004

Year	Farming system	Number weeds per m^{-2}	The most frequent varieties before harvest (skratky burín podľa EWRS- Bayerov kód)
1998	A	12,8	CIRAR, AVEFA, PERMA, TRIPE, SONAR, CONAR, a i.
	B	20,8	CIRAR, CHEAL, AVEFA, PERMA, SONAR, FALCO, a i.
1999	A	10,0	TRIPE, POLAV, AMARE, CHEAL, ECHCG, a i.
	B	8,0	AVEFA, PERMA, CHEAL, CIRAR, ATRAC, a i.
2000	A	4,3	CHEAL, CIRAR, AMARE, CONAR, ECHCG, AVEFA, a i.
	B	7,3	CIRAR, AMARE, AVEFA, CHEAL, a i.
2001	A	7,5	CHEAL, ECHCG, AVEFA, CIRAR, AMARE, POLAV, a i.
	B	10,5	CIRAR, PERMA, CONAR, AVEFA, TRIPE, CARDR, GALAP, a i.
2002	A	1,75	PERMA, CARDR, TRIPE, a i.
	B	3,5	PERMA, AVEFA, CHEAL, CIRAR, CHEHY, LACTA, a i.
2003	A	1,25	CIRAR, PERMA.
	B	31,25	AVEFA, CIRAR, FALCO, CHEAL, PERLA.
2004	A	10,75	AMARE, PLAME, TAROF, CONAR, ATRPA, CHEAL.
	B	17,25	AMARE, ATRPA, AVEFA, CAPBP, CONAR, ECHCG, CHEAL, PERLA, STEME, SONOL, TRIPE.
Average	X A	6,91	CHEAL, PERMA, CIRAR, TRIPE, AMARE, ECHCG, AVEFA, CARDR, TRIPE, SONAR, CONAR, POLAV, PLAME, TAROF, ATRPA.
	X B	14,09	CIRAR, AVEFA, TRIPE, CHEAL, PERMA, CARDR, ECHCG, SONAR, PERLA, FALCO, ATRAC, GALAP, LACTA, CHEHY, CAPBP, STEME.

Strong weed infestation with dominant species *Cirsium arvense, Stellaria media, Medicago sativa, Cardaria draba, Avena fatua, Tripleurospermum perforatum* have been noted. Herbicides used in common pea markedly reduced number and share of weed species in the integrated farming system during the years 1998-2004. The same results of actual weeds infestation gain Schreder and al 1993. From point of view of development of weed infestation in leguminous we can conclude that ecological farming system is beneficial for supporting of increasing the number of weed species in the same level of numbers of individuals plants per unit area. In the integrated farming system the number of individual plant weeds is increased.

Conclusions

On the base of received result and literature review the conclusions are:

1. Weather conditions had strong influence on state of growth crops and actual weed infestation.
2. We noted weed infestation differences between farming system during spring.
3. Used herbicides markedly decreased actual weed infestation in common pea growing in integrated farming system.
4. Regulation of weeds in by ecological growing of common pea without pesticides application is possible only by growing foliaged types of common pea.
5. The precondition of high competitive ability of common pea to weeds is early and properly sowing dates.
6. The use of plant competition is one of the cheapest and most useful general weed control practices available.
7. Attention must focus on managing threatened resources - crops, livestock, natural areas, landscapes.
8. Control of undesirable plants without improving management is usually futile.
9. Prevention is the most important but often least used control strategy.

10. Soil tillage enables the farmer to attack many weed survival mechanisms. For annual weeds, the tillage objective is to prevent seed production and deplete current seed reserves in the soil.
11. Annual and biennial weeds and non-creeping perennials can be destroyed by simply pulling them out. This is best done when the soil is moist and before seed is produced. This is only practical of course for small patches or individual plants

References

SCHROEDER, D. et al.: A European Weed survey in 10 major crop systems to identity targets for biological control. In: Weed Research, 1993, Vol. 33, p. 449-458.

TÝR, Š. – LACKO-BARTOŠOVÁ, M. – OTEPKA, P.: Weed infestation of winter wheat in integrated and ecological arable farming systems. In: Acta fytotechnica et zootechnica, 2001, Vol. 4, No. Special Number, p. 20-21. ISBN 80-7137-959-X.

VESETH, R.: Cropping Systems Approach to Crop Health Management in Conservation Tillage. The address is http://coopext.cahe.wsu.edu/~drycrops/ (verified 10.04.2005)

LEIBHARDT, W. - FRANCIS, C. and SANDS, M.: Research needs for soil fertility and the development of resource efficient technologies. The address is http://www.rodaleinstitute.org/education/home.html (verified 10.04.2005)

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THE IMPACT OF BIOPREPARATIONS APPLIED IN CONDITIONS OF DIFFERENT STAND ESTABLISHMENT OF WINTER WHEAT AND SPRING BARLEY

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Abstract

At present various technologies of stand establishment of field crops with biopreparations use considerably influence an agriculture production. In our field experiments different methods of stand establishment were used: a) classic technology with ploughing, b) sowing into shallow tilled soil and c) direct drilling into no-tilled soil for growing of winter wheat (cv. EBI) which was studied at experimental site in Prague-Ruzyně. We applied different biopreparations on the seed like: seed - treatment and the mixture with mineral fertilizers NPK, LAV (ammonium nitrate with limestone) - *for winter wheat* and with ammonium sulphate (AS)- *for spring barley*. The biopreparations used were as follows: Supresivit (effective fungus *Trichoderma harzianum*), Polyversum (effective fungus *Pythium oligandrum*) and Ibefungin (effective bacterium *Bacillus subtilis*). The experiments with spring barley (cvs. Akcent, Tolar) were based on the evaluation of grain yields, yield components, grain quality and health state. The positive effect of the combination on grain yield, stability of grain quality and improvement of plant health was recorded. The combination also contributed to better nutrient management at present the combination of mineral nutrients. We determinated different fungi from soil extracts which were cultivated on agar medium - Czapek-Dox agar at 20 ^{o}C for 14 days. We found out that before direct drilling into no-tilled soil higher amount of the fungi of the genus *Fusarium* and higher amount of phytopathogenic fungi (*Drechslera* sp.) was detected. The yield from this variant was the lowest one from among all 3 ways of soil tillage and by about 1-3% comparing with check variants with no biopreparation. We can recommend the combination of mineral fertilizer with Supresivit 0,5g per 1 kg fertilizer as sufficiently effective. The suppression of an occurrence of phytopathogenic fungi transferred from the soil was evaluated. The study of health state showed lower infestation with pathogenic fungi transferred by the soil (*Fusarium, Septoria, Drechslera*) positively influenced the yield and its quality.

Key words: winter wheat, spring barley, protection tillage technologies, biopreparations, phytopathogenic fungi

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Nowadays it is no doubt about the benefit of different soil technologies of stand establishment of field crops as a quite considerable change in the field of farming practices. We are giving the contribution to enhancement of the crop production, increase of soil quality and the effectivity of biopreparations against phytopathogenic fungi transferred mostly by the soil. Available application of soil technologies and biopreparations in view of their variants, site conditions and preconditions and crop demands are showed. Concomitant application of mineral fertilizer LAV with biopreparations for winter wheat was used. The fungi of the genus *Fusarium* should be suppesed by the bioagens from the biopreparations or other

mycoparasitic soil fungi. 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 condia 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* 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 distriburion of *Penicillium* and *Fusarium* as bioindicators to characterize organically cultivated soils. The importance of the crop was clearly demonstrated in the form of significantly higher 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 contribution was to present our knowledge about the influence of different biopreparations applied as a part of different soil tillage technologies (winter wheat) and before seed-treatment and like the mixture of biopreparations with mineral fertilizers (spring barley).

Methods

We verified the influence of different microorganisms from the biopreparations: *Trichoderma harzianum* (Supresivit), *Pythium oligandrum* (Polyversum), *Bacillus subtilis* (Ibefungin) composed with different technologies of soil preparation (classic technology with ploughing, sowing into shallow tilled soil, direct drilling into no-tilled soil). Like the control of chosen processes we used phytopathogenic fungi on winter wheat (cv. EBI) and without technologies on spring barley (cvs. Akcent, Tolar).

Spring barley had following variants:
1) Control, without fertilizing
2) The fertilization with ammonium sulphate (30 kg 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 (3 g per 1 kg of fertilizer)
8) The mixture of ammonium sulphate with Ibefungin (0,5 ml per 1 kg of fertilizer)
9) The mixture of ammonium sulphate with Supresivit (0,5 g per 1 kg of fertilizer)
10) Ammonium sulphate - spraying with Polyversum
11) Ammonium sulphate - spraying with Ibefungin
12) Ammonium sulphate - spraying with Supresivit

All parcels 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 determined by the cultivation of soil extract (5g per 500ml of distilled water) - 1ml on malt extract agar.

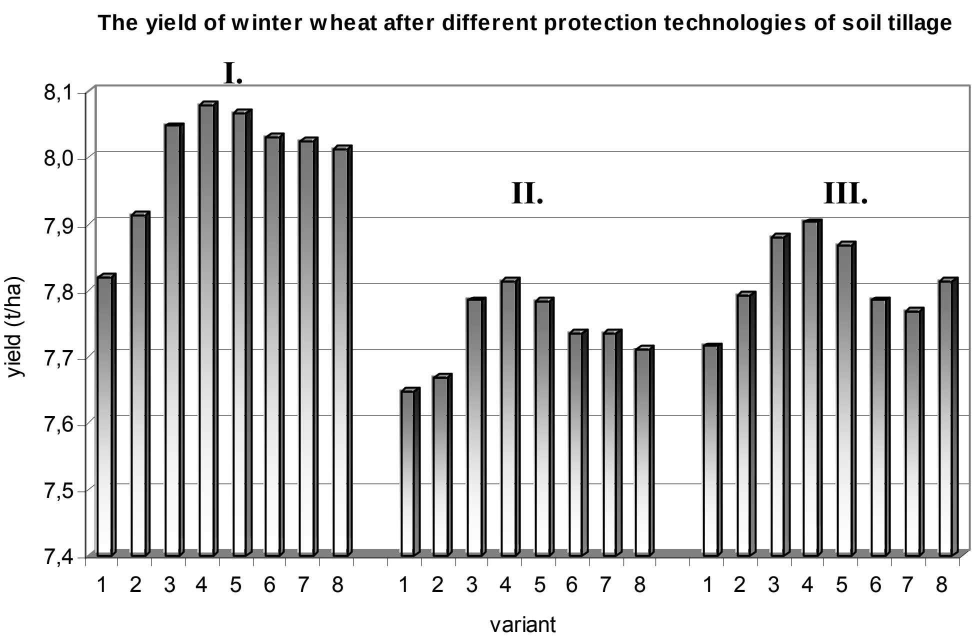
Variants for winter wheat:

1) Control variant without seed treatment
2) Control with seed-treatment with Vitavax 200 WP
3) Fertilizer fungi (LAV + 3g Polyversum per 1 kg of fertilizer)
4) Fertilizer fungi (LAV + 0,5 ml Ibefungin per 1 kg of fertilizer)
5) Fertilizer fungi (LAV + 0,5 g Supresivit per 1 kg of fertilizer)
6) Seed-treatment with Polyversum
7) Seed-treatment with Ibefungin
8) Seed-treatment with Supresivit

N- fertilizer (LAV) was applied in total doses 100 kg per 1 ha (40+30+30).

Results

The influence of joint application of mineral fertilizers and biopreparations Supresivit, Polyversum and Ibefungin on grain yields, yield components, grain quality and health state was recorded. The highest grain yield of winter wheat (to 8,08 t/ha) and also the highest increasing of the yield in the comparison with no-treated soil (0,26 t/ha, e.g. +3,3% - var.1) were reached after the classic stand establishment on the parcels treated with biofungicides in the form of the mixture with mineral fertilizer (LAV-fungi). The effect of single biopreparations was very similar. Higher values of yield was evaluated in all variants after the use of biopreparations. The study of health state showed lower infestation with pathogenic fungi transferred by the soil (*Fusarium, Septoria, Drechslera* etc.), positively influenced the yield and its quality. The results up to now confirm the important influence of site conditions, kind of technology as well on yields of tested crops. Long-term results displayed statistically significant higher grain yields of spring barley and winter wheat comparing with conventional tilling.

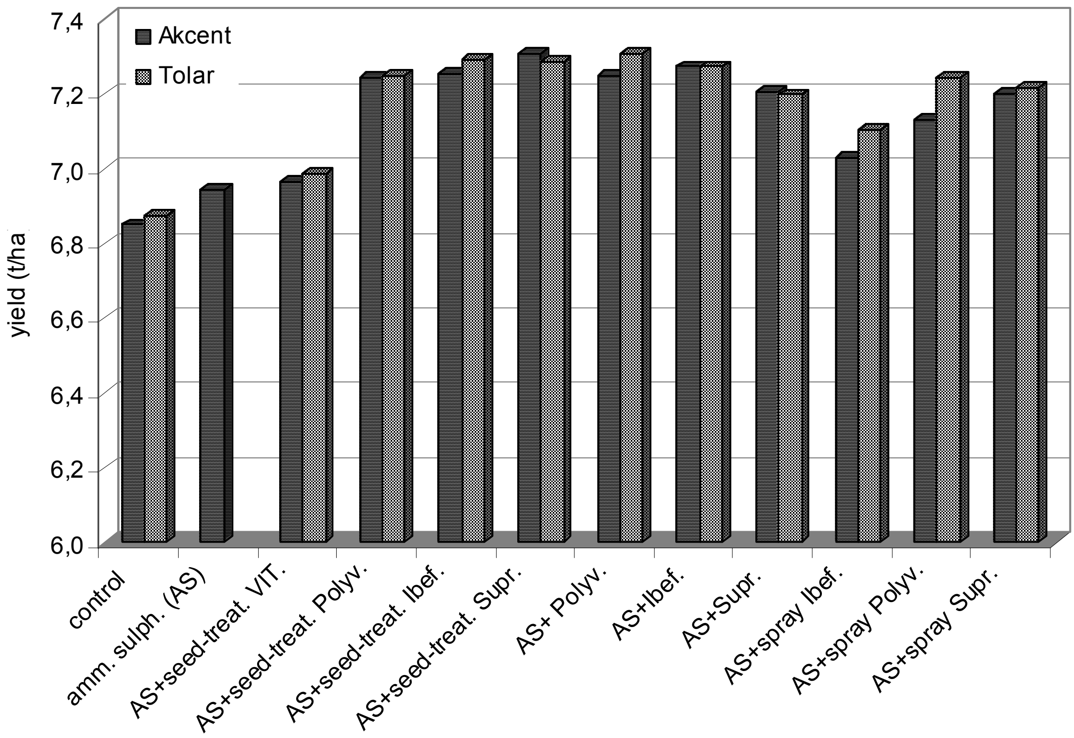


Variant		Ways of stand establishment [x)]		
		I	**II**	**III**
1.	Control	7,82	7,65	7,72
2.	Vitavax	7,91	7,67	7,79
3.	Vitavax + (LAV+ Polyversum)	8,05	7,79	7,88
4.	Vitavax + (LAV+ Ibefungin)	8,08	7,81	7,90
5.	Vitavax + (LAV+ Supresivit)	8,07	7,78	7,87
6.	(Vitavax + Polyversum) + LAV	8,03	7,74	7,79
7.	(Vitavax + Ibefungin) + LAV	9,03	7,74	7,77
8.	(Vitavax + Supresivit) + LAV	8,01	7,71	7,81
Mean grain yield (t/ha) :		**8,00**	**7,74**	**7,82**

[x)] **Ways of stand establishment of winter wheat:**

I. classic technology with ploughing
II. sowing into no-tilled soil with mulch of straw and postharwest residues of pre-crop
III. direct sowing into shallow-tilled soil with chopped pre-crop straw incorporated

The grain yield of spring barley in the year 2004



Discussion

The application of different biopreparations (Supresivit, Polyversum and Ibefungin) causes suppression of the fungi of the genus *Fusarium*. These fungi have persisted for a long-time in organically fertilized soils (Elmholt, 1997). The mechanism of surviving was another than in the form of sclerotium (Schreiber and Green, 1962). Different saprophytic mycoflora (Butler, 1953; Schreiber and Green, 1962; Bristow and Lockwood, 1975; Elmholt, 1997) was comparable with the mycoflora found out by us. Different ways of soil tillage technologies specificly influence the mycoflora. In the variant with direct drilling the biggest number of the genus *Fusarium* was found out. From reached results we can conclude that the effect of the mixture of antagonistic fungi or bacteria contents in the form of seed-treatment or with mineral fertilizer of LAV had favourable effect on winter wheat yield. Aside from different way of stand establishment of winter wheat it is possible to explain the yield effect after the use of biopreparations by the suppression of soil-borne phytopathogenic microorganisms namely micromycetes infestating the roots of plants. There was very important the reduction of the occurrence of the genus *Fusarium* and *Rhizoctonia* maintaining their infection soil potential in the forms of conidia and mycelium, which are on plant roots, invade the roots and case the disease. The decrease of occurrence was found after the infection with phytopathogenic fungi *Pyrenophora* (anamorph *Drechslera*) and *Septoria* - its species caused the damage of leaf area. We confirmed the reality that antagonistic fungi helped to deppress the population of phytopathogenic fungi and quantitative equilibrium of saprotrophic and phytopathogenic fungi.

Literature

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

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CONSERVATION SOIL TILLAGE EFFECTS ON SELECTED ENVIRONMENTAL PARAMETERS

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1. Introduction

The use of conventional tillage systems applying a mouldboard-plough on poorly drained soils has resulted in a gradual deterioration of soil structure. Conservation tillage, which involves the maintenance of crop residues on the soil surface, controls soil erosion effectively (Harrold and Edwards, 1974; Langdale et al., 1979) and enhances soil water conservation (Buchele et al., 1955; Unger, 1984; Mielke et al., 1986). According to Agricultural Research Service (1981) conservation tillage means any tillage and planting system that leaves at least 30% of crop residues on the soil surface after planting. Conservation tillage is an "umbrella" term encompassing several tillage systems including minimum tillage, reduced tillage, no tillage, mulch tillage and ridge tillage (Mannering and Fenster, 1983). However, adaptation of conservation tillage for maize (*Zea mays L.*) production on poorly drained soils is limited because it often results in yields lower than for maize grown under conventional tillage (Griffith et al., 1973; Dick and Van Doren, 1985).
Ridge tillage is a row-crop production system with the aim of soil protection and cultivation. Ridge tillage is characterized by permanent row-interrow configuration where the row is elevated 12 to 20 or 22 cm above the interrow throughout most of the year (Stone and Heslop, 1987; Stone et al., 1989; Lal, 1990; Liebig et al., 1993; Birkás et al., 1998). The soil is left undisturbed from harvest to planting except for strips up to one third of the row width. Planting is completed on the ridge and usually involves the removal of the top of the ridge. Planting is completed with sweeps, disk openers, coulters or row cleaners. Residue is left on the surface between ridges. Weed control is accomplished with crop protection products (frequently banded) and/or cultivation (Klein et al., 1996). Ridges are rebuilt during row cultivation. The method has been known for centuries in the United States and certain countries of Africa and belongs to the soil conservation systems (Lal, 1990; Vyn et al., 1990). The method had no precedence in the literature of the Central-European Region. The first publication in this topic was written by Birkás et al. (1998) in Hungary, which shows the results of soil condition analysis and yield in the ridge tillage trial set in Gödöllő, 1995.

Tillage decreases soil mechanical resistance as measured by cone index (Cox et al., 1990), but this is accompanied by a decrease in macropore continuity as earthworms produce fewer bio-channels than under reduced tillage conditions (Gyuricza, 2000). Use of a no-tillage cropping system achieves the greatest surface residue retention. However, surface and subsurface soil density and penetration resistance may increase naturally when using a no-tillage system (Ehlers et al., 1983; Mielke et al., 1986). Of particular concern are increased soil bulk density and penetration resistance, which among other things, can reduce water infiltration, plant root growth and crop yields. These increases result from raindrop impact and structural failure (collapse) of soils having low-stability aggregates. Soils with a high sand content are especially prone to develop a dense zone with a high penetration resistance. With no-tillage,

natural increases in soil bulk density and penetration resistance usually are limited to the upper 15 cm of the soil profile (Unger, 1996).
In Austria about 2.3 million ha is affected by water erosion, 380 000 ha are considered moderately to highly erosive. The yearly loss of soil is estimated to be 8 million tons. Radke (1982) concluded that ridge tillage could help control erosion by leaving crop residues on the surface. Erosion and nutrient losses with ridge tillage were 67 % less than in conventional tillage on land with 8 to 12 % slope (Römkens et al., 1973).
The objective of this study was to determine effects of different tillage systems on some soil quality parameters, e.g. bulk density, penetration resistance, water content, pore size distribution, soil temperature and earthworm activity in a long-term experiment under a semi-humid climate in Austria.

2. Materials and methods

2.1. Site location, climate and soil

The study was conducted in the experimental field of Pyhra Agricultural School, Austria, located at about 80 km west of Vienna (latitude 48º 14'; longitude 15° 72'). This region is located on the foothills of the Alps, at 325 m above sea level. The landscape is characterised by gently steep slopes. The area has a semi-humid climate with strong influence of the Alps characterised by relatively cold winters and moderately mild summers. The annual average precipitation (1950-2000) is 821 mm out of which about two-thirds (only about half in drier in periods) occurs in the growing season between April and September. The mean annual temperature is 8.8 ^{o}C. Although the average minimum temperature is 1.5 ^{o}C, it occurs several times that the air temperature is about –8 ^{o}C in winters in the region, which may result in soil freezing.
The soil at the site is sandy loam Typic Agriudoll, which is predominant in the area. The average texture analysis of this soil shows that 27% is sand, 52% is silt, and 21% is clay in the surface horizon (0-0.2 m depth) and an average organic carbon content is about 1.3%. In Austria, Typic Agriudoll is regarded as one of the most productive soils from an agricultural perspective. They normally have a good structure and condition with favourable water and nutrient holding capacity. Before the beginning of the study, the experimental site was under conventional cultivation for several years growing triticale, maize and winterwheat.

2.2. Tillage experiment and management

The experimental design was an one factor, strip-arranged small plot trial. Plot size was 9 m wide and 50 m long (450 m^2). In the experiment three tillage systems were compared, conventional tillage with autumn mouldboard ploughing (to 20-25 cm) (CT), ridge tillage (RT) and no-tillage (NT). The number of replications (r) is four, and the treatments were randomised on the area.
At the beginning of the experiment soil was prepared in case of NT in one pass together with the sowing and consisted of only the loosening of the seedbed. Under CT the autumn medium deep ploughing (0.20-0.25 m) and the smoothing were carried out in one pass. Ridge tillage consists of planting on existing ridges and rebuilding the ridge during cultivation. The autumn soil preparation under RT was the same in the year 1996 as in the case of the CT, and ridges were formed in spring. A potato ridge-filling cultivator was used to form the initial 0.18-0.20 m high ridges with spacing of 0.75 m and to cultivate and rebuild ridges. In June the ridges were readjusted with the machine that also undertook mechanical weed killing. In 1997 and 1998 there was no autumn base tillage, and next year ridges were formed before sowing and

after sowing in June. From 1999 an autumn ploughing was carried out also in ridge tillage treatment due to the increased weed infestation.
In the experiment maize (varieties: *DK 210* – 1997, 1998*; Magister RFZ 290* – 1999*, Coach* - 2000*,* 2001*; Brissac* 2002, 2003) was planted in monoculture at a 0.05 m depth, generally at the end of April. The row spacing was 0.75 m and the plant population 95 000 plants ha^{-1}, as this is a standard practice, except 2003 (84 000 plants ha^{-1}). Fertiliser was uniformly applied to all treatments. Chemical pest and disease control was not needed because of the low occurrence. Herbicides were applied only in no-tillage treatment (two times in May and June) and in the conventional tillage treatment (once in June). In 1997 and 1998 no chemical treatment was applied in ridge tillage, but after that period the same herbicide was applied as in the other two treatments.

2.3. Sampling and field measurements

The evaluation of the physical characteristics of the soil was carried out according to the results of bulk density, moisture content.
The soil bulk density was determined by the cylinder method. The cores (0.053 m i.d. by 0.05 m height) were taken from interrows at 0.05 to 0.10 m and 0.15 to 0.20 m soil depth, dried at 105 °C and weighed. Four samples from each plot were taken at emergence in the years 1998, 2000 and 2002.
The soil temperature was determined by the Eikelkamp thermometer. The device measures the temperature to the depth of 0.5 m.
Earthworms were sampled in May and September 2000. A timbered frame (0.25 m^2) was used to determine the earthworm abundance to a depth of 0.3 m. At each sampling point soil was removed and finely hand-shifted to collect all earthworm life stages. The number of worms and biomass were determined. Additionally, the number of earthworm channels was counted in 0.1 m depth according to a method of Edwards et al. (1988).

2.4 Statistical analyses

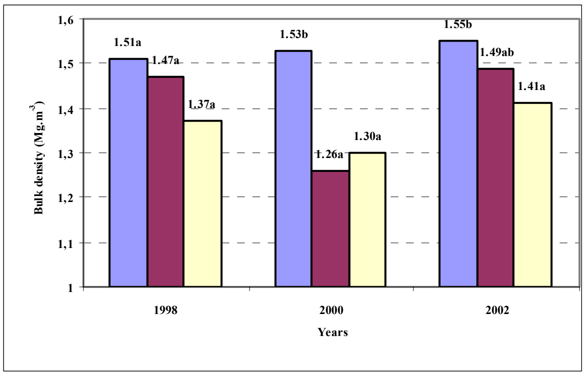
Bulk density, soil temperatures and earthworm density values were used for statistical analysis. The effects of treatments were analysed by using one-way ANOVA (Sváb, 1981).

3. Results and discussion

3.1. Soil bulk density

Soil bulk density (BD) is probably the most frequently measured soil quality parameter in tillage experiments (Rasmussen, 1999). It can be important especially for crops sown in the spring (Cannel and Hawes, 1994). Soil samples were taken for determining BD in every second year of the experiment (Soane and Ball, 1998). During the first measurement after two years of setting up the experiment the highest value of BD could be observed in NT (1.51 Mg·m^{-3}) at the 0.05-01 m depth, while under CT and RT 1.47 Mg·m^{-3} and 1.37 Mg·m^{-3}, but the differences were not significant (Fig. 1). The same is true for the 0.15-0.20 m depth with smaller differences between the treatments. These BD values are considered to be favourable in the middle of the vegetation period under the given soil conditions. The lack of differences in soil bulk density between treatments after two years of experimental treatments was probably due to the fact that there was insufficient time to achieve an equilibrium value (Ferreras et al., 2000). Our data are in line with the results reported by Stone and Heslop (1987) for a poorly drained soil after three years.

In the fourth year of the study (summer 2000) the bulk density in NT near the surface did not change greatly compared to 1998 (1.53 Mg·m^{-3}), while RT and CT showed significantly lower values due to regular soil disturbance. At the 0.15-0.20 m depth highest bulk density values were found in RT (1.52 Mg·m^{-3}). The 1.38 Mg·m^{-3} soil bulk density value determined on CT was significantly lower than in NT and RT. The reason for the relatively high bulk density under RT is perhaps the compacting effect caused by heavy machinery when rebuilding the ridges.



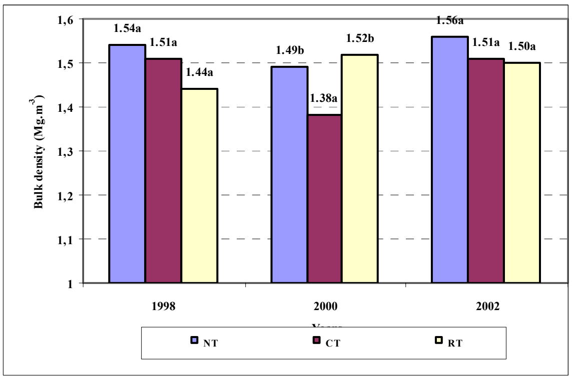
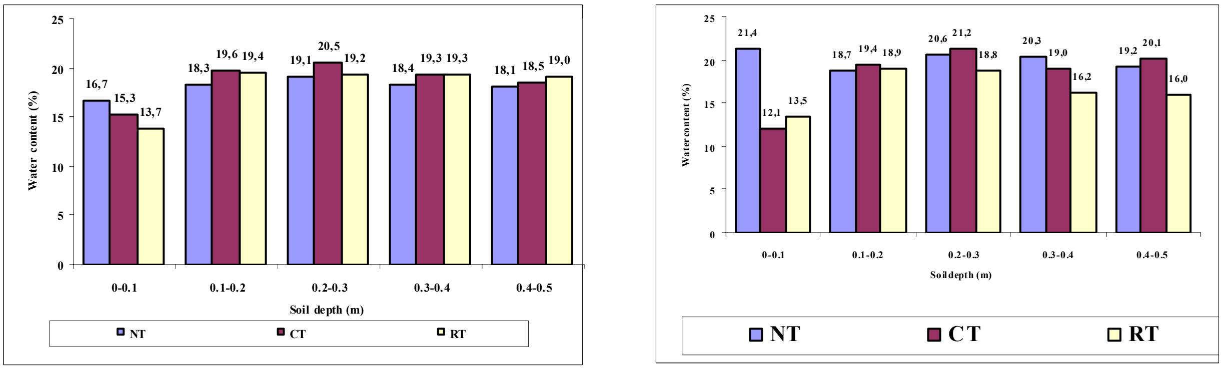


Figure 1. Soil bulk density in the tillage treatments at the depts of 0.05-0.10 and 0.15-0.20 m (Pyhra, 1998-2002)

During the sixth year of the experiment non-significant differences were observed in the topsoil between NT and CT plots (1.55 Mg·m^{-3} and 1.49 Mg·m^{-3}). This would probably be related to the existing mulch layer on the top of non-tilled soil (Tebrügge and Düring, 1999) that provides organic matter and food for soil fauna, which loosens surface soil by borrowing activities and improves the physical and the biological condition of soil (Birkás, 2000). On the contrary, several authors found that one of the most striking effects of ploughless tillage (including no-tillage) is the increased bulk density of the topsoil after more years' implementation (Rydberg, 1987; Rasmussen, 1999). The reason for the contradiction can be that soil bulk density after tillage can be affected by several soil properties (organic matter content, particle size distribution, aggregate stability etc.) and climatic conditions (e.g. precipitation). The lowest value of soil bulk density in the sixth year of our study was at the 0.05-0.10 m depth (1.41 Mg·m^{-3}) in RT differing significantly from CT and NT. At the 0.15-0.20 m depth no significant differences were found between the treatments. However, relatively high bulk density values were found during final measurements in all tillage treatments even when these soils are regarded as only slightly compacted.

3.2. Soil water content

The most important tasks of soil tillage practices are to provide sufficient amount of water for the cultivated plants and to maintain the favourable soil biological and physical condition. Changes in the soil water profile summarized for the years 1997-2000 and 2001-2004 are shown in Fig. 2. In the first period (1997-2000) differences in water content between the treatments only in the 0-0.1 m depth were observed. The highest values were measured for NT, however, lower water content was found compared to RT and CT below 0.1 m depth, but these differences were not significant (P<0.05%). Water content in the top horizon resulted in lower values at all treatments compared to the ones in the depths of 0.1-0.5 m. A similar pattern was observed by Fenyves (1997) where five different soil management practices were compared.



1997-2000 2001-2004

Figure 2. Soil moisture content of the tillage treatments (Pyhra, 1997-2004)
Four years averages of eight measurements - 1997-2000, 2001-2004)

During the second measurement period (2000-2004), bigger differences were found in moisture content among the treatments. On average, the highest soil water content occurred under NT in the topsoil (0-0.1 m), however, a substantially lower moisture content was obtained under RT and CT. However, soil water content under NT was, generally, similar to the one under RT and CT in the lower parts of the topsoil. Comparing the rainfall during the two measurement periods, it can be concluded that the amount and the distribution of the precipitation were similar. Two reasons could explain the differences in the water content of the topsoil between the different soil tillage practices, namely on the one hand the increased amount of plant residues on the surface of non-tilled soil reduced the evaporation and on the other hand the yearly repeated soil disturbance contributed to a higher moisture loss in RT and CT soil. Rydberg (1987) noted that a lower volume of macropores and a higher volume of medium, water holding pores are also possible reasons for the higher water content in the upper soil layers after reduced tillage.

Our data suggest that there were no differences between the ridge tillage and the conventionally ploughed methods. Several authors emphasized that water storage was greater in RT system compared to CT (Birkás et al., 1998; Hatfield et al., 1998). The reason for the lack of differences is probably that insufficient crop residues were replaced in the interrows after harvesting maize.

3.4. Soil temperature

Soil temperature in the seedbed is critical for rapid seed germination and emergence. Hatfield et al. (1998) emphasised that maize is especially sensitive because the epycotil growing point remains below ground until the sixth leaf emerges. The soil temperatures in the depth of 0-0.5 m at different soil tillage practices, 20 days after planting are presented in Table 1. NT reduced significantly the soil surface temperature related to CT and all parts of RT. The soil temperature was higher by 5 °C in CT related to NT. However, below the upper 0.1 m layer the coldest soil was observed under NT, but there were no statistical differences between CT and RT. The reason for a colder soil condition under NT is that the soil surface covered by residues resulted in decreased evaporation and higher soil moisture content. As a result at the beginning of the vegetation period crop emergence was delayed. 45 days after planting the maize height was 0.16 m in NT, while 0.22 m in CT and 0.19 m in RT. The same tendencies are presented by Elonen (1988) who pointed out that in spring the soil temperature was higher by 0.3-1.0 °C in the topsoil after ploughing compared to direct drilling. Rasmussen (1999) noted that the lower soil temperature might delay plant emergence, plant development and ripening especially in areas with late and short growing seasons. Contrary results were presented by Hussain et al. (1999) observing a greater maize height in no-tillage compared to the ploughed treatments on a silt loam soil.

Table 1. Soil tillage effects on soil temperature (°C) in the depths of 0-0.5 m at 20 days after maize planting (Pyhra, May 2000)

	Soil depth (m)					
	0 (surface)	0.1	0.2	0.3	0.4	0.5
NT	19,4a*	16,4a	15,7a	16,2a	16,5a	16,4a
CT	24,4c	19,5b	18,8b	19,1b	19,1b	19,1b
RT						
- Ridge top	24,9cd	20,1b	19,3b	19,6b	19,7b	19,7b
- Ridge side	25,5d	20,0b	19,7b	19,8b	19,8b	19,7b
- Interrow	22,8b	19,8b	19,3b	19,4b	19,3b	19,1b

*values followed by the same letter do not differ significantly ($P<0.05$)

Ridge configurations have special influences on the soil physical parameters that explain the different temperatures measured on different points of ridges. The warmest part of the ridge was shown on the top which can encourage plant emergence and development especially under moist soil condition. However, the interrows conserve soil water for the drier summer period. In our experience plant residues in the interrows were particularly important, when the annual precipitation was lower and summer was hot.

Higher soil temperature and better loosening on the side and the top of the ridges also supported the quick development of weeds besides the cultivated crop. In the first two years of the experiment the high weed coverage in RT system inhibited the maize development and the yield due to lack of mouldboard ploughing. The implementation of the ploughing in RT treatment led to the significant reduction of weeds during the growing seasons.

3.5. Earthworm activity

The number of earthworms and channels is often used as a biological indicator for soil quality or condition (Mele and Carter, 1999; Chan, 2001; Birkás et al., 2004). The population and the abundance of the earthworms in the experiment are presented in Table 2.

Table 2. Soil management effects on the number and mass of the earthworms within the surface 0.3 m (Pyhra, 2000)

Soil tillage treatment	Total	Earthworms per m^2 Length (cm)			Channels >2mm per m^2	Earthworm mass (g m^{-2})
		1-3	3-6	>6		
NT	72c	27b	20c	25c	425c	24.2c
CT	12a	5a	3a	4a	198a	3.5a
RT	32b	7a	14b	11b	293b	11.3b

*values followed by the same letter do not differ significantly (P<0.05)

Both the number and the weight of earthworms were significantly higher in the no-tilled treatment compared to RT and CT. Anken et al. (2004) noted that the earthworm density declined with the intensity of tillage. The analysis of the visible biopores (>2 mm) showed higher abundance under NT which can contribute to a better infiltration of surface water in the case of intensive rainfall due to their stability and their vertical orientation. Although the lowest total porosity including macroporosity was found for NT soil, it is assumed that the majority of these pores (>30 mm) belonged to the biopores responsible improving the general physical and biological state of soil. Our data are in line with the results of Sveistrup et al. (1997) as well as Tebrügge and Düring (1999) finding that these biogenic macropores in the soil profile were very resistant to pressure loading.

References

Agricultural Research Service, 1981. Report of the Soil Erosion-Soil Productivity Research Planning Workshop, Lafayette, IN, USA. U.S. Dept. Agric., Washington, D.C.

Anken, T., Weisskopf, P., Zihlmann, U., Forrer, H., Jansa, J., Perhacova, K., 2004. Long-term tillage effects under moist cool conditions in Switzerland. Soil Till. Res. 78, 171-183.

Benjamin, J.G., Baylock, A.D., Brown, H.J., Cruse, R.M., 1990 Ridge tillage effects on simulated water and heat transport. Soil Till. Res. 18, 167-180.

Birkás, M., 2000. Soil compaction occurence and consequences in Hungary, possibilities of alleviation. D.Sc Thesis. Hung. Acad. Sci., Budapest (in Hungarian).

Birkás, M., Gyuricza, Cs., Percze, A., Szalai, T., 1998. Experiments with the ridge-tillage of maize on brown forest soil in Hungary. Növénytermelés 47, 559-571 (in Hungarian).

Birkás M., Szalai T., Gyuricza Cs., Gecse M., Bordás K. 2002. Effects of disk tillage on soil condition, crop yield and weed infestation. Rostlinna Vyroba 48, 20-26.

Birkás, M., Jolánkai, M., Gyuricza, C., Percze, A., 2004. Tillage effects on compaction, earthworms and other soil quality indicators in Hungary. Soil Till. Res. 78, 185-196.

Buchele, W.F., Collins, E.V., Lovely, W.G., 1955. Ridge farming for soil and water control. Agric. Eng. 36, 324-329.

Cannel, R.Q., Hawes, J., 1994. Trends in tillage practices in relation to sustainable crop production with special reference to temperate climates. Soil Till. Res. 30, 245-282.

Carman, K., 1997. Effect of different tillage systems on soil properties and wheat yield in Middle Anatolia. Soil Till. Res. 40, 201-207.

Chan, K.Y., 2001. An overview of some tillage impacts on earthworm population abundance and diversity – implications for functioning in soils. Soil Till. Res. 57, 179-191.

Cox, W.J., Zobel, R.W., van Es, H.M., Otis, D.J., 1990. Tillage effects on some soil physical and corn physiological characteristics. Agron. J. 82, 806-812.

Dick, W.A., Van Doren, D.M., 1985. Continuous tillage and rotation effects on corn, soybeans, and oat yields. Agron. J. 77, 459-465.
Edwards, W.M., Norton, L.D., Redmond, C.E., 1988. Characterizing macropores that affect infiltration into non tilled soil. Soil Sci. Soc. Am. J. 52, 483-487.
Ehlers, W., Köpke, U., Hesse, F., Böhm, W., 1983. Penetration resistance and root growth of oats in tilled and untilled loess soil. Soil Till. Res. 3, 261-275.
Elonen, P., 1988. Reducerad jordbearbetning. Forskning I Finland. In: Hansen, L., Rasmussen, K.J. (Eds.) Proceedings of NJF Seminar, Reduced Cultivation. Div. Soil Management, Uppsala, Sweden, Report No. 77, 17-23.
Ferreras, L.A., Costa, J.L., Garcia, F.O., Pecorari, C., 2000. Effect of no-tillage on some soil physical properties of a structural degraded Petrocalcic Paleudoll of the southern "Pampa" of Argentina. Soil Till. Res. 54, 31-39.
Fenyves, T., 1997. Some effects of sustainable management on tillage, weed infestation and fertilization. PhD thesis, GATE Gödöllő (in Hungarian with English summary).
Gail, A.W., Wilson, R.G., Mahnken, G.W., Hanson, G.E., 1996. Influence of weed control on weed population in ridge-till Corn (Zea mays). Weed Sci. 4, 903-910.
Griffith, D.R., Mannering, J.V., Galloway, H.M., Parsons, S.D., Richey, C.B., 1973. Effect of eight tillage-planting systems on soil temperature, percent stand, plant growth, and yield of corn on five Indiana soils. Agron. J. 65, 321-326.
Gyuricza, Cs., 2000. Effects of the conventional and conservation tillage systems on selected physical and biological parameters of soil. PhD thesis, SZIE Gödöllő (in Hungarian with English summary). 148.
Harrold, L.L., Edwards, W.M., 1974. No-tillage system reduces erosion from continuous corn watersheds. Trans. Am. Soc. Agric. Eng. 17, 414-416.
Hatfield, J.L., Allmaras, R.R., Rehm, G.W., Lowery, B., 1998. Ridge tillage for corn and soybean production: environmental quality impacts. Soil Till. Res. 48, 145-154.
Hayes, W.A., 1982. Minimum tillage farming. No-till Farmer Inc. Brookfield, WI, USA.
Hussain, I., Olson, K.R., Ebelhar, S.A., 1999. Impacts of tillage and no-till on production of maize and soybean on an eroded Illinois silt loam soil. Soil Till. Res. 52, 37-49.
Ishaq, M., Ibrahim, M., Lal, R., 2002. Tillage effects on soil properties at different levels of fertilizer application in Punjab, Pakistan, Soil Till. Res. 68. 93-99.
Klein, R.N., Gail, A.W., Wilson, R.G., 1996. Ridge-till, an integrated weed management system. Weed Sci. 44, 417-422.
Lal, R., 1990. Ridge tillage. Soil Till. Res. 18, 107-111.
Langdale G.W., Barnett, A.P., Leonard, R.A., Fleming, W.G., 1979. Reduction of soil erosion by the no-till system in the Southern Piedmont. Trans. ASAE. 22, 82-86, 92.
Liebhard, P., 1993. Effekte langjähriger unterschiedlicher Primärbodenbearbeitung auf ausgewählte Bodenkennzahlen und das Ertragsverhalten von Winterweizen (Triticum aestivum L.), Körnermais (Zea mays L.) und Zuckerrübe (Beta vulgaris L. ssp. vulgaris var. altissima Doe. Habilitationsschrift, Universität für Bodenkultur Wien.
Liebig, M.A., Jones, A.J., Mielke, L.N., Doran, J.W., 1993. Controlled wheel traffic effects on soil properties in ridge tillage. Soil Sci. Soc. Am. J. 57, 1061-1066.
Mannering, J.V., Fenster, C.R., 1983. What is conservation tillage? Special Edition on Conservation Tillage. J. Soil Water Cons. 38, 141-143.
Materechera, S.A., Mloza-Banda, H.R., 1997. Soil penetration resistance, root growth and yield of maize as influenced by tillage system on ridges in Malawi. Soil Till. Res. 41, 13-24.
McInnes, K.J., Heilmann, J.L., Gesch, R.W., 1991. Momentum roughness and zero-plane displacement of ridge-furrow tilled soil. Agric. Forest Meteorology 55, 167-179.

Mele, P.M., Carter, M.R., 1999. Impact of crop management factors in conservation tillage farming on earthworm density, age structure and species abundance in south-eastern Australia. Soil Till. Res. 50. 1-10.
Mielke, L.N., Doran, J.W., Richards, K.A., 1986. Physical environment near the surface of plowed and no-tilled soils. Soil Till. Res. 7, 355-366.
Radke, J.K., 1982. Managing early season soil temperatures in the northern corn belt using configured soil surfaces and mulches. Soil Sci. Soc. Am. J. 46, 1067-1071.
Rasmussen, K.J., 1999. Impact of ploughless soil tillage on yield and soil quality: A Scandinavian review. Soil Till. Res. 53, 3-14.
Rátonyi, T., 1999. Measuring of the penetration resistance in a long-term soil tillage experiment. Ph.D Thesis, Debrecen, (in Hungarian).
Römken, M., Nelson, D.W., Mannering, J.V., 1973. Nitrogen and phosphorous composition of surface runoff as affected by tillage method. J. Environ. Qual. 2, 292-295.
Rydberg, T., 1987. Studies in ploughless tillage in Sweden 1975-86. Div. Soil Management, Uppsala, Sweden, Report No. 76, 35 pp.
Soane, B.D., Ball, B.C., 1998. Review of management and conduct of long-term tillage studies with special reference to a 25-yr experiment on barley in Scotland. Soil Till. Res. 45, 17-37.
Stone, J.A., Heslop, L.C., 1987. Blade cultivator, ridge and mouldboard plow tillage comparison on a poorly drained soil. Trans. ASAE, 30, 61-64.
Stone, J.A., Vyn, T.J., Martin H.D., Groenevelt, P.H., 1989. Ridge-tillage and early-season soil moisture and temperature on a poorly drained soil. Can. J. Soil Sci. 69, 181-186.
Stonehouse, D.P., 1997. Socio-economics of alternative tillage systems. Soil Till. Res. 43, 109-130.
Sváb J., 1981. Statistical methods in the research. Mezőgazdasági Kiadó, Budapest (in Hungarian).
Sveistrup, T.E., Haraldsen, T.K., Engelstad, F., 1997. Earthworm channels in cultivated clayey and loamy Norwegian soils. Soil Till. Res. 43, 251-262.
Tebrügge, F., Düring, R.A., 1999. Reducing tillage intensity – a review of results from a long-term study in Germany. Soil Till. Res. 53, 15-28.
Unger, P.W., 1984. Tillage and residue effects on wheat, sorghum, and sunflower grown rotation. Soil Sci. Soc. Am. J. 48, 885-891.
Unger, P.W., 1995. Organic matter and water-stable aggregate distribution in ridge-tilled surface soil. Soil Sci. Soc. Am. J. 59, 1141-1145.
Unger, P.W., 1996. Soil bulk density, penetration resistance, and hydraulic conductivity under controlled traffic conditions. Soil Till. Res. 37, 67-75.
Unger, P.W., Jones, O.R., 1998. Long-term tillage and cropping systems affect bulk density and penetration resistance of soil cropped to dryland wheat and grain sorghum. Soil Till. Res. 45, 39-57.
Várallyay, G., 1973. A new apparatus for the determination of soil moisture potential in the low suction range. Agrokémia és Talajtan, 22. 1-22. (in Hungarian).
Vyn, T.J., Stone, J.A., Raimbault, B.A., 1990. Corn development and crop yield response to ridge-plant systems on a poorly drained soil in southwestern Ontario. Soil Till. Res. 18, 207-217.
Wang, C., McKeague, J.A., Switzer-Howse, K.D., 1985. Saturated hydraulic conductivity as an indicator of structural degradation in clayey soils of Ottawa area, Canada. Soil Till. Res. 5, 19-31

CONTENTS

SOIL TILLAGE PRACTICES FOR THE PREVENTION OR REDUCTION OF THE RISK OF EXTREME MOISTURE REGIME

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The natural conditions in Hungary are **generally favourable for rainfed biomass production**. These conditions, however, show extremely high spatial and temporal **variability,** often **extremes** and sensitively react to various natural or human-induced **stresses** (Láng et al., 1983; Csete & Várallyay, 2004; Várallyay, 2004a; Várallyay et al., 1979, 1980a). The agro-ecological potential is mainly limited by three soil factors: **soil degradation processes (**Szabolcs & Várallyay, 1978; Várallyay, 1989, 2000); **extreme moisture regime:** simultaneous hazard of flood, waterlogging, over-moistening and drought sensitivity (Várallyay, 2004b, 2005); u**nfavourable changes in the biogeochemical cycles of elements**, especially of plant nutrients and environmental pollutants (Láng et al., 1983).

Extreme moisture regime

It can be forecast with high probability that in future **water** will be the determining (hopefully not limiting) factor of food security and environmental safety. Consequently, the **increase in water use efficiency** will be one of the key issues of agricultural production, rural development and environment protection and the **control of soil moisture regime** will be an imperative task without any other alternatives (Várallyay, 1988, 2004b, 2005).

Water resources are limited. The average 450–600 mm **annual precipitation** may cover the water requirement of the main crops even at high yield levels. But the average shows **extremely high territorial and temporal variability** – even at micro-scale. Under such conditions a considerable part of the precipitation is lost by surface runoff, downward filtration and evaporation. In addition to the hardly predictable atmospheric precipitation pattern, the two additional reasons of **extreme soil moisture regime** (the simultaneous hazard of waterlogging or overmoistening and drought sensitivity) are:

– the heterogeneous **microrelief** of the „flat" lowland;

– the highly variable, sometimes mosaic-like **soil cover** and the **unfavourable physical and hydrophysical properties of some soils** (mainly due to heavy texture, high clay and swelling clay content, or high sodium saturation: ESP).

According to our comprehensive assessment (Várallyay, 2004b, 2005; Várallyay et al., 1980b) 43% of Hungarian soils can be characterized by unfavourable, 26% by moderately (un)favourable and 31% by favourable moisture regime, as illustrated by Figure 1, indicating the main reasons of various moisture conditions.

Under such environmental conditions it is an important fact **that soil is the largest potential natural water reservoir** (water storage capacity) in Hungary (Várallyay, 2001, 2003). The 0–100 cm soil layer may store about 25–30 km³ water, which is more than half of the average annual precipitation. About 50% of it is „available moisture content". In many cases, however, this huge potential water storage capacity cannot be used because of four reasons:

– it is not „empty", it is filled to a certain extent by a previous source (rain, melted snow, capillary transport from groundwater, irrigation, etc.): "**filled bottle effect**";

CONTENTS

– the infiltration of water into the soils is prevented by the frozen topsoil ("**frozen bottle effect**");
– the infiltration is prevented or reduced by a nearly impermeable soil layer on, or near to the soil surface ("**closed bottle effect**");
– the water retention of soil is poor and the infiltrated water is not stored in the sol, but only percolates through the soil profile.

The schematic map of these situations is presented in Figure 2.

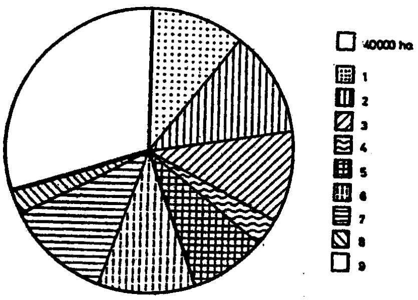

Figure 1 Distribution of soils according to their moisture regimes in Hungary.
1–5 = Soils with unfavourable hydrophysical properties (43%): 1: due to very coarse texture (10.5%); 2: due to very heavy texture (11%); 3: due to strong salinity-alkalinity (10%); 4: due to waterlogging (3%); 5: due to shallow depth (8.5%); 6–8 = Soils with moderately unfavourable hydro-physical properties (26%): 6: due to coarse texture (11%); 7: due to heavy texture or clay accumulation in the B-horizon (12%); 8: due to moderate salinity/ alkalinity in the deeper layers (3%); 9 = Soils with good hydrophysical properties (31%)

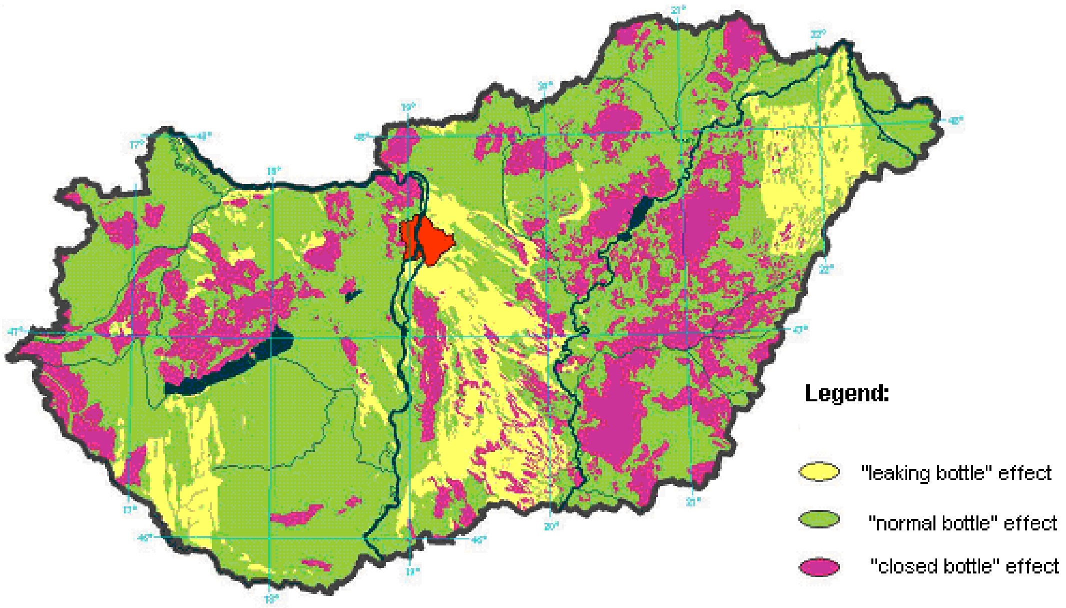

Figure 2. Limited infiltration rate and water storage capacity of soils in Hungary

The coincidence of all these factors resulted in the serious („havaria type") flood–waterlogging–overmoistening events in the first years of the millennia, which was followed by a drought catastrophe (in the same year, on the same territories) in the Tisza Plain covered by heavy textured (high clay content, high rate of expanding clay minerals) soils, sometimes with high sodium saturation (ESP).

Soil moisture control

In the last years a comprehensive soil survey–analysis–categorization–mapping–monitoring system was developed in Hungary for the exact characterization of hydrophysical properties, modelling and forecast of water and solute regimes of soils. The system may serve as a scientific basis for soil moisture control and it is efficiently used for practical soil water management both for crop production and environmental protection The most important elements of the system were as follows: (a) Category system and 1:100 000 scale map of the hydrophysical characteristics of soils (Várallyay et al., 1980b); (b) Moisture regime types of Hungarian soils and their 1:500 000 scale map (Várallyay, 1985); (c) Large-scale mapping of hydrophysical properties and moisture regime of soils.

In the Hungarian sustainable land use and site-specific soil management yield stability, risk reduction, soil conservation, and the prevention, elimination or moderation of extreme moisture situations have great significance and **soil moisture control** is of primary importance. Its three main elements are:

– help water infiltration into the soil;
– help water storage within the soil in plant available form;
– drain the surplus amount of water from the soil profile and from the area (vertical and horizontal drainage).

The main possibilities and methods of this moisture control have been developed. Most of these „moisture management actions" are – at the same time – efficient environment control measures. Soil tillage (may) play an important role in these actions (Soana & Ouwerkerk, 1994), especially under rainfed conditions, as in Hungary.

Soil tillage practices for the prevention or risk reduction of extreme soil moisture regime

Materials and methods

A long-term field experiment was established in the fall of 2002 near to Hatvan (60 km from Budapest) on the experimental field (Józsefmajor) of the Szent István University, Hungary (Birkás & Gyuricza, 2004a,b,c). The **tillage treatments** were as follows:

1. L+T: Loosening (35) and disking (16–20 cm)
2. T: Disking (16–20 cm)
3. K1: Strip tillage (12–15 cm) by a French cultivator
4. K2: Cultivator (12–15 cm) by a Hungarian cultivator
5. NT: Minimum tillage with direct drilling
6. Sz: Ploughing (26–30 cm).

The soil was a medium textured Pseudomyceliar (calcic) Chernozem, rather sensitive to soil compaction. Its main characteristics are: slightly acidic reaction (pH H_2O 6.38, pH KCl 5.43); sand–silt–clay ratio: 23–42–35% and 24–36–40%; organic matter content 3.2% and 2.5%; total N content: 0.13 and 0.082%; P_2O_5 content: 270 and 214 ppm; K_2O content: 110 and 85 ppm in the 0–20 cm and 20–40 cm soil layers, respectively.

The average annual **precipitation** is 580 mm, and 323 mm in the „vegetation season". 2002 was a medium, 2003 a dry and 2004 a wet year.

The **experiment** was conducted in a split-plot design on 13 x 200 m parcels with four replications. The soil was tilled in October 2002; the fertilizers (200 kg N, 150 kg P_2O_5 and 100 kg K_2O) were given uniformly before sowing (April 2002) and the corn was harvested in September. From each treatment undisturbed soil cores of 100 cm³ volume were collected six times during the vegetation period of 2003 from 4 soil layers (0–5, 5–10, 15–20 and 45–50 cm) in 3 replicates. Soil water retention characteristics were measured at pressure heads represented by the pF values of 0.0, 0.4, 1.0, 1.5, 2.0, 2.3, 2.7, 3.4 and 4.2 according to Várallyay (1973). Soil water content and soil texture were determined as well. Bulk density was calculated from dry soil weights and the volume of undisturbed samples.

In each tillage treatment 3T-System type capacitive probes were installed up to 80 cm depth with 10 cm increment to ensure continuous measurement of soil temperature and soil water conttent. Measurements were performed four times a day from 13 May until September 11 2003. Daily average values were used for the evaluation.
Differences in soil physical properties attributed to tillage treatment were analyzed by ANOVA. The F statistics was used to separate significant differences in response parameters due to tillage. Significance is indicated at $P < 0.05$ (Farkas & Gyuricza, 2004; Farkas & Tóth, 2004; Farkas et al., 2004; Farkas, 2004a).

Results and discussion

Some results of the **bulk density** measurements are summarized in Table 1.

Table 1 Bulk density (g/cm³) of soils under various treatments

Treatment*	5–10 cm			15–20 cm			45–50 cm	
	04.10.	06.30.	09.04.	04.10.	06.30.	09.04.	04.10.	06.30.
L+T	1.21	1.23	1.16	1.32	1.47	1.33	1.45	1.41
T	1.26	1.27	1.20	1.52	1.49	1.24	1.44	1.41
K1	1.33	1.41	1.22	1.45	1.45	1.32	1.45	1.36
K2	1.35	1.19	1.22	1.23	1.32	1.30	1.37	1.43
DV	1.27	1.28	1.21	1.54	1.48	1.25	1.42	1.46
SZ	1.26	1.32	1.24	1.22	1.41	1.38	1.45	1.46

*For explanation of treatments: see in the text

In the 5–10 cm layer there were no significant differences at the beginning of the vegetation period (April). During the vegetation season (till June) some compaction was observed but it disappeared by September. In the 15–20 cm layer bulk density was lowest in the Sz and K2 treatments; practically all layers were quite seriously compacted till June; and nivelated until September. In the 45–50 cm layer there was no measurable „treatment effect".
From the large collection of our **water retention measurements** some characteristic pF curve points were summarized in Figure 3.
At the beginning of the growing season soil water retention curves measured in the tilled layer (0–5, 5–10 and 15–20 cm) significantly differed in the low suction range (pF<1.5). The measured saturated water contents (Θ_s) were significantly larger (50–53 v%) in the Sz, T, DV and L+T treatments than in the K1 and K2 (47 and 43 v%, respectively). Soil water retention curves of the 15–20 cm layer, measured in April, were similar to those of the topsoil, but the differences between them were less expressed. These differences disappeared by the end of June, when the saturated water contents varied between 44 and 46 v%. The K2 treatment, with Θ_s= 49 v% was the only exception. A rather strong seasonal variability of water retention curves was detected. But no significant differences have been observed between the soil water retention curves of the 45–50 cm soil layer.
On the basis of water retention curves, the potential moisture content of saturated soils (pF0) and of field capacity (pF 2.0) are presented in Figures 4 and 5. The data were registered for 4 horizons (0–5, 5–10, 15–20 and 45–50 cm), for 3 intervals (April, June, September) and for each treatment.
Total water capacity (pF 0) was closely related to bulk density, expressing total porosity, which is the determining factor of the maximum value of the water storage capacity of the

soil. The soil can be saturated up to this point, and after that any additional drop of water may result in oversaturation and waterlogging („filled bottle effect"). Consequently, these data – with the infiltration rate (as an indicator of the „closed bottle effect"), and hydraulic conductivity (as an indicator of the „leaking bottle effect") – can be the scientific basis for the estimation and prediction of the **waterlogging hazard**.

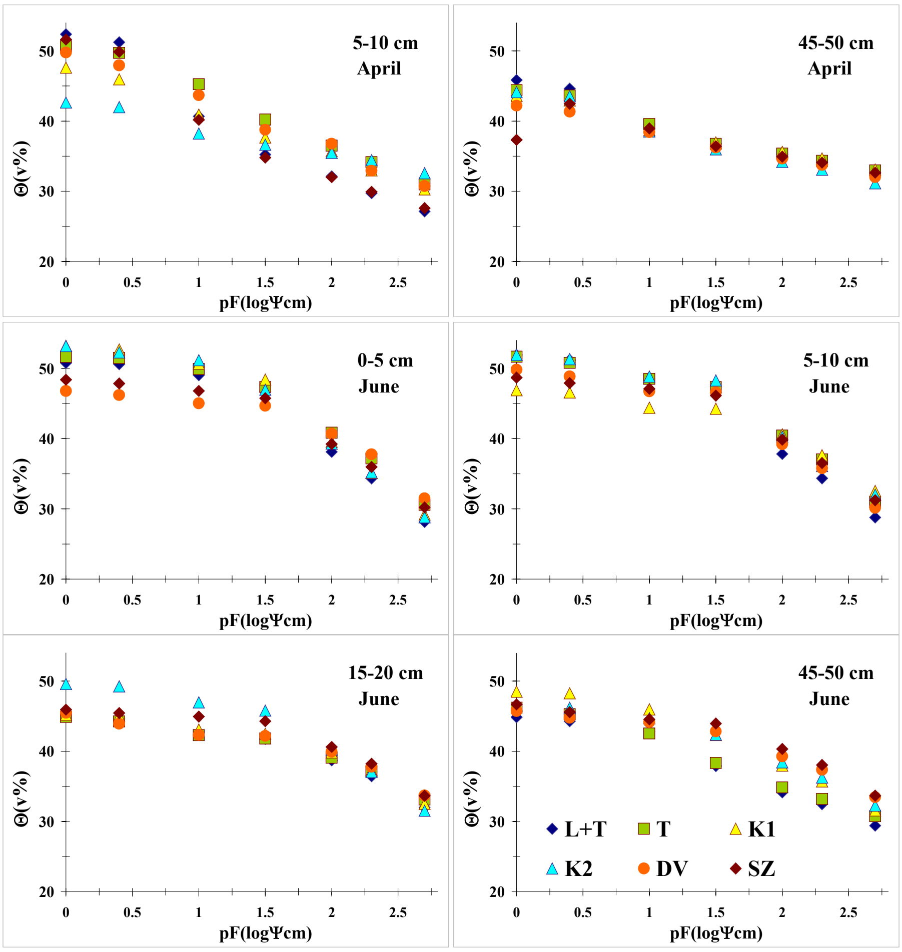

Figure 3. Water retention (pF) curves of soil under various treatments (Hatvan Józsefmajor, 2003). Selected dates (April, June) and depths. Explanation of figures see in the text

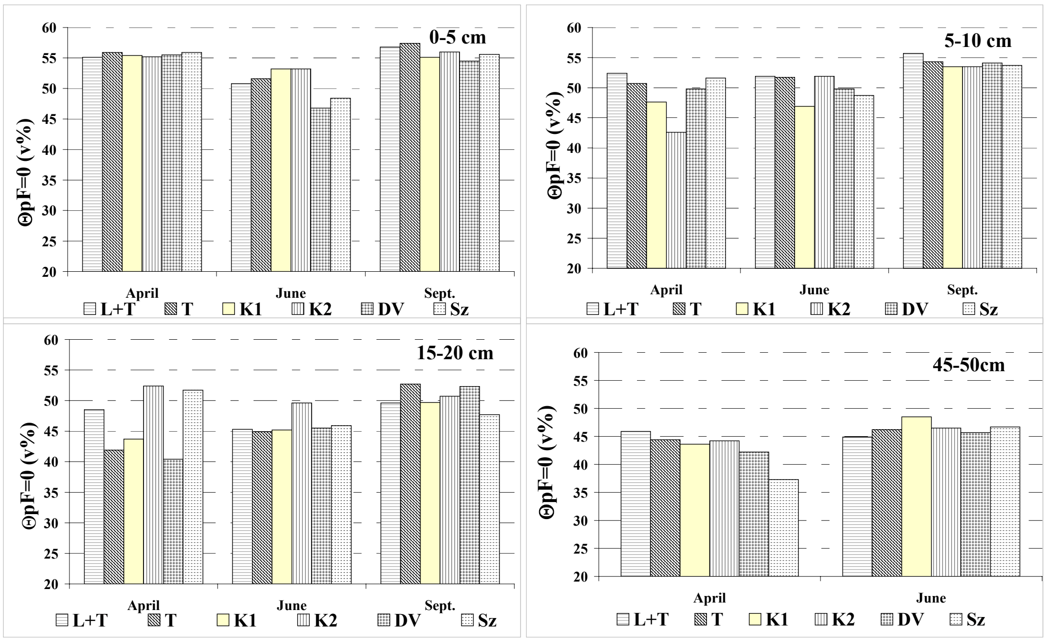

Figure 4. Moisture content in saturated soil under various treatments. (Hatvan Józsefmajor, 2003). Explanation of treatments: see in the text.

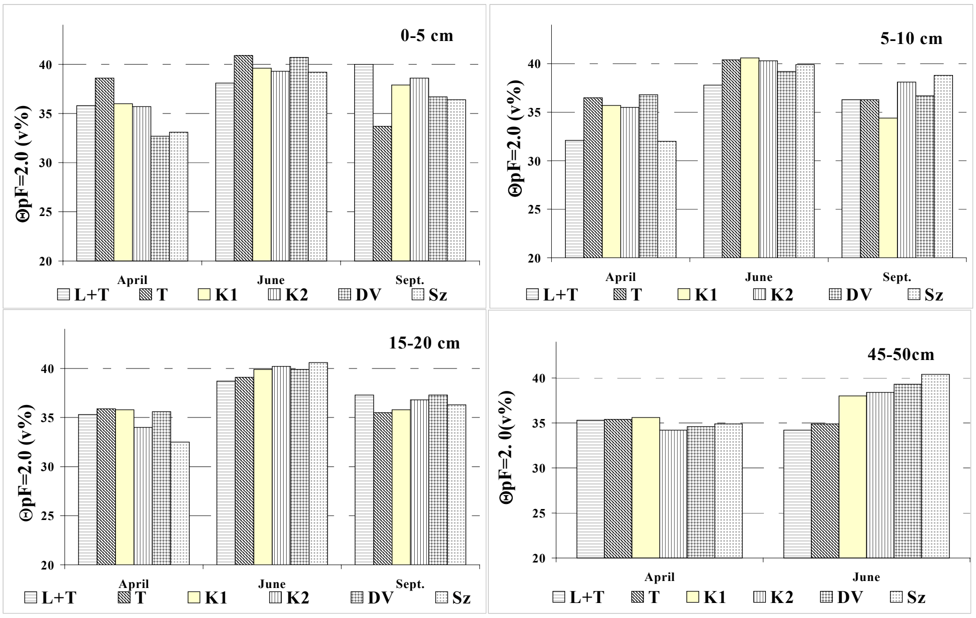

Figure 5. Field capacity of soil under various treatments. (Hatvan Józsefmajor, 2003) Explanation of treatments: see in the text.

Field capacity (in our case pF 2) expresses the quantity of water that can be retained within the soil profile against gravity. It depends both on texture (particle size distribution, clay and organic matter content, clay minerals) and structure (aggregate state and stability, rate of of compactness, swelling–shrinkage characteristics).

Figure 4 shows a similar consolidation tendency in the April–June period as in the case of bulk density. However, it was favourable for water retention (Fig. 5), especially in the near-surface layers. The treatment effect was quite randomic and did not give opportunity for drawing convincing conclusions.

The robust database of **soil moisture** measurements was condensed into Figure 6, showing the spatial and temporal distribution pattern in soils under various treatments. From these measurements the potential (pF 2.0– pF 4.2) and the actual **available moisture content** (AMC) was calculated in is shown in Figure 7. In case of the potential AMC the treatment effect was limited to the 0–20 cm layer, in the 40–45 cm layer it was non-significant. Among the treatments L+T and Sz were lower than T, K1, K2 and DV, almost equally. The actual (measured AMC results indicate an interesting (but not surprising) phenomena. In April the soil's potential water storage capacity was almost empty, especially in the 0–5 cm layer. The whole soil profile was dried out, especially the surface horizon irrespecitve of the treatments. From April till June the soils became filled up step by step, and the normal summer drought changed this situation only to a certain (quite limited) extent. The AMC in the 15–20 cm, and – especially – in the 40–45 cm layer increased. In the 40–45 cm layer it almost reached the „potential". However, in the surface layers (0–5, 5–10 cm) still a high amount of „free" soil pories remain „empty", due to the dry summer in 2003. It was rather surprising that no significant differences were observed among the various treatments. Neither the favourable mulch + undisturbance + direct drilling effect, nor the deep tillage and ploughing were convincingly proven by our results.

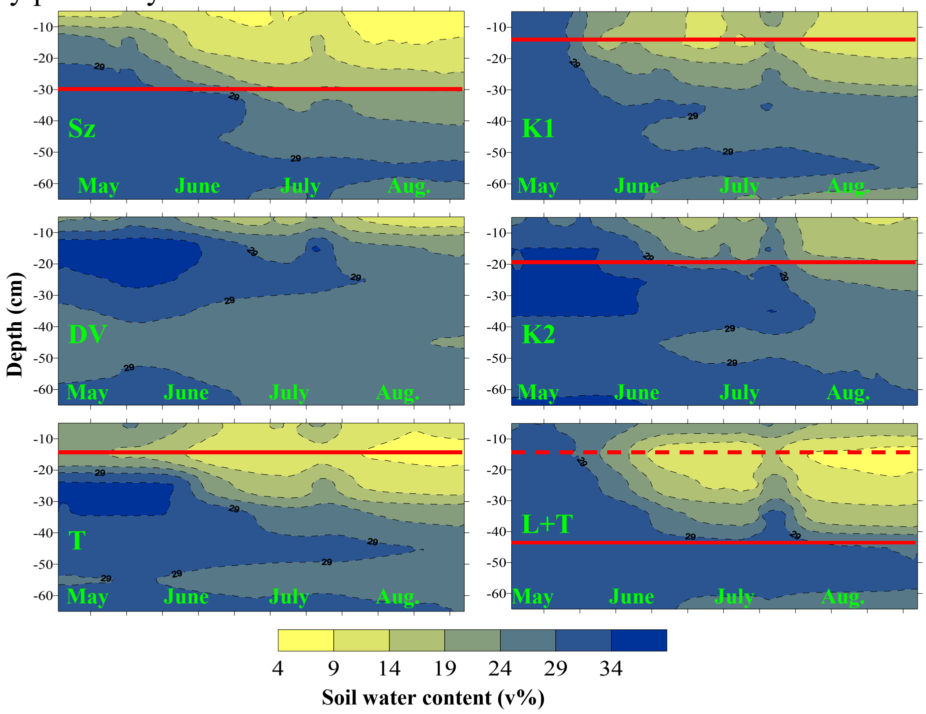

Figure 6. Spatial and temporal changes in soil moisture content in different treatments (Hatvan Józsefmajor, 2003). Explanation of treatments see in the text.

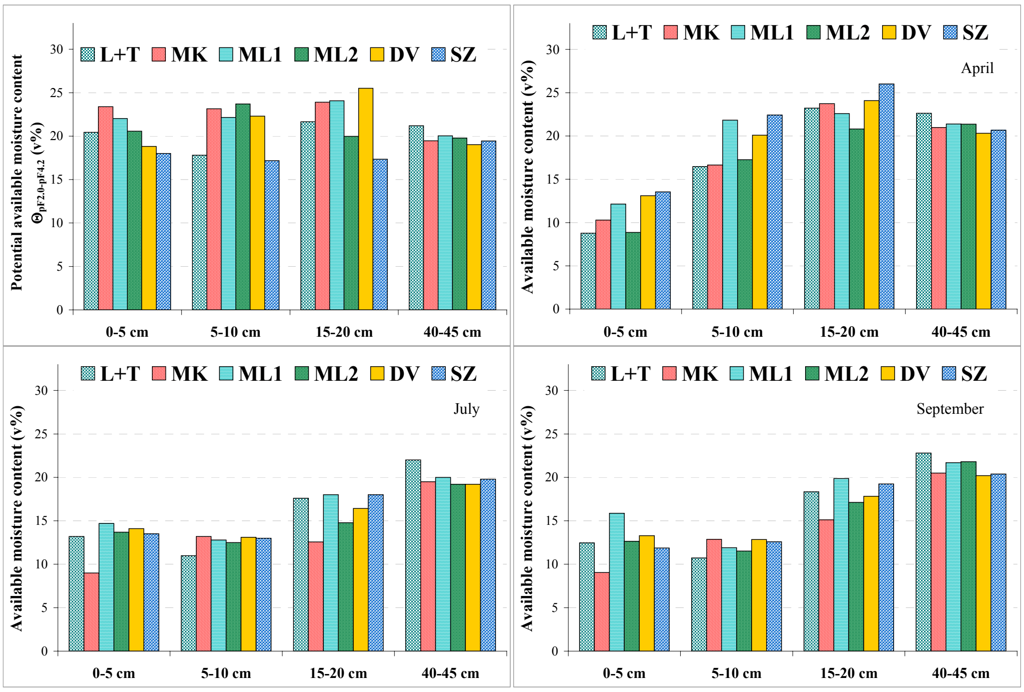

Figure 7. Potential (upper left) and actual available moisture content in the different layers of soils under various treatments, (Hatvan Józsefmajor, 2003). Explanation of treatments see in the text.

Conclusion

Under such ecological conditions as in Hungary (generally favourable for rainfed biomass production, but often extreme and sensitively reacting to environmental and human-induced stresses) it is rather hazardous to adapt technologies developed under various natural and socio-economic conditions. Another danger is uniformization, „over-standardization", because the future is for **site-specific precision agricultural development**.

Acknowledgement

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References

Birkás, M., Gyuricza, Cs., 2004a. [Tillage–Climate change–Technology] (In Hungarian) Szent István Egyetem, MKK Földművelési Tanszék, Gödöllő. 177 p.

Birkás, M., Gyuricza, Cs., 2004b. [Land use and climate change] (In Hungarian). In: [Tillage–Climate change–Technology] (In Hungarian) Szent István Egyetem, MKK Földművelési Tanszék, Gödöllő. 10–45.

Birkás, M., Gyuricza, Cs., 2004c. [Interrelations between elements of the agro-ecosystem in a soil tillage trial] (In Hungarian) In: „AGRO-21 Füzetek. No. 37. 97–110.

Csete, L., Várallyay, Gy. (Eds.), 2004. [Agroecology (Environmental interactions of agro-ecosystems and possibilities of their control)] (In Hungarian). „AGRO-21 Füzetek. No. 37. 217 pp.

Farkas, Cs., 2004a. [The impact of soil tillage and soil conditions on soil moisture regime] (In Hungarian). In: Szent István Egyetem, MKK Földművelési Tanszék, Gödöllő. 81–81.

Farkas, Cs., Gyuricza, Cs., 2004. Estimation of the soil water retention curves for intensively tilled agricultural soils. In: Proc. III. Alsp-Adria Scientific Workshop (2004 March 1–6, Dubrovnik). Hungarian Academy of Sciences, Budapest. 44–48.

Farkas, Cs., Tóth, E., Várallyay, Gy., 2004. [Physical properties of soil under different tillage systems] (In Hungarian) In: „AGRO-21 Füzetek. No. 37. 111–122.

Farkas, Cs., Várallyay, Gy., Tóth, E., 2004. The effect of some conventional and soil conserving tillage systems on soil hydraulic properties and soil water regime of a loamy Mollisol. In: Proc. 4th International Congress of the European Society for Soil conservation on Soil conservation in Changing Europe, 2004 May 25–28, Budapest). 329–333.

Láng, I., Csete, L. & Harnos, Zs., 1983. [Agro-ecological potential of Hungarian agriculture] (In Hungarian) Mezőgazdasági Kiadó. Budapest.

Soane, B. D., Ouwerkerk, C. van, 1994. Soil compaction problems in world agriculture. In: Soil compaction in crop production. Elsevier Sci. 1–21.

Szabolcs, I. & Várallyay, Gy., 1978. [Limiting factors of soil fertility in Hungary] (In Hungarian) Agrokémia és Talajtan. 27. 181–202.

Várallyay, Gy., 1985. [Main types of water regimes and substance regimes in Hungarian soils] (In Hungarian) Agrokémia és Talajtan. 34. 267–298.

Várallyay, Gy., 1988. [Soil, as a factor of drought-sensitivity of biomass production] (In Hungarian) Vízügyi Közlemények. LXXX. (3) 46–68.

Várallyay, Gy., 1989. Soil degradation processes and their control in Hungary. Land Degradation and Rehabilitation. 1. 171–188.

Várallyay, Gy., 2000. Risk assessment and prevention of soil degradation processes in Hungary. In: Foresight and Precaution. (Eds.: Cottam, Harvey, Pape & Tait). 563–567. Balkema. Rotterdam.

Várallyay, Gy., 2004a. [Soil as a fundamental medium of agro-ecosystems](In Hungarian) In: „AGRO-21 Füzetek. No. 37. 33–49.

Várallyay, Gy., 2004b. [Agro-ecology and water management](In Hungarian) In: „AGRO-21 Füzetek. No. 37. 33–49.

Várallyay, Gy., 2005. [Water storage of Hungarian soils] (In Hungarian). Agrokémia és Talajtan. 54. (In press).

Várallyay, Gy., Szűcs, L., Murányi, A., Rajkai, K. & Zilahy, P. 1979. [Soil factors determining the agro-ecological potential of Hungary and their 1:100 000 scale map. I.] (In Hungarian) Agrokémia és Talajtan. 28. 363–384.

Várallyay, Gy., Szűcs, L., Murányi, A., Rajkai, K. & Zilahy, P. 1980a. [Soil factors determining the agro-ecological potential of Hungary and their 1:100 000 scale map. II.] (In Hungarian) Agrokémia és Talajtan. 29. 35–76.

Várallyay, Gy., Szűcs, L., Rajkai, K., Zilahy, P. & Murányi, A., 1980b. Hydrophysical properties of Hungarian soils and the map of their categories in the scale of 1:100 000] (In Hungarian) Agrokémia és Talajtan. 29. 77–112.

CONTENTS OF MOBILE NICKLE IN SERPENTINITE RANKERS OF SERBIA

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Abstract

The paper presents the results of study of the content of mobile Ni in serpentinite rankers of Serbia. Samples were taken from seven wider locations (Zlatibor, Kopaonik, Miroč, Maljen, Bukovi, Suvobor and Bubanj Potok) in the altitude zone between 100 and 1700 m of altitude. Extraction of mobile Ni was conducted with 1.0 N HCl, and values were determined with the method of atomic adsorption spectrophotometry.
The results of analysis show that around 70% of tested samples contains 200 - 600 mg/kg of mobile Ni which is far above the allowed quantities.
Therefore, the serpentinite rankers of Serbia contain phytotoxic concentrations of mobile Ni which is one of the main reasons of poor growth of plants on these rankers.

Key words: Mobile Ni, serpentinite rankers, Serbia

Introduction

Serpentinites represents one of the most widely distributed groups of "sillicate" rocks of hilly - mountainous areas of Serbia which occupy around 280.000 ha. Of all supstrates, ultrabasic magmatic rocks and serpentinites based thereon are the richest in nickle, in which its average content is 2000 mg/kg, while the soils on these supstrates are even richer in Ni and contain sometimes even up to 5000 mg/kg, which means that it represents a macro and not microelement therein.
Soils on peridotites and serpentinites in the conditions of poor drainage are very rich in Ni and exceptionally they may contain even 0.8% of the total quantity, and up to 0.1%, i.e. 1000 mg/kg of easily mobile Ni (Scheffer et al. 1966). In such cases, the toxic influence of this element on the plants whose habitats are the soils based on peridotites and serpentinites may be expressed fully.

There are no proofs of the unreplacable role of Ni in plant metabolism. However, favourable effect of small quantities of this element on their growth has been established, which allows for the assumption that Ni may perform a certain function in plants (Kabata – Pendias, 1989).
Increased quantities of Ni in soils have toxic effect on plants. The most
obvious sympm of phytotoxic effect of Ni is chlorosis, which is possibly induced by the deficit in Fe. In case of Ni excess, sorption of nutritious substances decreases suddenly, metabolism is disturbed and growth of plants decelerated.
Toxic effect of Ni in natural conditions in the plants in the areas of serpentine and other soils rich in nickle is typical. Oats is the agricultural plant most sensitive to Ni excess (Kabata – Pendias et al.1989). These authors state that some plant species are typical for their high

tolerance to the effect of Ni and ability to collect it in their organs in large quantities (even 5.000 - 6.000 mg/kg in leaves and trees). Usually these are the types of plants (mostly from the family Boraginaceae, Cuciferae, Myrtaceae, Leguminodae and Caryophyllaceae) which are also Co concentrates.
Our studies were conducted on serpentinite rankers with Ah - C profile, in the altitude zone between 100 and 1700 m of altitude of the Republic of Serbia. These soils were described by the famous Czechoslovakian pedologists Novak and Pelišek (1938) in Moravska as a special type of redzin, entitled "magnesial redzins" which fall under the group of humus - sillicate soils (rankers) according to modern ideas.
The purpose of this study is to review the results of content of mobile Ni in serpententinite rankers of Serbia as one of the factors of decreased productive ability of these soils and phytotoxic quality of Ni therein.

Methods

These studies included seven wider locations (Zlatibor, Kopaonik, Miroč, Maljen, Bukovi, Suvobor and Bubanj Potok) in the altitude zone between 100 and 1700 m of altitude where 25 profiles were opened and 46 samples of soil taken for analysis.
The extraction was conducted in 1.0 N HCl, and the content values of mobile Ni were determined with the method of atomic - adsorption spectrophotometry.

Results and discussion

The tested soils of ranker type belong to the class of shallow and extremelly shallow soils, and according to their mechanical content to poorly skeletoid clay and with crumb-like granular structure.
Humus conetent in them is 10-20%, active acidity varies from pH 5.03-6.78 depending on the development phase and soil depth.
The proportion of the content of adsorbed cations is highly unfavourable. This is especially prominent in the proportion Ca/Mg which is less then one (Djordjević, 1997).
The results of study of the content of mobile Ni have been presented in table 1. The obtained values point to the increased content of mobile nickle in all tested samples of soil in all locations.

Tab.1 Content of easily accessible Ni in serpentinite rankers of Serbia

Locations	Altitude	No.prof.	Depth cm	Ni in 1.0n HCl mg/kg
Zlatibor	1029 m	4	0-20	309
		5	0-15	292
		9	0-15	391
			15-30	417
		10	0-15	500
			15-30	507
		17	0-15	321
			15-30	345
Kopaonik	1700 m	2	0-10	276
		3	0-5	215
		4	0-15	327
			0-15	226
			15-30	252
		5	0-15	592
Miro~	450 m	2	0-15	405
		3	0-12	349
		4	0-15	344
			15-30	407
Maljen	960 m	1	0-8	123
			10-25	86
		3	0-15	737
		4	0-15	577
		5	0-17	455
		6	0-10	786
		7	0-10	773
			10-20	920
Bubanj Potok	132 m	1	0-15	446
		3	0-20	482
		7	0-20	133
			20-40	117
			40-60	128
Bukovi	700 m	1	0-15	534
		2	0-15	379
			15-25	408
		3	0-15	623
			15-30	630
		5	0-17	415
			17-30	577
			30-45	477
Suvobor	650 m	1	0-10	408
			10-25	372
		2	0-20	441
		3	0-10	358
		4	0-20	149

The locations from which soil samples were taken are situated on different altitudes and expositions which points to the fact that serpentinite rankers are formed in different macroclimatic conditions, i.e. in different climatic zones. The only thing they have in common is geological supstrate naturally rich in Ni.
This is the main reason of the increased content of mobile Ni in the studied soils which was shown by the results of our study. In these tested samples the content of mobile Ni is increased above the allowed limit.
According to the average values of content of easily accessible Ni by locations, the lowest content (261 mg/kg) was determined in the serpentinite ranker in the area of Bubanj Potok, which the highest content (557 mg/kg) of easily mobile Ni was established in the ranker from the area of Maljen.

Conclusion

Study results on the content of mobile Ni point to the fact that serpentinite rankers of Serbia have naturally increased content of Ni, which significantly decreases their productive ability. These are typical lythogenous soils with pronounced influence of geological supstrate on the content of Ni, but also on other chemical characteristics of soil.

References

Kabata – Pendias, K., Pendias, H.(1989): Микроелементи в почвах и растенијах. Москва

Novak,V.A.,Pelišek,J.(1938): Studie o horecnatych rendzinach na serpentinech. Sbornik CAZ, Rocnik XIII, [e{it 4. Praha

Djordjević, A. (1997): Osobine ranker zemlji{ta serpentinitskih masiva Srbije s posebnim obzirom na uzroke njihove niske produktivne sposobnosti. Doktorska disertacija. Poljoprivredni fakultet, Beograd

SOIL TILLAGE AND GREENHOUSE EFFECT

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1.Introduction

The so called conventional tillage is a significant indicator of climatic changes. The regular turning of the soil with a plough largely increases the carbon dioxide emission of arable lands (*Reicosky* 1998). Soil cultivation increasing looseness, air supply changes, fast gas exchange is initiated. The growing oxygen content of the soil induces intense microbial activity; the carbon dioxide produced during the organic material degradation is released to the atmosphere. A number of research results prove that the intensive land use plays a role in the increasing atmospheric carbon dioxide, which especially became obvious during the last decades (*Lal et al.,* 1998; *Drees et al.,* 2001).
The intensive soil cultivation reduces the carbon reserve by 30-50%, which is mainly related to breaking the ground. Therefore the carbon dioxide, released due to the increased mineralization of the organic matter easily enters the atmosphere (*Cole,* 1996). On the contrary, by applying conservation technologies (tillage without turning, no-tillage, etc.) the humus content of the soil might increase by 1 ton per hectare annually. According to some calculations in the United States due to the advanced application of the conservation technologies in the last years the emitted amount of carbon dioxide reduced at a measurable level (*Pautian et al.,* 1998). If 100% of the arable land in Europe was cultivated with conservation technologies, that would reduce all emissions from the agriculture. This means 4,0% of all carbon dioxide produced in Europe, and in global level 0,8% of the annual emission.
In this study the results of carbon dioxide emission studies of two long term soil cultivation field experiments are explained in relation to other soil parameters (soil temperature, moisture content, penetration resistance).

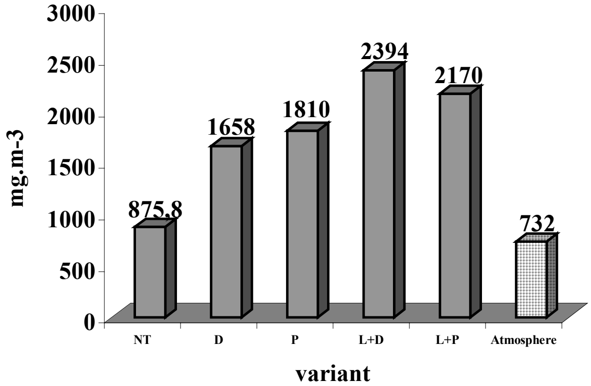
2. Material and methods

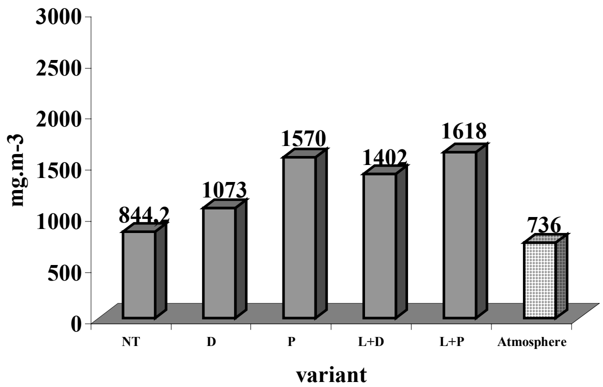
The studies related to soil cultivation and carbon dioxide emission were started in 2000 in long term soil cultivation field experiments. The locations of the studies were of Chromic Luvisol in Gödöllő, and Calcic Chernozem close to Hatvan (Józsefmajor). There were 5 types of cultivation operations used in the experiment at Gödöllő (no-tillage, disking 16-20 cm, ploughing 22-25 cm, loosening 35-40 cm and disking, loosening 35-40 cm and ploughing). The experiment in Józsefmajor was set up in 2001. Six cultivation operations were applied, namely: no-tillage, shallow loosening with cultivator (12-16 and 16-20 cm), with disk (16-20), ploughing (26-30 cm) and loosening (40-45 cm).
Carbon dioxide emission in 2000 was measured with INNOVA 1312 Photoacustic Multi-gas Monitor instrument on site. For the measurement we covered the soil surface with a cone, and determined CO_2 emission continuously, every 10 minutes. The data was registered by the instrument in the computer, allowing the later processing of the data. At the same time soil samples were taken from every soil cultivation operation to specify humus content. For the examinations in 2003 we used TESTO manual instrument. The method of the measurement

was identical with the ones in year 2000, however, this instrument cannot store data, and they had to be taken down continuously.

3. Results and discussion

Agricultural activity accounts for 5% of the worldwide total carbon dioxide emission (*Cole,* 1996). According to the *Kyoto Protocol* (1997) the increasing atmospheric carbon dioxide content may be one of the reasons for global climate changes. The carbon dioxide emission values measured in the Gödöllő soil cultivation experiment are shown in Figure 1. Measurements took place ten days after the basic cultivations. In every case we also determined the atmospheric carbon dioxide content as well, which provides appropriate correlation ground for evaluating the soil emission.





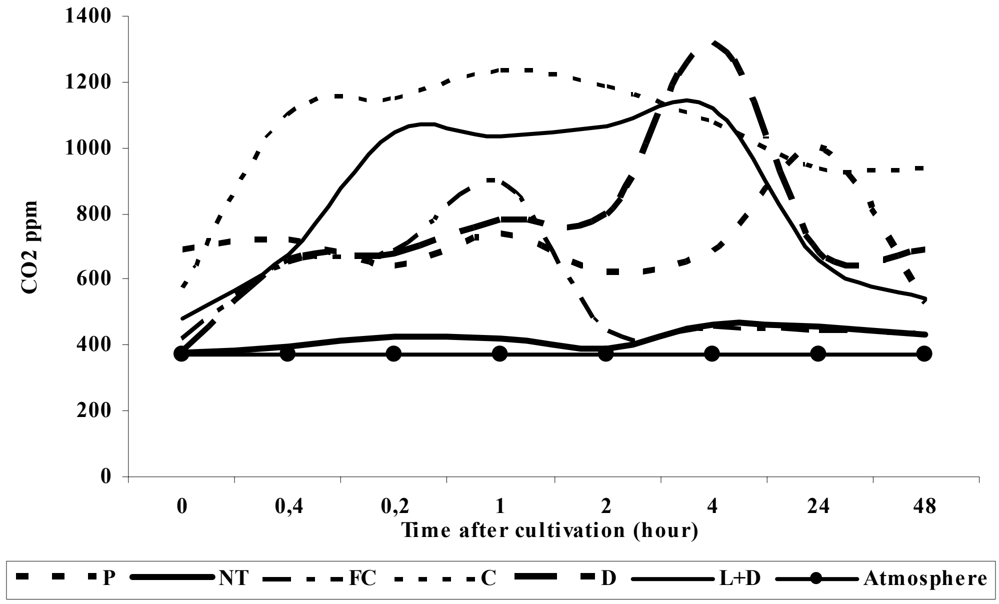
Abbreviations: NT=No-tillage; D=Disking (16-20 cm); P=Ploughing (22-25 cm); L+D=Loosening (35-40 cm) +Disking (16-20 cm); L+P=Loosening (35-40 cm) +Ploughing (22-25 cm)

Figure 1. Relationship between the soil cultivation and the CO_2-flux (Gödöllő, 2000)

Comparing the mean values specified from the first series of measuring we can state that no-tillage system exceeded the atmospheric carbon dioxide content only by 108 mg·m^{-3}, while in case of ploughing and ploughing combined with loosening this difference was 834 mg·m^{-3} and 892 mg·m^{-3} respectively. In case of no-tillage soil condition was not interrupted at all, providing conditions for increased microbiological activity. Disking moves 16-20 cm layer of the soil, increases air admission, provides favourable space for microbes, shown by the emitted amount of carbon dioxide.

The next part of the figure shows the averages of the values measured one hour later. In comparison to the data of the previous series of measuring there is hardly any difference in case of no-tillage, while on the cultivated parcels significantly higher carbon dioxide emissions were observed. The change was especially obvious in case of the cultivation combined with loosening, where the carbon dioxide emission was higher with 992 mg·m^{-3}. Since the sampling was taken in a closed space and the carbon dioxide produced for an hour was accumulated, we can gather what intensities of emissions might occur in case of the individual cultivations.

In the experiment at Hatvan (Józsefmajor), in 2003 after the winter wheat all operations received shallow stubble ploughing (except no-tillage). The basic operations were carried out afterwards, at the end of August. Figure 2 shows the carbon dioxide emission measured in the operations within 48 hours of cultivation.



Abbreviations: P=Ploughing (26-30 cm), NT=No-tillage, FC=French cultivator (12-16 cm), C=Cultivator (16-20 cm), D=Disking (16-20 cm), L+D=Loosening (40-45 cm) +Disking (16-20 cm),

Figure 2. CO_2 emission at different soil tillage practices (Gödöllő, 22 August 2003)

The highest average emission was measured in the operation cultivated with shallow cultivator; 30 minutes after the cultivation the CO_2 emitted to the atmosphere was 1148 ppm. Remarkable reduction took place only after 24 hours. *Szabó* (1992) and *Birkás* (2002) emphasise the structure protecting characteristics of tillage with a cultivator. According to our statements the aeration, the aerob microbial activity and the organic matter reduction increase only a little, the degradation of the humus material holding and cementing the soil crumbles together does not happen. One reason for the opposite results obtained during the examinations is loosening the top soil layer and the lack of treatment immediately after the cultivation. Significant emission was measured in case of cultivation with disk, too.

4. Conclusions

The so called conventional tillage is one of the main reasons for climate changes. The regular turning of the soil with a plough largely increases the carbon dioxide emission of the arable lands. Upon the impact of soil cultivation the soil is looser, the air supply changes, and quick gas exchange is initiated. The increased oxygen level of the soil induces intense microbial activity. The carbon dioxide, formed during the organic matter degradation is released to the atmosphere, which might be one of the reasons for global climate change.
The studies related to soil cultivation and carbon dioxide emission were started in 2000 in long term soil cultivation field experiments. The locations of the studies were of Chromic Luvisol in Gödöllő, and Calcic Chernozem close to Hatvan (Józsefmajor).
A direct relation may be observed between the soil cultivation intensity and the carbon dioxide emission: the higher the air phase ratio is within the pore space and the deeper the soil is loosened, the more intense the microbiological activity is, expressed in the increased carbon dioxide emission. During the examinations in 2000 the highest carbon dioxide emission was experienced after the cultivation with ploughing, while in 2003, due to closing the surface, a smaller value was measured. From the soil use methods the carbon dioxide emission of no-tillage hardly increases the level measured in the atmosphere, therefore it is the most favourable method from the aspect of greenhouse effect. In year 2003 the highest average emission was measured in the operation cultivated with shallow cultivator; 30 minutes after the cultivation the CO_2 emitted to the atmosphere 1148 ppm. Significant emission was measured in case of cultivation with disk, too.

References

Birkás M. (2002): Környezetkímélő és energiatakarékos talajművelés. Akaprint Press, Budapest.

Cole C. V. (1996): Intergovernmental Panel an Climate Change. 1995. Agricultural options for mitigation of greenhouse gas emissions IPCC Working Group 11, Chapter 23, Washington, D.C.

Drees, R.L., Wilding, L.P., Nordt, L.C., (2001): Reconstruction of soil inorganic and organic carbon sequestration across broad geoclimatic regions. Soil carbon sequestration and the greenhouse effect. SSSA Spec. Publ. No. 57., 155-171.

Lal, R., Kimble, J.M., Follett, R.F., Cole, C.V., (1998): The potential of U.S. cropland sequester carbon and mitigate the greenhouse effect. Sleeping Bear Press, 128.

Pautian, K., Cole C.V., Sauerbeck, D., Sampson, N. (1998): CO_2 mitigation by agriculture: An owerwiew, Climatic Change 40 (1):135-162.

Reicosky, D.C., (1995): Impact of tillage on soil as a carbon sink. In: Farming for a better environment. A White Paper, Soil, Water Conservation Soc., Ankeny, Iowa, 67.

Szabó I. M., (1992): A mikroorganizmusok aktivitásának szabályozása. A talajművelési eljárások, trágyázási és növénytermesztési rendszerek célszerű kombinációjával. In: Szabó I. M. Az általános talajtan biológiai alapjai. Mezőgazdasági Kiadó, Budapest, 325-335.

ECONOMIC AND ECOLOGICAL UTILIZATION OF PELLETS ON THE BASIS OF FLUID ASHES AND FLY ASHES FOR AGRICULTURE AND LANDSCAPING

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Abstract

Within the framework of the presented international research project Eureka, the potential use of large-volume wastes (generated by the power and metallurgic industries) not only in the building industry but also in landscaping is being studied in cooperation with foreign partners (Serbia, Turkey). The aim of the study conducted in the Czech Republic is to verify real possibilities of using free CaO, contained in ashes and fly ashes from fluid coal combustion in power plants or heating power plants, predominantly for modification of soil reaction. All test products (ashes and fly ashes produced by fluid coal combustion as well as pellets and granulates made from these fly ashes) were subjected to chemical analyses and ecological tests. The effect of pellets and granulates made from ashes and fly ashes on the soil environment was examined. In this context the studies concentrated on the growth and development of test crops, crop yields per unit area, health condition of the plant material produced, and the biological activity of soil.

Keywords: ashes and fly ashes, granules and pellets, soil pH, crop yields, biological activity of soil

Introduction

Within the framework of the international research project Eureka E!2936 the possibilities of using large-volume wastes from the power and the metallurgic industry not only in the building industry but also, for example, in landscaping were explored in co-operation with foreign partners (Serbia,Turkey).

In the course of the project research teams gathered information about the use of fly ashes in agriculture, forestry and about their potential use in the restoration of landscape damaged by anthropogenic activity. It was found that some components of the by-products from fluid coal combustion showed properties, which might open up possibilities of their commercial utilization in agriculture and forestry. When utilizing any product from coal combustion it is necessary to take into account potential impacts of long-term leaching in spite of relative chemical stability and "non-toxicity". One part of the interdisciplinary project carried out in the Czech Republic was to verify real possibilities of utilization of free CaO, contained in ashes and fly ashes from fluid coal combustion in power plants or heating power plants, as a product for modification of soil reaction.

According to a great number of authors the products from fluid coal combustion can have a positive effect predominantly on soil pH. Even the earlier studies made at Institute in Troubsko and in the Chemical Department in Brno emphasised that the decision about the application of particular fly ashes to the soil or other media should always respect the contents of heavy metals, free CaO content and acidity. With respect to a great variety of fly ashes, there is no single recipe for their utilization.

As many authors pointed out, products from fluid coal combustion may have a positive effect on soil pH, being a source of essential nutrients important for plant production and quality.

Now, it is important to mention some published findings:

Nechvatal, Michaud (1991) studied the effect of bottom ash on plants by comparing plant uptake of nutrients and heavy metals, plant growth and yields on soils treated with bottom ash. The research results indicated that the addition of ashes to heavy clay soils may complement the application of commercial fertilizers, replace lime in modifying soil acidity, increase the rate of water infiltration and increase crop yields. The effect of fly ashes on growth and yields of wheat was studied by Tripathy and Sahu (1997) who concluded that the soil mixed with fly ashes has a comparable effect on growth and yield as the soil mixed with compost and additional NPK. Ritchey (1997) found that fly ashes may be used in agriculture as a substitute for liming to increase soil pH of the subsoil. Sale, Chanasyk and Naeth (1997) investigated the effect of fly ashes incorporated into the soil on some physical properties of soil. They found that with the increasing amount of fly ashes soil bulk density increased and the proportion of structural elements smaller than 0.5 mm rose. Fly ashes were also applied to soil to discover changes in the physical and chemical properties of soil (Kuchanwar, Matte and Kene, 1997). Adding fly ashes caused largely a decrease in maximum water capacity and an increase in availability of N, P, K and exchangeable Ca and Mg and some trace elements. It also improved soil properties. Plant growth and nutrition as affected by incorporating fly ashes into different depths of soil were also studied by Bi, Y.L. *et al*. (2003). Pathan, S.M. (2003) examined changes in soil properties after adding fly ashes into sandy soils under grasslands.

The use of fly ashes from fluid coal combustion in agriculture, forestry and horticulture was the object of studies carried out by Hrubý and Brandštetr (1998). They pointed to the fact that the decision about the application of particular fly ashes to the soil or some other medium should necessarily be based on the knowledge of the content of heavy metals and acidity. They emphasized that with respect to a great variety of fly ashes it is impossible to follow a single recipe for their use. They also assessed pH changes in earth mixtures with the increased proportion of fly ashes from fluid coal combustion in the mixture.

Materials and methods

Products from fluid coal combustion can be divided into two basic types:

- Bottom ash – it has such granularity that it need not be modified for agricultural purposes. Before tests only ash quartation and homogenisation were made.
- Filter ash – it is very fine and, therefore, it is necessary to find the best method of compacting, as it is desirable to minimise dust formation during its application in agriculture.

The compacting method should be very simple from the aspect of fertiliser production (machinery) and successive procedures (drying, deposition, minimum of transport and transfer operations). With respect to these parameters three techniques of ash compacting with water were chosen:

A. Granulate production in a pelleting mill to make pellets of the size of 0-8 mm. This technique of pellet production seems unsuitable. Production is time-consuming in relation to the amount of the fly ashes processed, i. e. the number of pellets produced.

B. Granulate production on the pellet press (rolls) appears to be the best method with respect to the requirements for commercial fertilisers.

C. Using presses of higher dimensions and crushing the material into pellets of requested fineness appears to be unsuitable. It is necessary to ensure complete drying of the material to prevent sticking of the partially dried material to the crushing jaws and overloading the crushing machines. Complete drying of the material is time-consuming and costly.

At present other methods of pellet production using other binding agents are being tested.

Before starting the study a number of samples of ashes and fly ashes from fluid coal combustion were tested. Initial tests were complemented with ecological tests, which are prerequisites for hygienic safety of the product.
The tests included:
- basic initial physical analyses (sieve analysis, litre weight),
- chemical analyses,
- determination of eco-toxicity,
- analyses of heavy metal contents,
- determination of weight activity of radionuclides

and other major indices characterizing individual ashes and fly ashes from fluid coal combustion.
Similarly, all tested products – pellets and granulates – from ashes and fly ashes from fluid coal combustion were subjected to chemical analyses and tests of ecological suitability performed by Research Institute of Building Materials Brno.

In Institute in Troubsko further studies of the effect of pellets and granulates produced from ashes and fly ashes from fluid coal combustion and applied to the soil with different contents of free CaO were carried out:
- pot trials (predominantly on soils with reduced pH).
- small-plot trials (space enclosed) .

In small-plot trials the rates of tested materials applied to individual plots were determined on the basis of CaO content in the product. For each type of granulate there were three basic treatments. Within the treatments total rates and half rates determined on the basis of soil pH were applied and compared with the control (no application of ashes, fly ashes, pellets and granulates).

Determination of the maintenance rate of liming (Richter *et al*. 1993) for loamy soil and detected pH/KCl – 7.1 was calculated as 350 $kg.ha^{-1}.year^{-1}$ CaO i. e. 0.035 $kg.m^{-2}.year^{-1}$.

The below stated fly ash rates for experimental treatments were determined on the basis of the calculated maintenance rate of liming and the content of Ca in fly ashes:

- <u>A small-plot trial - Hodonín:</u>
Filter ash – 0.64 $kg.m^{-2}$ (reduced rate of 0.32 $kg.m^{-2}$), pellets
Bottom ash – 0.57 $kg.m^{-2}$ (reduced rate of 0.29 $kg.m^{-2}$), untreated fly ashes
In November 2003 the experimental material was applied to the experimental plots (4.2 m^{-2}) and then incorporated into the soil.

- <u>A small-plot trial - Třinec:</u>

Filter ash – 1.26 kg.m^{-2} (reduced rate of 0.63 kg.m^{-2}), pellets and granules
Bottom ash – 5.20 kg.m^{-2} (reduced rate of 2.60 kg.m^{-2}), untreated fly ashes
In spring of the year 2004 the material was applied to the experimental plots (4.2 m^{-2}) and subsequently incorporated into the soil.

The evaluation itself was made at pre-determined time intervals:

- soil pH at 2-month intervals, active (pH/H_2O) and exchangeable soil reaction (pH/KCl) is being studied continuously
- tests of ecological suitability were made at 6-month intervals, analysing soil and plant samples

In the year 2004 the following crops were tested in small-plot trials: spring barley (*Hordeum vulgare L.*), safflower (*Carthamus tinctorius L.*), mallow (*Malva verticillata L.*), and white mustard (*Sinapsis alba L.*).

The evaluation was carried out of

- growth and development of test plants,
- crop yield per unit area,
- health condition of the plant material produced,
- biological activity of soil (actinomycetes, micromycetes in relation to soil pH changes).

Tests of actinomycetes were performed using starch agar and the amount of micromycetes by Jensen agar. Measurements were made using the laboratory technique AOPK ČR part D, no.6, and the results were calculated in relation to the detected dry matter percent.
The analyses of the biological activity of soil were conducted by the Nature and Landscape Conservation Agency of the Czech Republic (Agentura ochrany přírody a krajiny ČR) an accredited laboratory ČIA no.1133.

Results and discussion

a) Evaluation of the pattern of soil pH changes

In the year 2003 small plot trials were established on a site at Troubsko, in which ashes supplied from the power plants at Hodonín and Třinec were applied at full and reduced rates.

<u>Basic soil characteristics of the small-plot trial:</u>

depth:	pH/KCl	P (mg/kg)	K (mg/kg)	Mg (mg/kg)	Nc (%)	Cox (%)
0.00 – 0.15 m:	7.1	87.5	180.1	251.0	1.75	1.74
0.15 – 0.30 m:	7.1	63.5	142.5	241.5	1.48	1.48

In these trials active (actual) and exchangeable soil reactions were studied. Active reaction represents the instantaneous status of free hydrogen ions in the soil solution, non-bound by the sorption complex and is measured in water extract. The exchangeable reaction is caused by adsorbed hydrogen and aluminium ions, which come into the solution, replacing basic cations of neutral salts in the solution. It is measured in soil extract by KCl or $CaCl_2$ solution.
Chemical analyses of soil samples taken from individual treatments showed that before the application of test materials exchangeable pH reached the values of 7.0-7.1 and after the application there was a gradual increase in the values of 0.1 to 0.3. As for active pH the

values were 7.2 -7.4 before the application of test materials. After the application soil pH increased by 0.5 – 0.7

This conclusion was also published by Hrubý, Dovrtěl (1996) and Hrubý, Dovrtěl, Brandštetr (1996) who conducted pot trials to test materials from fluid coal combustion in the power plant at Třinec. They showed that these materials may be used not only for modification of soil pH but also as components in composting organic substances and in slurry management.

Detailed results of analyses of individual treatments and test crops are given in Table 1.

Further evaluation of the development of soil reaction changes will be made in the following period at regular time intervals.

Studies were also made of technical and technological suitability of pellets applied to the soil environment. It seems that the first visible changes in the shape and consistency of pellets (granules) applied to the soil or to the soil surface might be seen after about 10 – 15 weeks. At this time they start to have a more marked effect on soil pH. Pellets of a smaller size seem to be more suitable because of their uniform spatial application to the soil and their contact with the soil.

b) Yields of harvested crops (forage and dry matter)

The test crops were harvested depending on stand maturation. Spring barley was harvested on 17 August 2004, white mustard on 30 August 2004, other crops such as mallow and safflower were harvested on 4 October 2004.

The harvested crops were weighed per plot and dried. DM yield per plot was determined (g) as well as the dry matter of the harvested material (%). Only spring barley straw and grain were evaluated separately.

The yield results in the first year of the experiment did not reveal any marked differences in forage and dry matter yields. Only in mallow there was a higher yield with the material supplied from Hodonín than with the material from Třinec. It appears that mallow yields were more markedly affected by the date of incorporation of test materials into the soil (Hodonín – autumn, Třinec - spring). The differences in mean yields of safflower were not considerably affected by the test material or by its incorporation into the soil. This crop seems to be less sensitive to changes in the soil environment than e.g. mallow.

It can be concluded that in the first experimental year there were neither depressive effects on the stands, nor marked differences in the growth and development of treated stands, compared with the control.

There was no marked effect of the material applied to the soil on the health condition of the test stands.

c) Biological activity of soil – actinomycetes and micromycetes

The activity of actinomycetes and micromycetes in the soil was studied in relation to changes in a soil environment (especially soil pH and humus content in the soil) after the application of pellets and granules produced from ashes and fly ashes after fluid coal combustion.

Actinomycetes, which belong to bacteria, thrive in a neutral to slightly alkaline environment. They break down various carbonaceous materials. Some of them also break down vegetable and animal fats. There is practically no organic material (except plastic) which cannot be broken down by actinomycetes. Studies of microbial activity in soil as dependent on various organic materials were conducted by Stahl, Parkin (1996) who found that actinomycetes, bacteria and fungi were more active when the content of organic material in the soil increased.

Micromycetes belonging to fungi are with yeasts an important component of abundant and species-diverse mycoflora which is part of biocoenosis. Their main reservoir is the soil and they are strictly aerobic. They are able to propagate even at low pH and low temperatures and also when water activity of the environment is low. A soil environment x microorganisms interaction was studied by Popowska *et al.* (2003). Micromycetes utilize carbon-containing nutrients very effectively and they are able to break down complex carbohydrates, proteins, fats, various cyclic components and other substances. They are dominant microflora of acid soils. They are markedly involved in the formation and maintenance of soil structure and they take active part in various mineralization and humification processes.
Actinomycetes and micromycetes are very sensitive to poor aeration at high soil moisture content. When the soil is very dry, they survive in absorbed water. With gradual decrease in soil moisture they create latent forms and their biological activity ceases. The development of actinomycetes and their fungal activity are higher at natural soil pH, as it was found by Weyman-Kaczmarkowa, Pedziwilk (1999).

After the first year of study it may be stated that the number of micromycetes was affected neither by the crop nor the amount of material applied to the soil, nor soil pH. The increased number of micromycetes occurred with mallow when a half rate of test materials from fluid coal combustion in the power plant Hodonín was applied. After bottom ash application the number of actinomycetes decreased more than after the application of pellets (material was supplied from the power plant Třinec)

Conclusion

The study of how to reduce the ever-increasing volume of wastes is becoming more and more important. The reasons are their load on the environment and the limited space on the Earth whose resources are limited and also largely exhausted. Any free space must be used reasonably and economically, which may be achieved by utilizing large volume waste materials in different branches of industry, agriculture and other areas. The possibility of liming soils by products from fluid combustion has thus become an interesting option.
The hitherto results have indicated that the application of test materials from fluid coal combustion to the soil (pellets, granules) has a positive effect on its pH. In the year 2004 these materials did not have any marked effects on the growth and development of stands of selected crops, their yield and health. The biological activity of soil (actinomycetes, micromycetes) was not markedly affected by these treatments in the first year of study.

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Literature

Bi, Y.L., Li, X.L., Christie, P., Hu, Z.Q., Wong, M.H.: Growth and nutrient uptake of arbuscular mycorrhizal maize in different depths of soil overlying coal fly ash. Chemosphere. Chemosphere Feb 2003. v. 50 (6), p. 863-869

Hrubý, J., Brandštetr, J.: Využití elektrárenských popílků fluidního spalování uhlí v zemědělství ,lesnictví a zahradnictví. Farmář, 4, 1998, čís. 5, str. 18-19

Hrubý, J., Dovrtěl, J.: Sb. K 85.výročí založení fakulty chemické VUT Brno, 1996, s. M-16

Hrubý, J.,Dovrtěl, J., Brandštetr, J.:Možnosti využití popílků z fluidního spalování uhlí v rostlinné výrobě. In: Ekonomické a ekologické systémy hospodaření na půdě. Brno,1996, s.29-33

Kuchanwar, O., Matte, D., Kene, D.: Effect of fly ash application on physico-chemical properties of soil. Journal of Soils and Crops, 1997, čís.l ,str. 73-75

Nechvatal,T. M., Michaud, D. T.: Crop and soil responses to land application of bottom ash. NIAUS, 1991, sv.3, str.1-7

Pathan, S.M., Aylmore, L.A.G., Colmer, T.D.: Soil properties and turf growth on a sandy soil amended with fly ash. Plant and soil. 2003 Sept., v. 256, no. 1, p. 103-114

Popowska-Nowak, E., Bajan, C., Augustyniuk-Kram, A., Kolomiec, E., Chikileva, A.: Interactions between soil microorganisms: bacteria, actinomycetes and entomopathogenic fungi of the genera Beauveria and Paecilomyces. Polish Journal of Ekology, 2003, v. 51 (1), p. 85-90

Richter, R. et al.: Výživa a hnojení rostlin.VŠZ Brno,1993,198 s

Ritchey, K. D.: Methods for predicting agronomic response to coal combustion bioproduct application on acid soils. PCCBMU, 1997, sv.1, str.1-11

Sale, L., Chanasyk, D., Naeth, M.: Temporal influence of fly ash on select soil physical properties. Canadian Journal of Soil Science, 1997, 77: čís.4, str. 677-683

Stahl, P.D., Parkin, T.B.: microbial production of volatile organic compounds in soil microcosms. Soil Science Society of America, 1996, v. 60(3), p. 821-828

Tripathy, A., Sahu, RK: Effect of coal fly ash on growth and yield of wheat. Journal of Environmental Biology, 1997, 18, čís. 2.str. 131-135

Weyman-Kaczmarkowa, W., Pedziwilk, Z.: Development of actinomycetes and fungistatic activity of soil as affected by pH and soil type. Acta Microbiologica Polonica, 1999, v. 48(1), p. 85-92

Table: Metering results of soil pH after application of supplies from fluid burning of coal
Troubsko 2004

Variant	Marking	**6.4.2004**		**1.6.2004**		**5.8.2004**		**4.10.2004**	
		KCl	H_2O	KCl	H_2O	KCl	H_2O	KCl	H_2O
Hodonín (filter) 1/2	H_f(0,32)	7,1	7,3	7,1	7,5	7,0	7,4	7,2	7,8
Hodonín (filter)	H_f(0,64)	7,1	7,3	7,2	7,5	7,1	7,6	7,3	7,8
Hodonín (bottom) 1/2	Hl(0,29)	7,1	7,3	7,1	7,5	7,0	7,4	7,3	8,0
Hodonín (bottom)	Hl(0,57)	7,2	7,3	7,1	7,6	7,1	7,4	7,3	7,9
Třinec (filter) 1/2	T_f(0,63)	7,0	7,3	7,2	7,5	7,1	7,4	7,3	7,9
Třinec (filter)	T_f(1,26)	7,0	7,3	7,2	7,6	7,1	7,5	7,3	7,8
Třinec (bottom) 1/2	Tl(2,6)	7,1	7,4	7,2	7,6	7,1	7,5	7,3	7,9
Třinec (bottom)	Tl(5,2)	7,1	7,4	7,2	7,6	7,3	7,5	7,4	8,1
Třinec (filter) 1/2	T_f(0,63)*	7,0	7,3	7,1	7,5	7,1	7,4	7,3	8,0
Třinec (filter)	T_f(1,26)*	7,0	7,3	7,1	7,5	7,1	7,5	7,3	8,0

power plant: H - Hodonín
T - Třinec

testing material: f - fluid ash (in form pellet)
l - bottom ash
* - fluid ash (in form granule)

comment: The number in parenthesis indicate applied dose in gramme per 1 m^2

STABILITY VERIFICATION OF COMBUSTION PRODUCTS FOR UTILISATION IN AGRICULTURE AND FOR RECULTIVATION OF LANDSCAPE

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Abstract

Project EUREKA No. E!2936 "Economical and ecological utilisation of selected residual industrial materials in landscape creation" started in September 2003. It deals with possibilities of large-volume utilisation of energy and metallurgical industrial wastes in civil engineering and in agriculture for recultivation purposes. The project arosed in the scope of the international program EUREKA (European co-operation in the sphere of applied and industrial research and development), which is aimed to products innovation, technology and progressive services in individual countries and also in the whole EU. In addition it incorporates the environmental problems.

Introduction

The increasing amount of waste brought about at the growing consumption of population is getting the more important problem in EU and also in other countries. The most important problem is the production of large-volume waste of energy and metallurgical industry (in millions tons annually). Solution is reusing of waste materials in industrial branches, in agriculture and other areas. In this way it is possible to save natural raw materials, energetic savings and reduction of emissions (for example CO_2) etc.

Project EUREKA No. E!2936 "Economical and ecological utilization of selected residual industrial materials in landscape creation" is aimed on possibilities of utilisation of large-volume waste of energetic and metallurgical industry in civil engineering and in agriculture for reclamation purposes. In the project take part solvers from three countries:

Representatives from Turkey (Tubitak MRC., Erdemir Steel Plant, ISTON) deal with utilisation of steel slag in the production of concrete products.

Representatives from Serbia (JP Elektroprivreda Srbije a Center for Multidisciplinary Studies of Belgrade University) deal with utilisation of fluidised ashes and fly ashes in the building production.

Representatives from the Czech Republic (Research Institute o Building Materials, JSC., Brno – leading of the Project and Research Institute for Fodder Crops Ltd., Troubsko are engaged in production of granulation products on base of ashes and fly-ashes for agriculture and landscape creation.

In the Czech Republic the project is aimed at the utilisation of products of fluidised combustion (further FPP) at the landscape conditioning, backfilling, at the clean up of devastated areas, sludge beds, dumps etc. This type of combustion products is characterised by especially higher content of free CaO which at the utilisation in reclamation activities can favourably influence the pH of the soil. Prerequisite is therefore also the utilisation of FPP as a substitute for lime fertiliser.

For application of a concrete FPP into soil or substrate were determined requirements for the following factors:

- easy flexibility and prevention of dustiness
- content of free CaO
- ecological suitability

Preparation of FPP for embedding process into soil

On FPP samples ware carried out the base entry tests, chemical analyse and tests of ecological suitability.

From the aspect of FPP utilization as a lime fertiliser were most important parameters of the screen analyze and free CaO content.

From the aspect of the screen analyze FPP can be devide into two main types:

- fluidised bed ash - it has appropriate granularity so that it is not neccessary to adapt it for agriculture purposes.

- fly ash from bag filters - it is very fine and therefore it is neccessary before application to compact it.

For proposed purposes it was neccessary process FPP from filters into a form which enable its easy manipulation and reduces dustiness at the application into soil. On the base of experiences of agricultural experts was proposed granulate of fraction 4 - 8 mm.

The method of compacting should be simple on supposed granulate production from the point of view of machine equipment and following procedures (drying, storage, minimum of transport and loading). With regard to these required parameters three methods of compacting were chosen – Granulate production on semi industrial pelletizer, on granulating cylinders and pressing corpuscles of greater size with following crushing.

It was found out that the most appropriate way is the method of compacting with granulating cylinders.

Figure 1 – Specimen of granulate produced on a pelletizer and on granulating cylinders

Fundamental decisive influence for presumed utilisation is content free CaO (usually about 5 %, exclusively about 15 %), which is the presumption for the pH soil adjustment. This value is at various FPP types different with regard to combustion method, coal quality and quantity of additives added at the combustion process. For FPP producers means higher content of CaO sorbent wasting, but in the contrary for purposes of the project is higher content of Cao the main advantage. Owing to often variability of characteristics, it will be neccessary to determine the CaO content more often, preferably by saccharate titration method. At compacting with water it comes to content lowering of free CaO because it will be used by creation of the new reaction products (reaction water + fly ash). From this reason we accepted the granulate production with determined water content, it means for example compacting with spirit, starch, molasses or mineral components of zeolitic character with utilisation of their ions replaceable properties, which can at the same time immobilise toxic substances included in the products of combustion.

Ecological suitabitity

On FPP specimens and on resulting granulates were (apart from basic input analyse) determined mass activity of radionuclides, leaching activity and harmful substances in dry matter and ecotoxicity.

1. Mass activity of radionuclides
Mass activity of radionuclides was determined by spectrometric method of gamma radiation in the Radionuclide laboratory of the Research Institute of Building Materials. All measured specimens did not exceed the directive value I1 given by the notice No. 307/2002 Sb. Attachment No. 10, Table No. 1. Specimens consequently comply with requirements on content of natural radionuclides.

2. *Determination of harmful substances in dry matter*
Content of harmful substances in dry matter was determined according to valid standards ČSN in laboratory LABTECH. For individual harmful substances are given the limit values by public notice of MŽP No. 13/94. The following table compares achieved values at the tested FPP with given limits.

Specimen	Bed Hodonín	Bed Třinec	Filter Hodonín	Filter Třinec	Limit values
As	48,3	4,1	105	21,5	30
Cd	0,3	0,3	0,4	0,3	1
Cr	37	39	107	62	200
Cu	29	32	71	68	100
Hg	0,005	0,004	0,4	0,352	0,8
Mo	2,4	2,5	4	2,6	5
Ni	31	25	80	48	80
Pb	12	18	21	47	140
Zn	43	41	86	74	200

At FPP Hodonín was found out that in case of As the values exceed the permissible limit of heavy metals. These FPP it is neccessary before compacting dilute with shady material – soil. Defined limit values of heavy metals content do not exceed granules with content 100% FPP Třinec and granules with content 70% FPP Hodonín + 30% soil substrate.

3. Ecotoxicity
This test is important also in the case when determination of harmful substances accomplished given limits, because combination of some matters may have toxic effects too. Determination of ecotoxicity includes complex of the following prescriptions:

- Determination of lethal toxicity of substances for freshwater fishes
- Inhibition test of move ability of Daphnia magna Stratus – test of acute toxicity
- Inhibition test of freshwater algae growth
- Root growth test of white mustard

In the case of Hodonín FPP was confirmed the neccessity of diluting with shady material in relation 70:30 (see article 2)
The ecotoxicity test results showed also the neccessity of using of shady material at FPP Třinec (sufficient addition is 10% of soil).

Assessment of FPP influence

Assessment of applied FPP influence on soil environment, soil chemistry, tested crop-plant harvest and biological soil activity – actinomycetes is carried out in Research Institute for Fodder Crops Ltd., Troubsko on the following areas:

- arable land – small plot tests – Troubsko
- permanent herbage – small plot tests Troubsko, Domanínek
- pot tests

Granulate dose on plots was determined on the base of CaO content. For each granulate type were created three main plots of size 4,2 m^2 on which were applied:
- whole granulate dose
- half granulate dose
- without granulate (control)

In autumn 2003 and in spring 2004 were on the test plots sowed annual test crop-plants at which was assessed:

- growth and development of vegetation
- occurrence of diseases and pests in comparison with the control variant
- soil pH - in two months intervals
- ecological suitability after the vegetation season

Conclusions

At sowed annual test crop-plants (barley, safflower, and mallow) growth and vegetation development, occurrence of diseases and pests, soil pH in time dependence and ecological suitability were tested. Soil pH value in the range of 7.0 - 7.1 before application was increased about 0.5 - 0.7 after application. Health condition of vegetation was not distinctively affected. At observation of crop it was found out that only at FPP Hodonín got to some changes, depressive effects in comparing with the control samples were not noticed.

At the cropped material were chemical analyses carried out. It showed that there exists certain tendency of increasing of nitrogen volume in plants with applied FPP in particular at barley. In the area of soil microbiology was examined whether FPP do not influence the microbial activity of actinomycetes and micromycetes. It was found out that number of actinomycetes decreased after bed ash activation more then at the granulate.

Research works will continue also in the years 2005 and 2006. Only then it will be possible to carry out more detailed assessment.

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References

Suchardová M., Hrubý J.: Ekonomické a ekologické využití vybraných zbytkových průmyslových materiálů při tvorbě krajiny [Economical and ecological utilisation of selected residual materials for landscape creation], Sborník VIII. konference Výzkumného ústavu stavebních hmot Ekologie a nové stavební hmoty a výrobky, Telč, červen 2004, str. 47-49

Chromková I., Vojáček J., Hrubý J.: Ověřování využití odpadních FPP jako cenné suroviny v zemědělství a při tvorbě krajiny [Utilisation assessment of waste FPP as valuable raw material in agriculture and for landscape creation], Sborník konference Recykling 2004, Ostrava, říjen 2004

Günay, E., Kara, M., Bodur, H., Berk, C., Zeytin, H. K., Abanoz, D.: Economical and Ecological Utilization of Selected Residual Materials for Landscape Creation, TUBITAK The Scientific and Technical Council of Turkey, Marmara Research Centre, Turkey, 12/2004

Petrasinovic-Stojkanovic, L., Komljenovic, M., Nesic, G., Bascarevic, Z.: Economical and Ecological Utilization of Selected Residual Materials for Landscape Creation – Annual Report 2004, Center for Multidisciplinary Studies, University of Belgrade, Serbia and montenegro, 12/2004

Karakas, Y., Sönmez, B., Yildirim, C., Yenicerioglu, M., Tasel, M. R., Akbas, I., Sagtekin, O.: Economical and Ecological Utilization of Selected Residual Materials for Landscape

Creation – Progress Report 2004, R&D Department, Eregli, Iron and Steel works Co., Turkey, 12/2004

Petříková V.: Využití sorpčních schopností popele k omezení transferu těžkých kovů [Utilisation of ash sorptive capability for transfer restriction of heavy metals]. Sborník z mezinárodního semináře – Těžké kovy v zemědělské půdě a v rostlinách VÚRV Praha, říjen 1995

Němec J., Štolbová M., Vrbová E:, Čermák P., Novák P., Vašků Z.: PŮDA, Situační a výhledová zpráva MŽP, 2003 [Situational and prospective report of Ministry for Environment, 2003]

Ledererová J.: Využití odpadů z elektráren pro zpracování ve stavebním průmyslu v rámci systému bezodpadových technologií [Utilisation of wastes from power plants for processing in bulding industry in the system of wasteless technologies] Závěrečná zpráva výzkumného projektu MPO ČR, 1995-1999

Sedláková M.: Ekotoxicita stavebních hmot z produktů spalování [Ecotoxicity of building materials from combustion products] , Sborník ze semináře Využití elektrárenských a teplárenských odpadů – Ekokontakt, Ostrava 1997

Chromková I.: Využití slévárenských písků v keramice a do betonu [Utilisation of foundry sands in ceramics and for concrete production], Diplomová práce, 1997

Ledererová J., Lejsek L., Suchardová M., Khazal W.: Odpadní produkty z elektráren a tepláren [Waste products from power and heating plants], Odpady č. 11/1998, str. 10-16

Ledererová J., Chromková I., Těhník V.: Možnost využití slévárenských písků ve výrobě stavebních hmot, část I. Zkušenosti s využitím slévárenských písků [Utilisation possibilities of foundry sands in building materials production, Part I. Experience with utilisation of foundry sands] , Sborník konference RECYKLING 1998 – Brno

Ledererová J., Sedláková M., Suchardová M.: Nové soubory ČSN k využití klasických a fluidních popelů a popílků pro stavební účely [New normative sets of ČSN for utilisation of classical and fluidised ashes and fly-ashes for building purposes], Sborník konference Odpady v energetice, Pardubice, září 1999, str. 5-9

Ledererová J., Sedláková M.: Druhotné suroviny a životní prostředí [Secondary raw materials and environment], Sborník VI. konference Výzkumného ústavu stavebních hmot Nové stavební hmoty a výrobky, Brno, říjen 2002, str. 148

Kukletová I.: Testy ekotoxicity na autotrofních organismech [Ecotoxicity tests on autotrophic organisms], Sborník VI. konference Výzkumného ústavu stavebních hmot Nové stavební hmoty a výrobky, Brno, říjen 2002, str. 156

Hrubý,J., Brandštetr,J.: Využití elektrárenských popílků fluidního spalování uhlí v zemědělství,lesnictví a zahradnictví [Utilisation of power plant ashes from fluidised coal conbustion in agriculture, forestry and gardening. Farmář, 4, 1998, čís. 5, str. 18-19

USING MULTIVARIATE GEOSTATISTICS FOR DESCRIBING SPATIAL RELATIONSHIPS AMONG SOME SOIL PROPERTIES

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1. Introduction

The soils represent critical environment at the interface among rock, air and water; they can then be centre of various chemicals, deriving from several human activities (industry, agriculture, transports, etc), but, at the same time, be the living pollution sources for superficial and deep waters, for organisms, sediments and oceans. Optimum benefits on profitability and environment protection depend on how well land use and remediation practices are fitted to variable soil conditions.
The crucial problem is to characterize soil with precision, both quantitatively and spatially (Castrignanò et al., 2000), because soil variability is the result of both natural processes and management practices, acting at different spatial and temporal scales. For this reason it is necessary to use adequate techniques of analysis, capable to put in evidence important spatial relationships and identify those factors that control the variability of geochemical data.
Multivariate geostatistics uses information coming from the relationships among variables in order to improve estimation precision and to disclose the different causes of variation working at different spatial scales. Some of the several factors that govern soil variations are likely to have a short-range action, whereas others operate at longer distances. As a consequence, soil variables are expected to be correlated in a way that is scale-dependent.
The main objective of this paper is to study the scale-dependent correlation structure of some soil variables, supposing that it can reflect the different sources of variability. This requires a particular statistical approach that combines classical Principal Component Analysis, to describe the correlation structure of multivariate data sets, with geostatistics, to take into account the regionalized nature of the variables. We then applied a method, called Factorial Kriging Analysis (FKA) and originally developed by Matheron (1982), to study the correlations among some soil properties at the different spatial scales.

2. Material and Methods

2.1. Multivariate geostatistical approach

Multivariate spatial data set can be analyzed by FKA, a relatively recent geostatistical method developed by Matheron (1982). The theory underlying FKA has been described in several publications (Goovaerts and Webster, 1994; Castrignanò et al.,2000b; Wackernagel, 2003); here we will describe only the most salient points. The approach consists of decomposing the set of original second-order random stationary variables $\{Z_i(\mathbf{x});\ i=1,...,n\}$ into a set of reciprocally orthogonal regionalised factors $\{Y_v^u(\mathbf{x});\ v=1,...,n;\ u=1,…,N_S\}$ where N_S is the number of spatial scales, through transformation coefficients a_{iv}^{u}, combining the spatial with the multivariate decomposition:

$$\boldsymbol{Z}_i(\mathbf{x}) = \sum_{\boldsymbol{u}=1}^{N_S}\sum_{\boldsymbol{v}=1}^{\boldsymbol{n}} \boldsymbol{a}_{iv}^{u}\boldsymbol{Y}_v^{u}(\mathbf{x})$$

The three basic steps of FKA are the following:
1) modelling the coregionalization of a set of variables, using the so called Linear Model of Coregionalization (LMC);
2) analysing the correlation structure between the variables, at the different spatial scales by applying Principal Component Analysis (PCA);
3) cokriging specific factors at characteristic scales and mapping them.

2.1.1. Linear Model of Coregionalization

The LMC, developed by Journel e Huijbregts (1978), assumes all the studied variables are the result of the same independent processes, acting at different spatial scales *u*. The $n(n+1)/2$ simple and cross semivariograms of the *n* variables are modelled by a linear combination of N_S standardized semivariograms to unit sill $g^u(\boldsymbol{h})$. Using the matrix notation, the LMC can be written as:

$$\boldsymbol{\Gamma}(\boldsymbol{h}) = \sum_{\boldsymbol{u}=1}^{N_S} \mathrm{B}^{\boldsymbol{u}} \boldsymbol{g}^{\boldsymbol{u}}(\mathbf{h})$$

where $\boldsymbol{\Gamma}(\boldsymbol{h}) = [\gamma_{ij}(\mathbf{h})]$ is a symmetric matrix of order *n x n*, whose diagonal and non diagonal elements represent simple and cross semivariograms, respectively for lag *h*; $\boldsymbol{B}^u = [b^u_{ij}]$ is called coregionalization matrix and it is a symmetric positive semi-definite matrix of order *n x n* with real elements b^u_{ij} at a specific spatial scale *u*. The model is authorized if the mathematical functions $g^u(\boldsymbol{h})$ are authorized semivariogram models.
In the linear model of coregionalization the spatial behaviour of the variables is supposed resulting from superimposition of different independent processes working at different spatial scales. These processes may affect the behaviour of experimental semivariograms, which can then be modelled by a set of functions $g^u(\boldsymbol{h})$. The choice of number and characteristics (model, sill, range) of the functions $g^u(\boldsymbol{h})$ is quite delicate and can be made easier by a good experience of the studied phenomena (Chiles and Guillen, 1984). Fitting of LMC is performed by weighed least-squares approximation under the constraint of positive semi-definiteness of the $\boldsymbol{B}^u$, using the iterative procedures developed by Goulard (1989). The best model was chosen, as suggested by Goulard and Voltz (1992), by comparing the goodness of fit for several combinations of functions of $g^u(\boldsymbol{h})$ with different ranges in terms of the weighted sum of squares.

2.1.2. Regionalized Principal Component Analysis

Regionalized Principal Component Analysis consists of decomposing each coregionalization matrix $\boldsymbol{B}^u$ into two other diagonal matrices: the matrix of eigenvectors and the diagonal matrix of eigenvalues for each spatial scale *u* through the matrix $\boldsymbol{A}^u$ of order *n x n* of the transformation coefficients a_{iv}^{u} (Wackernagel, 2003). The transformation coefficients a_{iv}^{u} in the matrix $\boldsymbol{A}^u$ correspond to the covariances between the original variables $Z_i(x)$ and the regionalized factors $\boldsymbol{Y}_v^{u}(\mathbf{x})$.

2.1.3. Mapping multivariate spatial information

The behaviour and relationships among variables at different spatial scales can be displayed by interpolating the regionalized factors $Y_v^u(\mathbf{x})$ using cokriging and mapping them (Castrignanò et al., 2000a). The cokriging system in FKA has been widely described by Wackernagel (2003).

2.2. Sampling and measurements

In the year 2003, the spatial variability of some soil properties was studied in an industrial area of 300 ha located in Taranto (Apulia Region, southern Italy). A monitoring net composed by 184 boreholes was placed on the site and in each point a sample was collected at 1 m depth. These samples were analyzed in laboratory in order to evaluate different soil properties. The final database consisted of 184 samples and 16 variables, which were the following: Be, Cd, Va, Zn, total Cr, Hg, Ni, Pb, Cu, Cation Exchange Capacity (CEC), Organic Carbon, Fraction (%) of soil particle size from 2 mm to 20 mm, Fraction < 2 mm, light hydrocarbons, humidity at 105°C, pH. It is important to underline that the soil matrix did not result to be contaminated because no sample value overcame the critical threshold imposed for each compound by the Italian decree D.M.471/99.

3. Results and discussion

3.1. Exploratory analysis
First of all we determined the descriptive statistics of all variables, as reported in Table 1.

Table 1. Descriptive statistics of the soil properties

Variable	Mean	Min	Max	Standard Deviation	Skewness	Kurtosis
Be (mg Kg^{-1})	1.14	0.05	9.72	1.39	2.74	13.10
Cd (mg Kg^{-1})	0.06	0.00*	0.51	0.05	3.58	26.61
CEC	24.29	8.90	45.60	7.83	0.29	2.39
Organic Carbon	0.25	0.01	1.24	0.21	1.72	6.64
total Cr (mg Kg^{-1})	7.99	0.8	46.10	8.28	2.73	11.23
Fraction 2mm - 20mm (%)	21.30	0.00*	69.50	17.35	0.71	2.89
Fraction < 2mm (%)	74.89	0.00*	100	22.07	-1.37	5.27
light hydrocarbons (mg Kg^{-1})	4.69	0.10	308	33.25	8.22	70.94
Hg (mg Kg^{-1})	0.02	0.00*	0.44	0.04	6.70	60.07
Ni (mg Kg^{-1})	7.77	0.70	67.50	10.75	3.15	14.05
Pb (mg Kg^{-1})	6.10	0.22	34.40	5.62	2.33	9.38
Cu (mg Kg^{-1})	7.17	0.60	138	12.33	7.17	70.87
Va (mg Kg^{-1})	11.49	1.10	38.10	6.00	1.21	5.08
Zn (mg Kg^{-1})	16.26	1.60	154	17.61	3.78	25.76
pH	8.28	7.25	11.55	0.52	2.25	13.60

*detection limit

From the inspection of the table, we can notice high shifts of skewness and kurtosis from 0 and 3, respectively, which are the characteristic values of normal distribution. Therefore, the variables generally exhibit non symmetric distributions, with long tails and several outliers. The variables were then normalised and standardised to 0 mean and unit variance.
The visual inspection of the variogram maps, (not shown) did not reveal any significant anisotropy in chemicals distribution, therefore an isotropic model of variogram was assumed.

3.2. Coregionalization analysis
Before performing a coregionalization analysis to separate the different sources of variation, we decided to select a smaller number of the most relevant variables, in order to save computer time and make easier the interpretation of the results. As to the selection, the following five variables total Cr, Ni, Pb, Va and organic carbon were analysed, because they appeared to be the more spatially structured and correlated variables. A LMC was fitted to the set of the 15 direct and cross-variograms including 3 basic spatial structures: 1) a nugget effect; 2) a spherical model with range=249.58 m ; 3) an exponential model with range=1300.00 m. Most of direct and cross-variograms appeared well spatially structured and for some pairs of variables (Ni-Cr,Va-Cr) the spatial cross-correlation was very strong, close to the maximum corresponding to intrinsic correlation. The inspection of fig.1 shows also that the goodness of fitting was generally quite high with the exception of some dismatch at the origin, quite probably because of the presence of outliers. The goodness of fitting was also tested by cross-validation, calculating mean error and reduced variance (variance of standardised error),which were close to 0 and 1, respectively (not reported).These results mean that the estimates were unbiased and the estimation variance reproduced experimental variance accurately. The cokriging maps of the estimated values of organic carbon, total chromium, nickel, lead and vanadium contents are reported in fig 2 (a,b,c,d,e). For any estimated value, the cokriging has allowed also to calculate the variance of the estimation error associated to it, giving a measure of the reliability of the estimation (not shown). Once LMC was estimated, cokriging was applied to the transformed data to obtain the estimates which were then back-transformed to express them in the original variable.

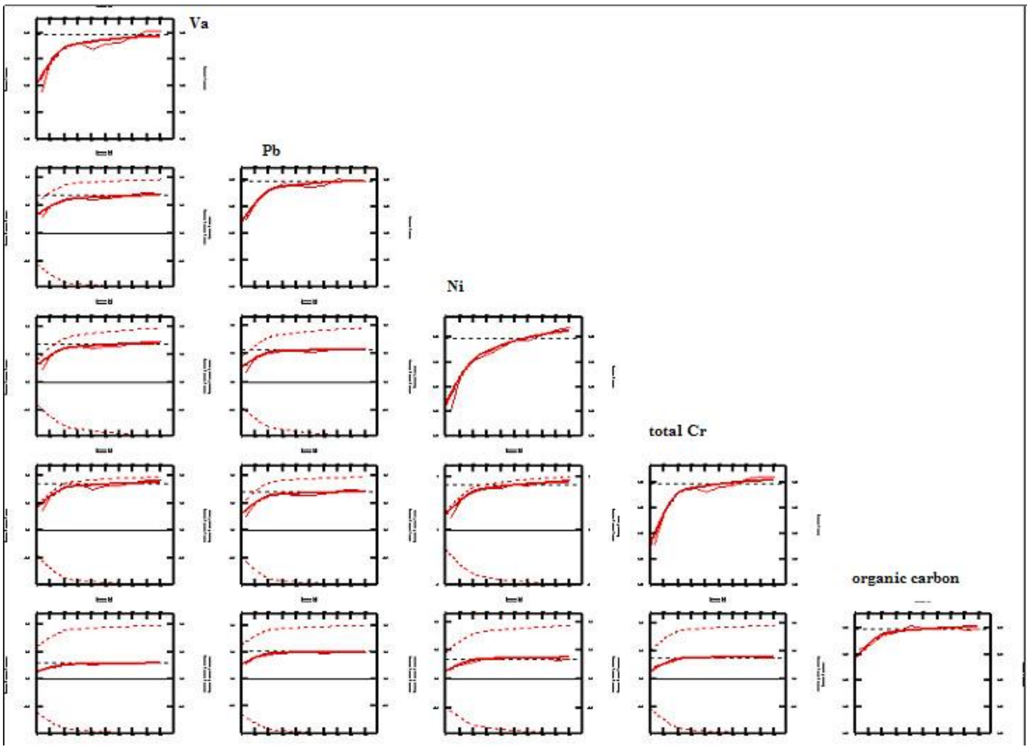

Figure 1. Experimental direct and cross semivariograms (fine line) with the fitted linear coregionalization model (bold line); the dashed line in cross-variogram represents the maximum correlation between the two variables.

The obtained maps put into relevance how total chromium and nickel on one hand and vanadium and lead on the other show similar spatial distributions, whereas organic carbon looks quite different from all the other variables. At this point, we wanted to inquire more deeply into the different sources of variation working in the study area.

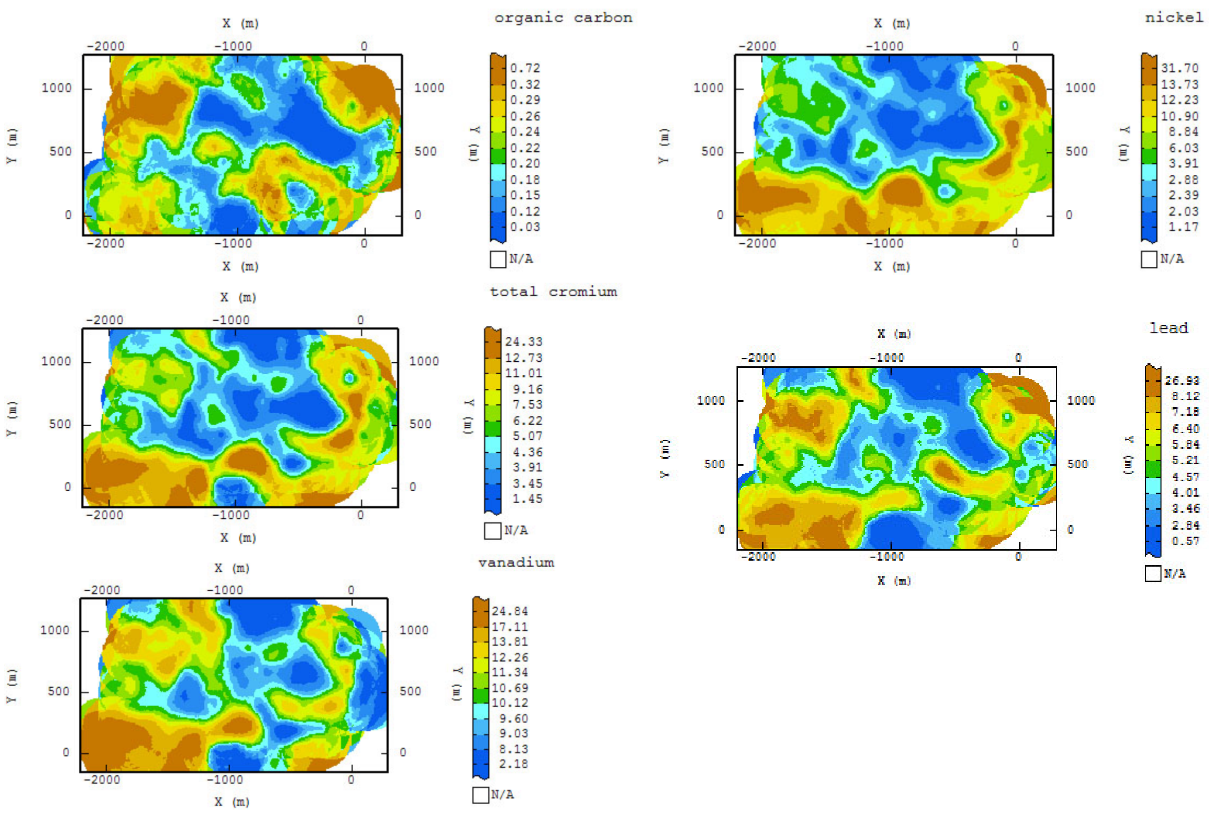

Fig. 2 : Cokriging maps of OC, Va, total Cr, Ni and Pb

The Factorial Kriging

FKA has allowed to isolate the first 2 regionalized factors that, at the cost of an acceptable loss of information, have given a synthetic description of the process in study at the different selected spatial scales. Passing over the nugget effect, because mostly affected by measurement error, we will concentrate on the short-range and long-range components of the first two regionalized factors.

S1 : **Nugget effect**

Coregionalization matrix :

	Carbon	Cr	Ni	Pb	Va
Carbon	0.6968	0.1378	0.1396	0.2679	0.1378
Cr	0.1378	0.3919	0.2922	0.2970	0.4083
Ni	0.1396	0.2922	0.3188	0.2506	0.2939
Pb	0.2679	0.2970	0.2506	0.5980	0.3268
Va	0.1378	0.4083	0.2939	0.3268	0.5147

Eigen vectors matrix:

	Carbon	Cr	Ni	Pb	Va	Eigen Val.	Var. Perc.
Factor 1	0.3778	0.4488	0.3744	0.5173	0.4981	1.5472	61.39
Factor 2	0.8806	-0.2750	-0.1706	0.0488	-0.3427	0.5880	23.33
Factor 3	0.2804	0.2539	0.1988	-0.8542	0.2963	0.2501	9.92
Factor 4	-0.0561	0.0000	0.8272	-0.0197	-0.5587	0.1049	4.16
Factor 5	-0.0017	-0.8115	0.3270	0.0023	0.4842	0.0300	1.19

S2 : **Spherical - Range = 249.58m**

Coregionalization matrix :

	Carbon	Cr	Ni	Pb	Va
Carbonio	0.2041	0.2119	0.1699	0.2024	0.1037
Cr	0.2119	0.4340	0.3258	0.3054	0.3181
Ni	0.1699	0.3258	0.2556	0.2478	0.2476
Pb	0.2024	0.3054	0.2478	0.2597	0.2151
Va	0.1037	0.3181	0.2476	0.2151	0.2805

Eigen vectors matrix:

	Carbon	Cr	Ni	Pb	Va	Eigen Val.	**Var. Perc.**
Factor 1	0.3105	0.5755	0.4479	0.4370	0.4252	1.2688	**88.49**
Factor 2	0.7476	-0.1462	-0.0580	0.2844	-0.5793	0.1461	**10.19**
Factor 3	0.0806	0.7487	-0.1752	-0.5401	-0.3325	0.0189	1.32
Factor 4	-0.0733	-0.1630	0.8743	-0.3330	-0.3045	0.0000	0.00
Factor 5	-0.5769	0.2457	0.0303	0.5705	-0.5295	0.0000	0.00

S3 : **Exponential - Scale = 1300 m**

Coregionalization matrix :

	Carbon	Cr	Ni	Pb	Va
Carbon	0.1267	0.0650	0.0804	0.0348	0.0574
Cr	0.0650	0.2254	0.3278	0.1192	0.1717
Ni	0.0804	0.3278	0.5623	0.0879	0.1747
Pb	0.0348	0.1192	0.0879	0.1538	0.1695
Va	0.0574	0.1717	0.1747	0.1695	0.1996

Eigen vectors matrix:

	Carbon	Cr	Ni	Pb	Va	Eigen Val.	**Var. Perc.**
Factor 1	0.1525	0.4944	0.7316	0.2496	0.3670	0.9182	**72.42**
Factor 2	0.1092	0.0347	-0.5379	0.6223	0.5570	0.2423	**19.11**
Factor 3	-0.9796	0.0491	0.0748	0.1591	0.0836	0.1067	8.42
Factor 4	0.0430	-0.8609	0.4089	0.2589	0.1508	0.0006	0.05
Factor 5	-0.0572	-0.1036	-0.0508	-0.6769	0.7248	0.0000	0.00

Table 2. Linear Model of Coregionalization with reported for each spatial scale (S): the coregionalization matrix, the eigen vector matrix, the corresponding eigen values and the percentage of variance explained by them.

In table 2 for each spatial scale are reported:
1)the variance-covariance (coregionalization) matrix;
2) the eigen vector matrix;
3) the eigen values which represent the variances of the corresponding eigenvectors;
4) the percentage of variance explained by each eigen vector.

The first two factors explain most variance both at short and long range (98.68%, and 91.51%, respectively).The short-range component of the first factor (F1) explains 88.49% and is mostly correlated with chromium (0.5755) and in smaller measure with the other variables, whereas the long-range component of F1 explains the 72.42% of the variance and is mainly correlated to nickel (0.7316) and in smaller measure to chromium (0.4944).
The second factor F2 at short range explains the 10.19% of variance and is strongly correlated with organic carbon (0.7476) whereas at long range explains the 19.11% of the variance and is positively correlated with lead (0.6223) and vanadium (0.5570) and less with the others (negatively with nickel).
The above results lead to think that organic carbon is more linked to intrinsic factors of the soil; it doesn't influence the mobility and the distribution of the examined inorganic chemicals, with whom it doesn't look to be much spatially correlated
The distributions of the two factors both at short and at long range looks as "pepper and salt" type with a high component of erraticity. This puts into evidence that the points of emission for the examined inorganic chemicals *are not concentrated*: more precisely we could assert that in the study case we are in presence of *more than one points of emission,* jointly working and being ascribed to causes of anthropic origin. The analysis of the cycle of production and of the activities carried out in the areas, disclosed by the maps of the regionalized factors, will allow to individuate the cause or the causes of the presence of chemicals. The probable sources of Cr variation operate at both short and long distances, whereas Ni acts rather at longer ranges, like lead and vanadium. However, lead and vanadium perform differently from Ni but quite similarly between them.

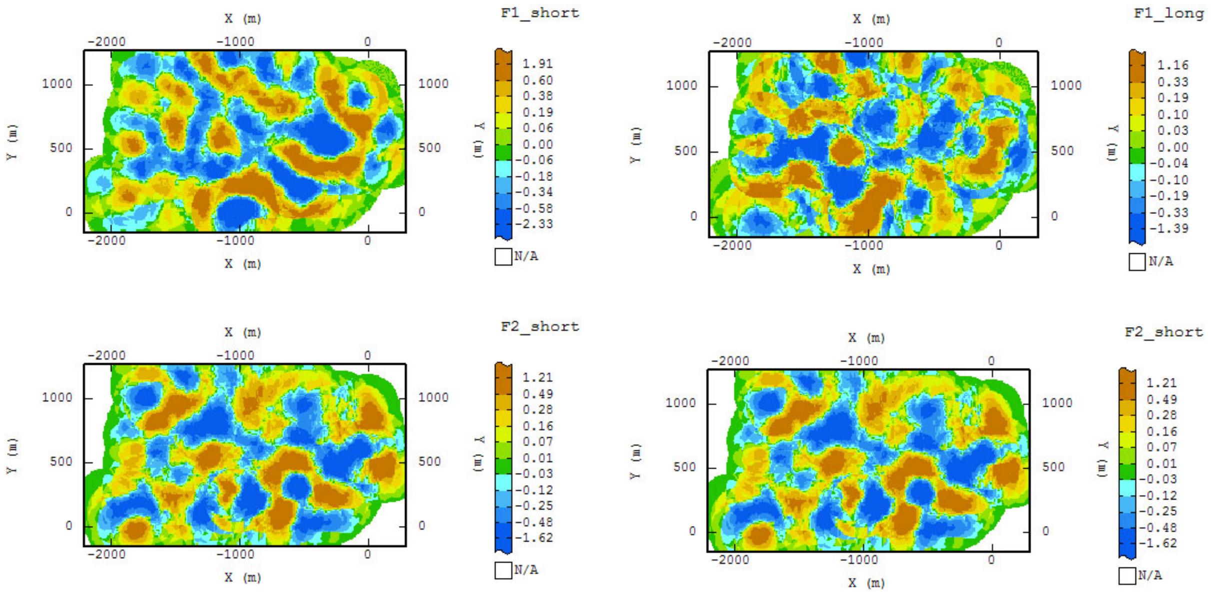

Fig 3. Cokriged maps of the short-range (a) and long-range (b) spatial components of the first two principal components (F1,F2).

4. Conclusions

Spatial variability of some soil components, measured in an industrial area of southern Italy, is the result of superimposed processes acting at different spatial scales.
The study shows that the points of emission for the examined inorganic chemicals *are not concentrated*: more precisely we could assert that in the study case we are in *presence of more points of emission evenly distributed.* The lacking of large structures of spatial dependence means quite probably that the origin of soil variability may mostly be ascribed to human activities. It needs to emphasize however that the high value of the nugget shown by the experimental variograms of Va and Pb suggests to refine the mesh of investigation. Intensifying the sampling might so allow local variation to be adequately taken into account in designing monitoring net and in planning land recovery.

References

Castrignanò, A., Giugliarini, L., Risaliti, R., Martinelli, N., 2000a. Study of spatial relationships among some soil physico-chemical properties of a field in central Italy using multivariate geostatistics, Geoderma 97, 39-60.

Castrignanò, A., Goovaerts, P., Lulli, L. Bragato, G. 2000b A geostatistical approach to estimate probability of *Tuber melanosporum* in relation to some soil properties.
Geoderma 98 (2000) 95-113

Chiles, J.P., Guillen, A., 1984. Variogrammes et krigeages pour gravimétrie et le magnétisme. Sciences de la Terre, Série Informatique 20, pp. 455-468

Goovaerts, P., Webster, R.,1994. Scale.dependent correlation beetween topsoil copper and cobalt concentrations in scotland. Eur. J. Soil Sci. 45, 79-95

Goulard, M., Voltz, M.,1992. Linear coregionalization model : tools for estimation and choice of cross-variogram matrix. Math. Geol. 24 (3), 269-286

Journel, A.G., Huijbregts, C.J., 1978. Mining Geostatistics. Academic Press, London, 600 pp.

Matheron, G., 1982. Pour une analyse krigeante des données regionalisées in Report 732. Centre de Geostatistique, Fontainebleau

Wackernagel, H. Multivariate Geostatistics An Introduction with Applications, 2003. Third Edition Springer Verlag

HOW TO USE INFORMATION ABOUT SOIL CHARACTERISTICS

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Abstract

Based on our own investigations and specialized literature, an analysis of problems associated with the use of information on soil characteristics and assessment of soil fertility in relation to farming sustainability was carried out. It was found that application of the methodological approaches to the assessment of sustainability developed for conditions of West European countries, i.e. smaller farms with stable economic and possessive relations, is disputable in the Czech Republic due to larger agricultural enterprises (farms) and fields. If analyses are carried out on large farms, some information on the heterogeneity in the system can be lost and results can be biased. Therefore, the characteristics and indicators used for assessing field fertility were judged considering the following aspects:
- labour and time demands for determination and needs of information from agronomic and accounting records,
- application on individual levels of the agrosystem (region, farm, crop, field and its part),
- usability by various users (farmers in primary production, state representatives).

The assessment of heterogeneity in soil characteristics within fields, which meets the concept of precision agriculture and allows site-specific application of cropping treatments and limitation of unfavourable impacts on the environment, is complicated in reality by special and interdisciplinary demands. Information on internal heterogeneity of fields is provided to farmers separately according to individual soil characteristics without sufficient interconnection that affects effectiveness of practical use.
Another handicap is still insufficient methodological interconnection between use of the information on heterogeneity in soil characteristics within fields obtained from precision agriculture and generally applied methods for the assessment of farming sustainability that are mostly oriented on higher levels of the agrosystem (region, farm, and field). Detailed analyses of several soil characteristics and their variability within fields are not common. Here is a space for system research aiming at closer interconnection of sustainability conception and precision agriculture. It is also a field for application of information technologies and special models that enable to assess a huge amount of information of various characters.

Key words: soil fertility indicators, heterogeneity within agroecosystem, sustainability assessment

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Introduction

Soil is a basic element of the environment, where field plants grow and develop, affects processes of yield formation and production quality. A question is how correctly and effectively soil properties can be described, used and preserved. Soil fertility is generally defined as the ability to provide plants with nutrients and moisture. It is influenced by physical, chemical and biological properties.

Based on our own investigations and specialized literature, the contribution gives an analysis of problems associated with use of information on soil and assessment of soil fertility in relation to farming sustainability.

Conception of sustainable development

Numerous definitions of sustainable agriculture have been published. Christen (1996, 1998) describes the six aspects of sustainable farming:

1. ethic element (intergeneration equality),
2. protection of resources (protection of soil, water, air),
3. preservation of biological diversity (reduction of interference in natural ecosystems),
4. assurance of economic viability of farms,
5. responsibility of agriculture for food production and quality,
6. global components of sustainable development.

Christen (1999) states that agriculture, as the greatest land user, is particularly responsible for its preservation. For this, it is necessary to find appropriate ways of assessment, which are considered to be indicators of farming sustainability.

Indicators related to soil fertility

To ensure an evidence ability of individual indicators, a level of primary agronomic records on farms, best of all by means of expert systems (AGROKROM, LANDATA, and others) or precise conduct of field books, is important.

Yield of a main product and by-product

The level of yields produced by individual crops is one of the most important criteria of soil fertility and of all methodical approaches in systemization of indicators. Data on yields are mostly easily available on farms since they are usually kept precisely enough. They should be combined with other values, particularly of economic and ecological characters. To interpret individual yields, it is useful to compare these data with yield potential of the concerned region, effectiveness of cropping treatments and individual agronomic measures. Such a comparison should take into account long-term time series.

Kudrna (1979) defines bioenergetic potential of soil (E_p), characterized as an energy status of active surfaces in the rhizosphere determined by an ion concentration flowing into the plant root system. It can be expressed using the formula $E_p = Y_s / H$ ($t.ha^{-1}$), where Y_s is a total yield of crop dry matter, H is the amount of pure nutrients in mineral fertilizers.

Kostelanský et al. (1997) use the concept “site fertility”, it means the ability to produce biomass or economic yield depending on all factors, not only soil ones. They also use the concept “environmental productivity” as a synonym.

In the field of ecology and population biology, Hardin (1974) indicates site productivity by the term “environment carrying capacity”. It is defined as a set of vegetation factors that are available to the plant to grow and develop in the given space and time. It is as maximum biomass amount, which can be produced at the given site.

Christen and O´Halloran-Wietholz (2002) point out that yields of individual crops must be interpreted along with specific yield potential and as well as with a level of plant nutrition and protection.

Soil erosion and compaction

Erosion adversely affects particularly soil fertility and water eutrophication. A number of papers refer to topsoil loss due to erosion. There are methods for reduction in unfavourable effects of water and wind (minimum soil tillage practice, windbreaks, transversal soil tillage on slopes, anti-erosion strips on slopes, etc.), however to measure erosion itself is difficult.

Wischmeier and Smith (1978) worked on the development of erosion simulation models for conditions of the USA. The following input factors were defined: a rainfall factor, factor of soil erosion (annual loss related to rainfall erosion affect), factor of slope length, factor of slope gradient, factor of soil cover, and protection factor of erosion.

Soil compaction generates if pressure load by a mechanization means surpasses a bearing limit. Measurement of soil compaction with a penetrometer enables to determine physical properties of topsoil and subsoil. Horn and Fleige (2001) tried to simulate the development of compaction. If they joined several physical factors, the interpretation of results was problematic.

Extensive investigations have provided findings how to reduce both erosion risk and soil compaction. Christen (1999) states that the first attempts to convert these ideas into corresponding guidelines have come across some difficulties because potential risks can vary a lot depending on soil texture, crop structure, and actual soil moisture.

Plant nutrition

Plant nutrition in sustainable agriculture is aimed at nutrient cycling, maximum utilization, minimum loss, and particularly at supply of off-taken nutrients (Hartman, 2002; Hlušek et al., 2003). Furthermore, it is desirable to harmonize mineralization processes in soil with the period, when plants need nutrients for their growth and development, and to stimulate immobilization processes in order to avoid leaching nutrients from soil in the period, when they are not able to uptake them. In this context, the absolute amount of applied nitrogen to produced yields is of critical importance. For this purpose, all agronomic treatments that facilitate optimum use of yield potential of the given location are useful.

The level of nutrient supply in mineral and organic fertilizers is one of the most important sustainability indicators. A reason is, on the one hand, the effect of fertilization on a yield level, and on the other hand, there is a danger of the environment pollution, particularly impacts on drinking water quality (nitrate leaching, water eutrophication, and others).

Christen and O´Halloran-Wietholz (2002) state that the simplest indicator of nutrient management is their balance related to the area. Provided there is equilibrium in soil, balance excesses can be interpreted like potential losses. The inputs generally include mineral and farm fertilizers, pollutants and symbiotic fixation. Some methodologies also take into account estimation of soil N mineralization (Hülsbergen and Diepenbrock, 1997). The outputs include nutrient off-take by the main product and by-product, inclusive their losses.

The greatest attention in literature is paid to nitrogen balance considering yield and quality aspects of production and the environment. The more positive N balance (nitrogen loss potential), the greater danger of N escape through or leaching into ground water. Input of mineral nitrogen in individual rates can be determined from agronomic records. Pollutants are measured within regions by the Czech Hydrometeorological Institute, Central Institute for Supervision and Testing in Agriculture and some other institutions. There are still problems with the assessment of the value of symbiotic fixation. Precise measurements are costly and associated with a number of methodical problems. Similarly, it is difficult to determine the amount of nitrogen in organic manures, therefore tabular values (Kavka, 2003) are used that provide general data.

Characteristics of soil organic matter

Ecological functions of organic matter in soil are listed in Leithold (1984). The amount and quality of soil organic matter are influenced by physical and chemical soil properties that have direct impacts on characteristics of soil fertility. From the ecological point of view, the soil organic matter is a reservoir of carbon and nitrogen organically bounded in soil (Christen and O´Halloran-Wietholz, 2002). If these characteristics are used as indicators, it is necessary to distinguish between organic matter content and its modifications over time by means of humus balance. Substantial factors for humus content at the given site are temperature and moisture. At identical farming practices, there are higher C_{ox} values at drier sites because mineralization processes are slowed down.

The importance of humus is related to comprehensive influence of all soil properties and functions. Numerous degradation processes of substances in soil are induced by organic matter supply. Monitoring the management of organic substances on agricultural land use is a significant aspect not only for maintaining the yield potential of soils, but it also affects other ecological functions, especially control of C and N exchange.

Soil pH

Soil reaction is determined by a hydrogen ion concentration. The hydrogen ions are present either in soil solution, and thus they determine actual (active) reaction, or they are bound by soil colloids, and thus determine exchange (potential) reaction. The soil acidity affects the number of chemical, physical and biological properties (soil structure, nutrient availability, presence of aluminium ions, nitrification, and activity of soil microbes). An important property that is influenced by soil pH is its buffering ability.

Aggregation of indicators

There are literature sources referring to ambiguous conclusions whether it is useful to join particular indicators in a final aggregate index or to interpret them separately. Yli-Viikari (1999) does not suppose the aggregation of indicators to be necessary, on the contrary, he stresses spatial and temporal diversity of sustainable development. Likewise, Christen and O´Halloran-Wietholz (2002) state, that the aggregation of indicators results in information loss.

Barnett et al. (1995) measured sustainability of the farming system according to the method developed by the Rockefeller foundation using a *total factor productivity* (TFP) that is based on data on soil, labour, seed, fertilization, soil tillage, etc. If externalities, such as water quality or impacts on surrounding ecosystems, are included, a *total social factor productivity* (TSFP) is defined. The authors do not believe to form the TSFP by involving externalities. They are of the opinion that individual parameters (soil erosion, soil nutrient supply, and others) will provide more information and summary values. Results of TFP calculations strongly depend on yields and therefore they are more useful to carry out analyses on farm or regional levels (Křen, 2002).

Importance of agrosystem structure

Definitions of sustainability cover in most cases a spatial dimension as well. Lowrance et al. (1986) distinguish:

1. a level of fields and their parts (agricultural sustainability),
2. a level of an agricultural enterprise – farm (microeconomic sustainability),
3. a regional level (macroeconomic sustainability).

Sustainability can be defined on various levels using substantially different ways. Herdt and Steiner (1995) recommend, for practical reasons, to allocate the investigations concerning the sustainable development to smaller geographical elements (individual fields or their parts).

The development of new findings and technologies, originally often produced out of agriculture, allows more profound knowledge and evaluation of the relationships mentioned above. Using them, relevant issues of farming in the landscape can be solved:

- description of internal heterogeneity, which is important for the assessment of farming sustainability particularly in larger agricultural enterprises,
- site-specific farming, i.e. modification of farming practices, variable cropping treatments and application of agrochemicals in relation to site conditions,
- effective management of data and information, foundation and building of databases of information so that they would enable to keep records on fields and their parts, and identification of targeted individual operations and inputs within cropping practices, i.e. providing preconditions for solving problems associated with plant product quality and health safety (traceability tools).

Such approaches lead toward breaking the paradigm of homogenous field as a basic unit of agrosystems, on which a traditional concept of agricultural and relevant disciplines is based. Application of the new conception necessitates thorough knowledge of site conditions as a entirety and simultaneously detailed information on micro- and mesorelief, variability in soil, microclimate and stand organization within the field. Detailed evaluation of heterogeneity in site conditions is of variable use and meets the concept of precision agriculture aiming at effective use of natural resources and limitation of unfavourable impacts on the environment. However, introduction of elements of precision agriculture into practice is complicated by special and interdisciplinary demands (it requires knowledge of agronomy, the latest technology, and informatics). Information on internal heterogeneity of fields is usually provided separately according to individual soil characteristics without sufficient interconnection that influences effectiveness of practical use.

At present, there is another handicap consisting in insufficient methodological interconnection between use of the information on heterogeneity in soil characteristics within fields obtained from precision agriculture and generally applied methods for the assessment of farming sustainability that are mostly aimed at higher levels of agrosystem (region, farm, and field). Detailed analyses of several soil characteristics and their variability within fields are not common even though agricultural practice would urgently need them. Here is a space for system research aiming at closer interconnection between sustainability conceptions and precision agriculture. It is also a field for application of information technologies and special models that enable to assess a huge amount of information of various characters.

Table 1 gives characterization of selected indicators based on our investigations (Dubec, 2005). To achieve a regional level, which is required in some cases, it is possible to evaluate farms in the given region and calculate mean values for individual parameters. The level of crops can be used particularly for optimization of plant nutrition. In such a way, the balance method enables to derive nutrient demand for a chosen level of yields or to correct already used rates of organic and mineral fertilizers.

On the level of fields and their parts, it is advantageous to calculate balances of organic matter and nutrients that are important for formation and maintenance of soil fertility. At present, when crop rotations are not kept in agricultural practice, history of individual fields is to be observed and corresponding measures are to be derived. Though the observation of individual fields does not substitute beneficial effects of crop rotation (keeping principles of crop alternation), it is a useful tool to avoid potential faults that can occur, when a regular crop rotation is not kept.

Individual indicators can be of various importance to users depending on the fact to whom and when the certain information is provided. The need of information is different for the farmer who strives to work as effectively as possible and to achieve a profit. Also, it will be different for the state which is concerned particularly with impacts of farming on the environment and source use, and which applies various measures, such as management tools (laws and notices) determining farming conditions in agriculture.

Table 1: Suitability of used indicators for sustainability assessment

Way of sorting	Level	Indicator			
		N balance	P and K balance	humus balance	energy balance
Level of agroecosystem	farm	++	++	++	++
	crop	++	++	++	++
	field	++	++	++	+
	field part	++	++	++	-
Time effects	no differentiation	short-term	long-term	long-term	short-term
Criterion of optimum	no differentiation	equal balance (range can be tolerated)	equal balance	equal balance (range can be tolerated)	minimum of energy consumption; maximum of energy profit
Way of use	farmer	crop, field	crop, field	crop, field	crop
	state	farm, field	farm, field	farm, field	crop
Data need for calculation	no differentiation	yields, N pollutants, seeding rate, symbiotic fixation, fertilization with organic and mineral fertilizers	yields, seeding rate, fertilization with organic and mineral fertilizers	yields, fertilization with organic manures, straw, green manure and nitrogen	yields, soil tillage, sowing, plant protection and nutrition, agronomic treatments during the growing season, harvest and transport

++ very suitable, + suitable, - unsuitable

Conclusions

The information that is used for the calculation of soil fertility indicators should meet the following criteria:

- it should be based on high-quality statistics, it means on a suitable temporal-spatial level, reasonable ratio between costs and evidence ability, monitoring at regular intervals in longer periods,
- it should be clearly methodically derived and reflect a current state of scientific findings; a basic requirement is their validity according to international standards,
- it should be clear, comprehensible and logically explicable.

Most ways of the assessment of farming sustainability continue, through various modifications, the methodology which was originally developed within the Research Network of the EU and associated countries for the designing and testing of integrated and ecological arable crop production systems (Vereijken, 1992 and 1997), which can be now considered as the classic approach in such types of research. This methodology was developed for smaller farms with stable economic and possessive relations. The values of indicators are expressed by weighted mean on a farm level. Such an approach seems to be disputable in the Czech Republic due to larger farms and fields. If analyses are carried out on large farms, some information on systems heterogeneity can be lost and results can be biased.

A suitable tool for the assessment of soil fertility as part of farming sustainability and environmental impacts can be the REPRO model (Hülsbergen, 2003).

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References

Barnett, V., Payne, R., Steiner, R. A. (1995): Agricultural sustainability – Economic, Environmental and Statistical considerations. John Wiley & Sons, Chichester, New York, Brisbane, Toronto, Singapore. pp. 1–257, ISBN 0-471-95009-2.

Dubec, J. (2005): Hodnocení trvalé udržitelnosti hospodaření zemědělských podniků. Disertační práce, MZLU v Brně, s. 115.

Hardin, G. (1974): Living on a lifeboat. Bioscience, 24, pp. 561-568.

Hartman, I. (2002): Tvorba prototypů systémů integrované rostlinné produkce. Disertační práce, MZLU v Brně, Brno, s. 113.

Herdt, R.W., Steiner, R.A. (1995): Agricultural Sustainability: Concepts and Conundrums. In: Barnett, V., Payne, R., Steiner, R. Agricultural sustainability – Economic, Environmental and statistical considerations. John Wiley & Sons, Chichester, New York, Brisbane, Toronto, Singapore, p. 3-13, ISBN 0471-95009-2.

Hlušek, J., Richter, R., Budňáková, M., Klír, J., Balík, J. (2003): Výživa rostlin v ČR – její stav a perspektivy. Sborník referátů z mezinárodní konference, MZLU v Brně, Brno, 315, s. 9-18, ISBN 80-7157-664-6.

Horn, R., Fleige, H. (2001): Prediction of the Mechanical Strength and Ecological Properties of Subsoils for a Sustainable Landuse. In: Christen O. a O´Halloran-Wietholz, Z. (2002): Indikatoren für eine nachhaltige Entwicklung der Landwirtschaft, Institut für Landwirtschaft und Umwelt, Bonn, S. 54, ISBN 3-926898-17-8.

Hülsbergen, K. J., Diepenbrock, W. (1997): Das Model REPRO zur Analyse und Bewertung von Stoff- und Energieflüssen in Landwirtschaftsbetrieben. In Hülsbergen, K. J. (2003):

Entwicklung und Anwendung eines Bilanzierungsmodells zur Bewertung der Nachhaltigkeit landwirtschaftlicher Systeme. Berichte aus der Agrarwissenschaft. Aachen: Shaker Verlag, S. 79-90. ISBN 3-8322-1464-X.

Hülsbergen, K. J. (2003): Entwicklung und Anwendung eines Bilanzierungsmodells zur Bewertung der Nachhaltigkeit landwirtschaftlicher Systeme. Berichte aus der Agrarwissenschaft. Aachen: Shaker Verlag, S. 292, ISBN 3-8322-1464-X.

Christen, O., O´Halloran-Wietholz, Z. (2002): Indikatoren fűr eine nachhaltige Entwicklung der Landwirtschaft. Institut fűr Landwirtschaft und Umwelt, Bonn, 3, S. 7- 84, ISBN 3-926898-17-8.

Christen, O. (1996): Nachhaltige Landwirtschaft („Sustainable agriculture“) – Ideengeschichte, Inhalte und Konsequenzen fűr Forschung, Lehre und Beratung. Berichte űber Landwirtschaft, 74, S. 66-86.

Christen, O. (1998): No more definition please! Some reflections about the ideas and principles of sustainable agriculture. In: EL BASSAM, N., BEHL, R. K., PROCHNOW, B., (1998): Sustainable Agriculture for Food, Energy and Industry, James & James, London, p. 48-52, ISBN-1-873936-1.

Christen, O. (1999): Nachhaltige landwirtschaft, Von der Ideengeschichte zur praktischen Umsetzung. Institut fűr Landwirtschaft und Umwelt, Bonn,1, p. 7-66, ISBN 3-926898-14-3.

Kavka, M. (2003): Příručka pro zemědělce a poradce. Technologické, technické a ekonomické normativní ukazatele pro zemědělství České republiky. Ministerstvo zemědělství České republiky, Agrospoj, Praha, s. 280, ISBN 80-7271-135-0.

Kostelanský, F. et al. (1997): Obecná produkce rostlinná. Skriptum 1. vyd. Brno: MZLU v Brně, s. 114, ISBN 80-7157-245-4.

Křen, J. (2002): Hodnocení trvalé udržitelnosti systémů rostlinné produkce. In: Sborník příspěvků z odborného semináře "Racionální rostlinná produkce a precizní zemědělství", AF MZLU Brno, 5. 9. 2002, s. 39-47.

Kudrna, K. (1979): Zemědělské soustavy (Agrosystems). Státní zemědělské nakladatelství, Praha, 719, s. 560, ISBN 07-007-85.

Leithold, G. (1984): Untersuchung der Beziehungen zwischen ackerbaulichen Massnahmen, Ertrag und Humusreproduktion sowie Erarbeitung einer Methode zur Berechnung des Bedarfs des Bodens an organischer Substanz. Habilitationsschrift, Martin–Luther–Universität Halle–Wittenberg, 127 S.

Lowrance, R., Hendrix, P.F., Odum, E.P. (1986): A hierarchical approach to sustainable agriculture. American Journal of Alternative Agriculture, 1, p. 169-173.

Vereijken, P. (1992): A methodic way to more sustainable farming systems. Netherlands Journal of Agricultural Science, 40, p. 209-223.

Vereijken, P. (1997): A methodological way of prototyping integrated and ecological arable farming systems (I/EAFS) in interaction with pilot farms. In: Ittersum van, M.K., Van de Geijn, S.C. (1997). Perspectives for Agronomy, Adopting Ecological Principles and Managing Resource Use. Special issue of European Journal of Agronomy, 7, 286 pp.

Wischmeier, W.H., Smith, D.D. (1978): Predicting rainfall erosion losses – A guide to conservation planning. In: Christen, O., O´Halloran-Wietholz, Z., (2002): Indikatoren für eine nachhaltige Entwicklung der Landwirtschaft, Institut für Landwirtschaft und Umwelt, Bonn, S. 54, ISBN 3-926898-17-8.

Yli-Viikari, A. (1999): Indicators for sustainable agriculture – a theoretical framework for classifying and assessing indicators. Agriculture and food science in Finnland, 8, p. 365-283.

THE INFLUENCE OF FERTILIZATION AND MANAGEMENT RESIDUES ON SEASONAL CHANGES OF C_{OX}, TOTAL NITROGEN AND BASAL RESPIRATION OF SOIL UNDER SPRING BARLEY CULTIVATION

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Introduction

Management effects on carbon accumulation or loss in soil are expressed through two key metabolic processes: photosynthesis and respiration. Carbon dioxide is assimilated by crops and – at least temporarily- sequestered in biomass and soil. Conversely CO_2 is released back to the atmosphere as an end product of respiration by soil fauna and flora.
Carbon dioxide uptake and emission are not tightly linked in most agro ecosystems, so knowledge of both processes is required to understand soil carbon dynamics and how it is affected by management. Inclusion of high residue-producing crops, forages, or legume green manures in rotation can increase SOC. (Liebig, Gollany 2005).
Nitrogen fertilization can increase SOC over time, but this effect is generally found only in continuously cropped management systems. Fertilization effects on C storage are more complex than just C sequestration rates. Fertilization effects on the net balance of greenhouse gases must include not only potential increase in SOC, but CO_2 emission from the manufacture of N fertilizer as well as nitrous oxide emission from soil. (Lemke, 2004).
Judicious crop rotation may be a useful strategy for increasing short-term SOM and for increasing healthy, fertile and productive soils. Amounts of post harvest crop residues vary widely depending on the crop and intensity with which it is harvested. Mitchell et al. (2000). Rotation that include small grain crops such as wheat, barley, oats, rye, or triticale can offer more possibilities for using post harvest residues with different impact on SOM.
On the short term scale soil respiration is regulated by temperature and soil moisture. This can be shown by diurnal courses of measurements over periods of several days of weeks, respectively. The influence of soil moisture on basal respiration rates measured during drought period at three different plots of the crop rotation field. It is obvious that at each plot the soil respiration rate decreases with decreasing soil moisture content. The decreasing of soil respiration is related to field water capacity and content of SOM via decreasing of water holding capacity (Kutsch and Kappen 1997, Smatana 2000).

Materials and methods

The aim of this study was to evaluated the crop management practices on biological activity of the soil, soil organic matter and total content of nitrogen. The field trials was conduced at the Experimental station of Slovak Agricultural University in Nitra - experimental station Dolná Malanta, during 2001-2003 years. The experimental site belongs to warm and moderate arid climatic region in the south-west of Slovakia. The average precipitation is 561 mm, for the growing season 327 mm. Average air temperature is 9.7°C. The main soil type is Orthic Luvisol with good supply of accessible N, P and K and pH 5.7 in average. Clover (*Trifolium pratense L.*) - winter wheat (*Triticum aestivum L*) - common pea (*Pisum sativum L.*) - **maize**

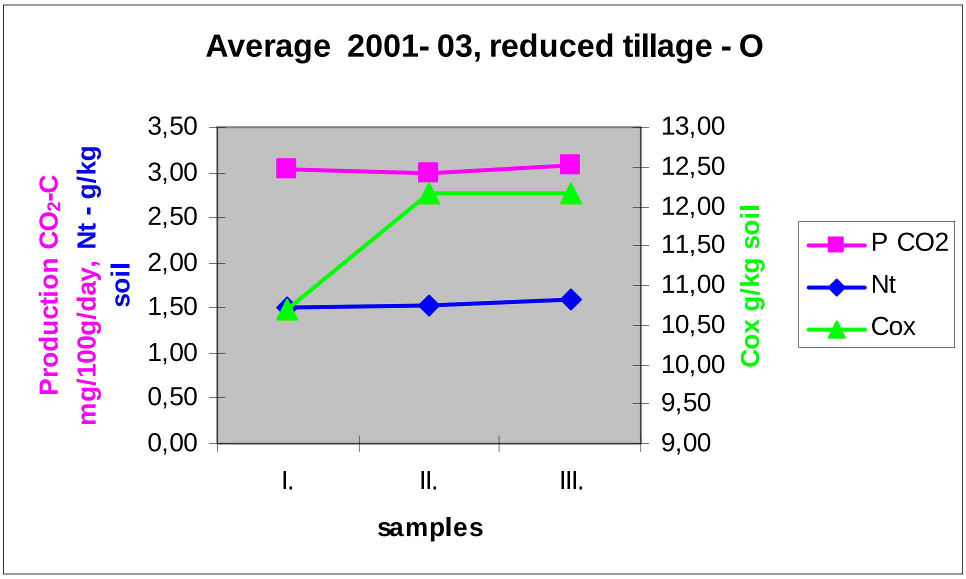
(*Zea mays L.*) - **spring barley** (*Hordeum vulgare L.*) were under different residue management practices. Three fertilization management practices as follows: 0 - zero level without organic or inorganic fertilization, respectively, F - mineral fertilizer calculated to the designed yield level, PR – incorporating all above-ground plant material as a source of organic matter and mineral fertilizer for the balance equilibrium level. Reduced tillage to the depth 0.10-0.12m + surface cultivation has been used. Common pest and disease control practices were used. Plots were divided into subplots (11 x 40m) and were subjected to fertilization treatments with four replications. The soil samples were collected from the 0.075m topsoil layer three times (spring- 2-3 weeks after sowing, summer -2 days before harvest, autumn- second decade of September). The soil samples were incubated at 28 ^{o}C, and soil basal respiration was measured 21 days five times a week according Bernát Seifert method.

Results and discussion

Effect of crop and rotation phase on soil organic carbon and total nitrogen content which create C:N ratio, and soil basal respiration have been studied under reduced tillage in spring barley rotation phase.

The rate of basal respiration during vegetation period of spring barley rotation phase has the equilibrium level represented by soil basal respiration in narrow interval 3.0 -3.08 mg/100 g of soil sample per day. The level of basal respiration indicated rate of mineralization of soil organic matter. The high and increasing level of CO_2 flux from soil due to respiration processes on treatments without fertilization and by removing all about ground residues was influenced predominantly by growing crop. The roots exudates and other accessible organic mater increased also the content of organic carbon content (Cox). It is evident from second sample analysis of average data during 2001-2003. According results demonstrated on Fig. 1 the increasing of organic carbon expressed as C_{ox} from top layer of evaluated treatments was influenced by growing crops. First sample was taken during time of small plantlet of barley 3-4 weeks after seeding. The seasonal content of Nt (total nitrogen) was in narrow interval.

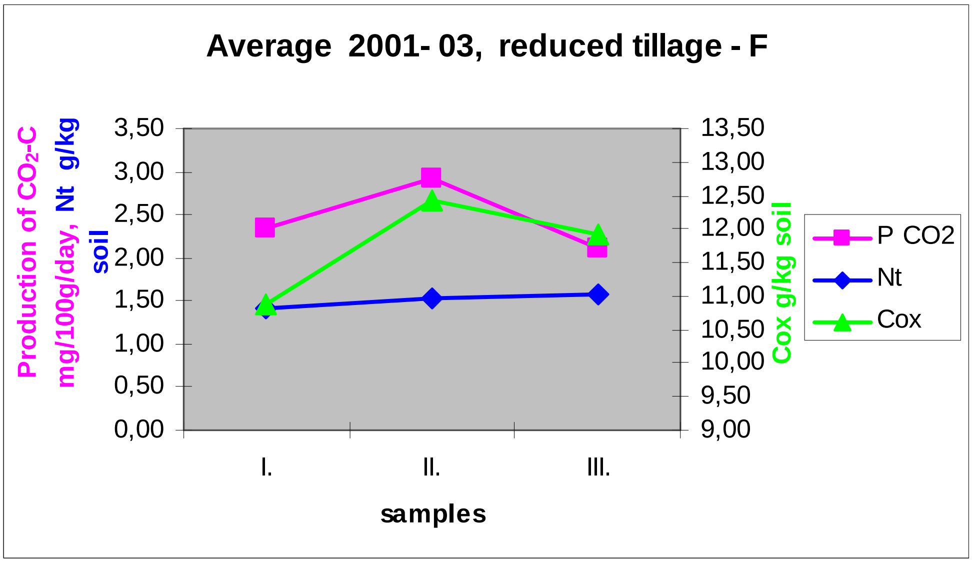
Fig.1



As expected, rotation phase did not influence soil organic carbon on treatments with removing forecrop above ground residue of maize. (Fig. 2). The seasonal changes of organic carbon content has the same course and level as zero treatments.

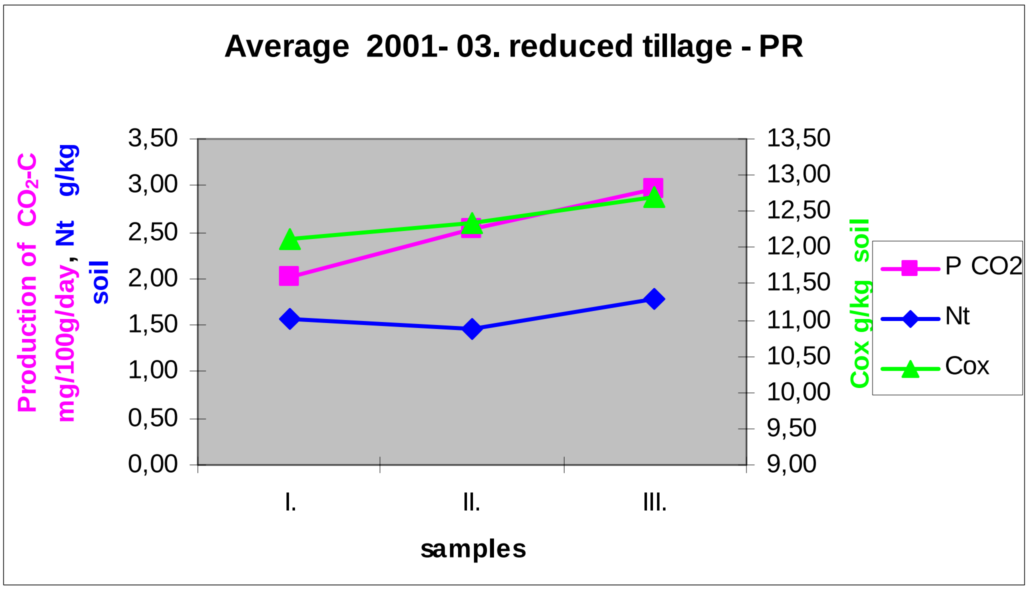
The positive secondary effect of fertilization on content of organic carbon has been not observed. The assessment of basal respiration indicated the changed tendency in SOM status (Macák, Pospišil 2001). In the same way Mülbachová and Růžek (2000) mentioned correlation between content of total organic carbon and basal respiration of soil.

Fig. 2



The influence of forecrop incorporated above ground material and growing crops on evaluated parameters is documented on Fig. 3. The treatments with incorporation of crop and post harvest residues reflect condition for nutrient cycle of C and biological activity of soil. The average content of organic carbon was in interval 12.13-12.7 g/kg of soil. The differences in carbon organic content on the same type of the soil in ecological system (13.1 g/kg) and integrated system (12.5 g/kg) noted Szombatová (1999). Relatively balanced C:N ratio 7.8:1, 8.4.1, 7,14:1 was reached during spring, summer, autumn samples.

Fig. 3



According the three years evaluated period (2001-2003) with history of treatments from 1994 we can make preliminary conclusion:

- Relatively high level of basal respiration and flux of carbon dioxide from unfertilized zero treatments or mineral fertilization only, pointed out the threaten of soil organic matter pool from long term perspective.
- The basal respiration and organic carbon content were influence during vegetation period of growing crop.
- The seasonal changes of C:N ratio were caused due to changes of organic carbon content with steady increasing tendency of Nt. Relatively balanced C:N ratio 7.8:1, 8.4.1, 7,14:1 was reached during spring, summer, autumn samples of treatments with incorporation about ground plant material.
- The positive secondary effect of fertilization on content of organic carbon has been not observed.
- The treatments with incorporation of crop and post harvest residues reflect positive condition for balance of organic C content by medium level of basal respiratory activity of soil.

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References

Kutch W.L, Kappen L (1997) Aspect of carbon and nitrogen cycling in soils of the Bornhoved Lakes district II. Modeling the influence of temperature increase on soil respiration and organic carbon content in arable soils under different management. Biochemistry. 39, 207-224

Lemke, R. (2003): No till, carbon sequestration, and nitrous oxide emission. In: Proc. Direct Seeding Advantage. Nov.2003, Nisku, AB. Reduced tillage Linkages

Liebig M.A, Gollany, H.T. (2005): Sequestering Carbon in Cropland, Effects of Management in Semiarid Regions of NW USA and Western Canada. USDA, 105 p.

Macák M., Pospišil, R. (2001): The influence of different crop management practices on soil biological characteristics. ISTRO Proceeding, Brno 2-5 October 2002, p.217-219. ISBN 80-902436-7-3

Mitchell, J. et al. (2000): Soil management and soil quality for organic crops. University of California: Division of Agriculture and Natural Resources. Publ. No. 7248

Mülbachová, G., Růžek, P. (2000): Bilogical indication of heavy metal contamination of soils by the incubation method. In. Rostlinná výroba. Vol.46, 2, p.87-92

Smatana, J. (2000): Zhodnotenie vplyvu rozličnej intenzity obrábania pôdy na dynamiku pôdnej vlhkosti pri pšenici letnej formy oimnej. In: Proceedings. Pestovanie a využitie obilnín na prelome milénia. Nitra: SPU, 114-118.

Szombatová, N. (1999): Comparison of soil carbon susceptibility to oxidation by KMNO4 in different farming system in Slovakia. In: Humic substances in the environment. Vol. 1, No.3/4, p. 35-39

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