# ISTRO – BRANCH CZECH REPUBLIC

(International Soil Tillage Research Organization)

by **Research Institute for Fodder Crops, Ltd., Troubsko**

**7th International Soil Conference**

# SOIL MANAGEMENT IN SUSTAINABLE FARMING SYSTEMS

Proceedings of Conference

**Křtiny near Brno, Czech Republic**

**June 25 – 27, 2014**

## Organizing committee of the conference

**Members:**

Smutný Vladimír e-mail: smutny@mendelu.cz
Badalíková Barbora e-mail: badalikova@vupt.cz
Bartlová Jaroslava e-mail: bartlova@vupt.cz
Winkler Jan e-mail: winkler@mendelu.cz
Procházková Blanka e-mail: proch@mendelu.cz
Lukas Vojtech e-mail: vojtech.lukas@mendelu.cz
Dryslová Tamara e-mail: dryslova@mendelu.cz
Neudert Lubomír e-mail: neudert@mendelu.cz

**Scientific board:**

Hula Josef e-mail: hula@vuzt.cz
Kren Jan e-mail: kren@mendelu.cz
Procházka Jaromír e-mail: prochazka@vupt.cz
Kroulik Milan e-mail: kroulik@tf.czu.cz
Rosner Josef e-mail: josef.rosner@noel.gv.at
Birkás Marta e-mail: Birkas.Marta@mkk.szie.hu
Jug Danijel e-mail: djug@pfos.hr
Smutný Vladimír e-mail: smutny@mendelu.cz
Lehóczky Eva e-mail: lehoczky.eva@agrar.mta.hu

---

**Contributions were reviewed by Members of Scientific Committee**

## Conference topics:

1. Soil fertility and plant nutrition (soil physics, soil and water management, soil chemistry, soil biology, erosion)
2. Soil tillage in relation with crop protection (role of soil tillage in integrated pest management, occurrence and harmfulness of diseases, pests and weeds)
3. Perspective soil tillage practices (mechanization of agriculture, energy inputs, economy)
4. Cropping systems (modification crop management practices adapted to the soil conditions – crops and crop varieties, crop rotation, fertilization in conventional, organic and precision agriculture)

## Location

The Conference will be held in Chateau Krtiny (www.zamek-krtiny.cz) owned by Mendel University in Brno. **Krtiny** is a market town in Blansko District, South Moravian Region (20 km far from Brno), Czech Republic, lying on boundary of the Moravian Karst nature reserve. The town is an old Marian pilgrimage site (administered by the Premonstratensians) and is dominated by a Baroque pilgrim complex; the original project by Jan Santini Aichel was modified during construction and was not fully completed. It comprises the Church of the Holy Name of Mary (houses a Gothic statue of the Virgin Mary), St. Anne Chapel, Provost Residence and other buildings.

**Position GPS**:
49°17'49,323''N
16°44'31,606''E

Křtiny • Mapy.cz Stránka č. 1 z 1


http://beta.mapy.cz/ 3.6.2014

# CONTENT

# INTRODUCTORY WORD

**Ladies and Gentleman,**

I am sincerely honoured to welcome you on the Istro conference 2014 on behalf of the Research Institute for Fodder Crops, Ltd. Troubsko (hereinafter refferd as "RIFC"), that participates on the conference organisation as a host organisation.
Scientific committee gave a special attention to elect interesting topics for oral and poster lectures and I believe they will attract your attention. I consider discussions about new perspectives in soil management and its role in sustainable agriculture very vital. Agricultural sector is facing a new seven years period of EU programme. Soil management is challenging for new practice application as soil is one of the main nature resource. Protection of soil quality and organic soil life is very important not only for current agricultural production but mainly for future utilization of soil as basic part of landscape. The discussion how to balanced food production, non – food production and also agro fuel policy must begin sooner than later not only on the national levels, but primarily on the European level. Farmers will be receiving support to increase effectiveness of that agriculture production that will also guarantee protection of culture and nature heritage.
I believe that our conference will help to improve the agriculture production as the presented papers will provide information about new agriculture technologies and innovation, the conference itself is a great opportunity for discussions between leading experts of agriculture research, public bodies and agriculture producers.
Conference also creates an opportunity to present the host institution. Therefore I would like to introduce you the Research Institute for Fodder Crops, Ltd. Troubsko and its daughter company Agriculture Research, Ltd. Both companies are established as private research institutions specialized particularly in applied research in agriculture and food processing industry and in environmental area. The range of studied species includes aside from fodder crops another plant species interesting for floricultural and manufacturing practice. The experimental activity is aimed for the research of basic genetic and breeding parameters, seed production, harmful factors protection, basic agricultural engineering and environmental research including the landscape revitalization.
RIFC has experience in commercialization of research results. It is the holder of rights to several varieties, which are marketed through either direct selling of seeds or through assigning of licenses to the growers. It holds several utility models such as liquid fertilizer on bread with added non-traditional legume mixtures of plant species for pollinators or for efficient production of fodder. These legally protected results tries to apply on market through its partners. Another form of transfer of results and their commercialization is issuing certified methodologies that are used in counselling activities of the applicant or directly distributed to the users - breeders, farmers, government. This type of results is provided to the users on equal terms. Agriculture Research, Ltd. was founded in 2003 and immediately embarked upon the research project "Genetic breeding and technological aspects of sustainable fodder crops production". It is currently carrying out a number of publicly co-financed research projects.

RIFC is holder of ISO certificates of management quality and environmental management, it is the coordinator and leading partner of many national and international R&D projects and we are open to new partnership and cooperation in new R&D projects. We can offer rich experience in the implementation of long-term research projects, commercialization of R&D results, and established network of partners such as public and private R&D institutions,

public organisations and non governmental bodies from both Czech republic and abroad. More information can be find on our web pages www.vupt.cz.
I hope that the Istro conference 2014 will be inspirative for you all and that you will enjoy the stay in the Czech republic. I wish you pleasant stay in Brno and I am looking forward to meet you during the conference.

**Contact address:**

RNDr. Jan Nedělník, Ph.D.
Director
Research Institute for Fodder Crops, Ltd. Troubsko
Zahradní 1
66441 Troubsko, Czech Republic
e-mail: nedelnik@vupt.cz

# CHANGES IN SOIL STRUCTURE AND WATER RESISTANCE OF SOIL AGGREGATES AFTER THE APPLICATION OF WINE MARC COMPOST

**B. Badalíková, J. Bartlová, T. Vymyslický**

Research Institute for Fodder Crops, Ltd., Troubsko, Czech Republic

**Abstract**

The effect of incorporated grape marc compost on the development of soil structure and water resistance of soil aggregates is monitored in two experimental sites, namely on arable land and in a small plot trial since 2012. Climatic and soil conditions of both localities are different. The obtained results indicated that the application of higher doses of grape marc compost into the soil showed a positive effect both on the soil structure and the water resistance of soil aggregates.

**Key words:** compost; soil structure; wine marc; soil aggregates

## Introduction

The use of organic materials enhancing properties of soil is a traditional method that enables to improve its physicochemical properties, structure, temperature and humidity on the one side and to increase the content of nutrients that are necessary for the growth and development of plants on the other. The application of organic materials into the soil may cause changes in soil microflora and soil microfauna that involves also a very extensive and very diverse group of nematodes (Renco, 2013).

It was found out that composts made of separated manure or wine marc inhibit the occurrence of galls (cecidia) on tomato roots that are caused by pathogenic nematodes of the species *Meloidogyne javanica*. Results published by Oaka & Yermiyahu (2002) indicated that a high concentration of oxygen in soil and a high electrical conductivity of soil aggregates contributed to the capacity of these composts to inhibit and/or kill nematodes.

Brown & Cotton (2011) quantified positive effects of compost application into cultivated soils. They found out that – as compared with control – the application of compost resulted in a threefold increase in the content of soil organic nitrogen and in a twofold increase in the soil microbial activity. The process of composting is a conventional method how to liquidate organic wastes. If we want to reach a balance in properties of the final product of composting (e.g. its good physicochemical properties, capacity to inhibit and/or suppress phytopathogens, good degree of humification etc.), it is necessary to use for making such composts different source materials (Moral et al., 2009). It was also found out that on non-permeable clayey subsoil a greater depth of the compost application into the soil improved the runoff and reduced the degree of waterlogging while on more permeable clayey subsoils this method of compost application extended the period of draught, above all in deeper soil layers (Whelan et al., 2013).

## Material and methods

Since 2012, changes in soil properties after the application of compost made of grape marc and some additive components were monitored in several selected localities. Compost was made in a closed composting plant EWA in the town Město Albrechtice. Samples used for the evaluation of soil properties were collected at the beginning and to the end of the growing season.

Estimations of soil structure and water stability of soil aggregates were performed in the pedological laboratory of the Research Institute for Fodder Crops in Troubsko. Soil structure was assessed by sieving dry soil through sieves with the mesh size of 0.25; 0.5; 2. 5; 10 and 20 mm. Soil samples were taken always in three replications from two different depths, viz. 0 – 0.15 and 0.15 – 0.30 m. Each structural fraction was separately weighed and converted to percentages. The evaluation itself was performed on the base of calculated coefficients of structurality that expressed the relationship between structural elements of agronomic value (0.25-10 mm) and those of a lower value (>10 and <0.25 mm). The water stability of soil aggregates was assessed using the method of wet sieving (Kandeler 1996). In individual soil samples, percentages of stable soil aggregates (i.e. those that were not destroyed by water) were calculated using a special formula. Soil was sampled in two replications again in two different depths, viz. 0 – 0.15 and 0.15 – 0.30 m. The content of water in soil (expressed as its percentage by weigth - wt%) was estimated in three replications by means of gravimetry in depths of 0 – 0.10; 0.10 – 0.20 and 0.20 – 0.30 m.

Experiments were established in two different localities, i.e. in Troubsko (a small-plot experiment) and in Rakvice (a field experiment).

*Soil and climatic conditions*

A) The small-plot experiment in Troubsko (district Brno-County): This locality is situated in a sugar-beet-growing region and is classified as mildly warm and mildly dry. Its altitude is about 333 m above sea level. The soil is classified as a chernozem developed on the loessial subsoil with the loamy to clayey-loamy texture. The long-term annual sum of precipitations is 547 mm (of this, 344 mm occur within the growing season). The long-term average annual temperature is 8.4 $^0$C (within the growing season, the average temperature is 14.8 $^0$C). The plot is situated on flatland.

B) The field experiment in Rakvice (district Břeclav): This locality is situated in a maize-growing region and is classified as very warm and dry. Its altitude is about 164 m above sea level. The soil is classified as pellic chernozem (vertisol) that developed on very heavy substrates (clays, marls, Carpathian flysch and tertiary sediments). These soils are classified as heavy to very heavy with a lighter ploughing horizon; here and there they contain admixtures of 10 % gravel and are prone to a surface waterlogging. The plot is akso situated on flatland.

Variants of wine marc application:

Troubsko
Variant 1 – Control, without compost
Variant 2 – 50 t / ha
Rakvice
Variant 1 – Control, without compost
Variant 2 – 50 t / ha
Variant 3 – 100 t / ha

**Results and Discussion**

Structural data assessed within the framework of the small-plot experiment established in Troubsko in Variant 1 and in Variant 2 by means of the coefficient of structurality are presented in Fig. 1. The obtained results indicated that in the second year of this experiment, the soil structure improved in both soil layers and in both variants. In Variant 2, the improvement of soil structure was the most marked in the surface soil layer, i.e. in the depth of 0 – 0.15 m.

Structural data about soils in Rakvice are presented in Fig. 2. As far as values of the coeffiucient of structurality are concerned, in this locality the soil texture is not so good as in Troubsko. It was found out that in all variants its values in the upper soil layer were higher than 1; in the bottom soil layer they were higher than 3 only in Variant 3 (i.e. with the maximum dose of grape marc compost).. In average, the highest values of the coefficient of structuraliy were recorded in variants with the highest dose of compost in both years. In 2013, there was a decrease in structural values (probably due to a dry summer season; in this year there were no rainfalls for 2.5 months so that the decomposition of applied compost was not possible and did not take place). Because of the compactness of soil, the applied compost caused a transient deterioration of soil structure. In spite of this, however, a better soil structure was observed in the deeper soil layer.

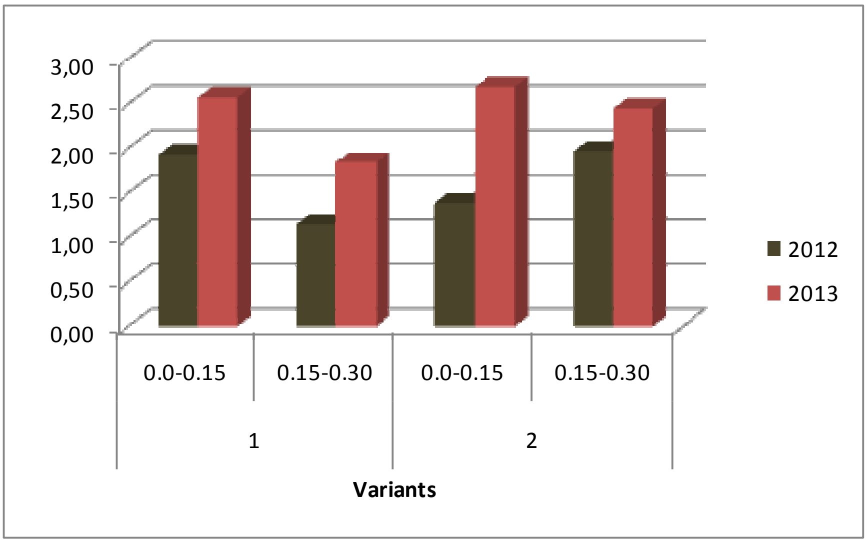



**Fig.1: Soil structure in different variants with applied grape marc compost (Troubsko, 2012-2013)**

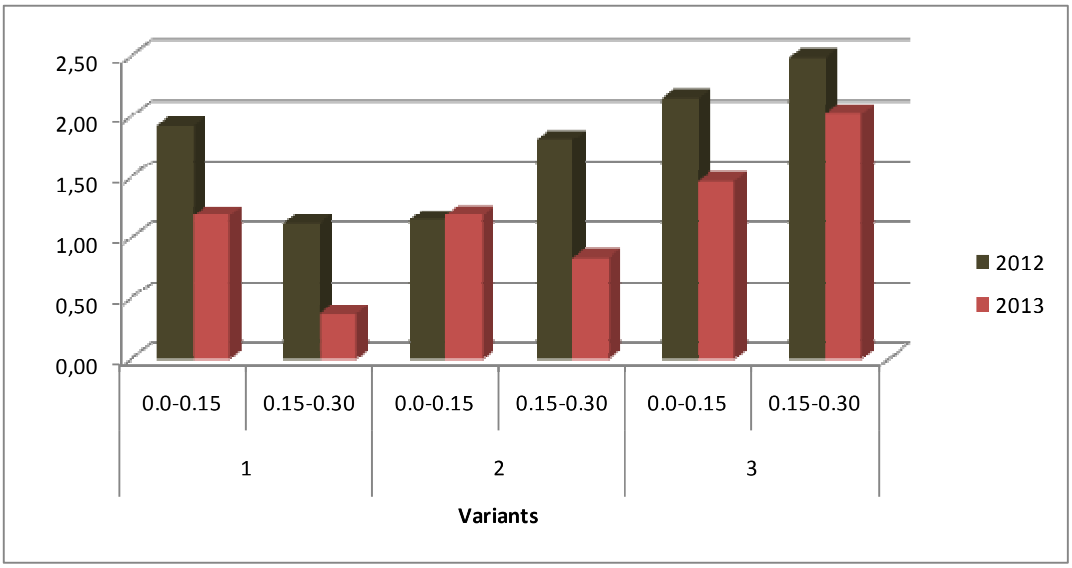



**Fig.2: Soil structure in different variants with applied grape marc compost (Rakvice, 2012-2013)**

As far as the stability of soil structure within the soil profile was concerned, there were differences caused by changing contents of organic matter and by presence of different forms of calcium carbonate, iron oxides, clay particles and $pH_{KCl}$ (Kodešová et al., 2009; Annabi et al., 2007).
The water resistance of soil aggregates was estimated only once in the course of the growing season, viz. to the end of August. This was sufficient to evaluate this soil property.
In Troubsko, the measured values of water stability were at a medium level in both years (Tab. 1). In Variant 2, the recorded values were slightly higher. Also in this locality a decrease in the water resistance of soil aggregates in deeper sampling layers was obvious.
Results obtained in the field experiment are presented in Tab. 2. As one can see, higher values were recorded in Variant 3. Values of water resistance were better than those recorded in Troubsko. In 2012, differences between individual experimental variants were great while no significant differences were found out in 2013. A better stability of soil aggregates was observed in the deeper soil layer; this finding was correlated with values of soil structure. Zhang et al. (2014) observed that the application of organic material (e.g. straw) increased the stability of soil aggregates and, thus, also improved the soil structure.

**Table 1: Water stability of soil aggregates in different variants with applied grape marc compost – Troubsko, 2012-2013**

| Variants | Soil depth (m) | Years | |
|---|---|---|---|
| | | 2012 | 2013 |
| 1 | 0.0-0.15 | 22.32 | 28.74 |
| | 0.15-0.30 | 15.81 | 29.54 |
| | mean | 19.07 | 29.14 |
| 2 | 0.0-0.15 | 24.29 | 39.06 |
| | 0.15-0.30 | 21.44 | 27.82 |
| | mean | 22.87 | 33.44 |

**Table 2: Water stability of soil aggregates in different variants with grape marc compost – Rakvice, 2012-2013**

| Variants | Soil depth (m) | Years | |
|---|---|---|---|
| | | 2012 | 2013 |
| 1 | 0.0-0.15 | 30.93 | 40.73 |
| | 0.15-0.30 | 31.38 | 47.66 |
| | mean | 31.16 | 44.20 |
| 2 | 0.0-0.15 | 46.89 | 36.29 |
| | 0.15-0.30 | 38.33 | 48.22 |
| | mean | 42.61 | 42.25 |
| 3 | 0.0-0.15 | 52.45 | 39.56 |
| | 0.15-0.30 | 53.14 | 48.92 |
| | mean | 52.79 | 44.24 |

In the small-plot experiment in Troubsko (Tab. 3), contents of soil moisture were similar in both variants in 2012 while in 2013 higher levels were recorded in Variant 2. Higher levels of soil moisture were recorded in the upper soil layer in both variants and in both experimental years.

**Table 3: Soil moisture in different variants with grape marc compost – Troubsko, 2012-2013**

| **Variants** | **Soil depth (m)** | **Years** | |
|---|---|---|---|
| | | 2012 | 2013 |
| | | **% wt.** | |
| 1 | 0.0-0.10 | 22.55 | 19.23 |
| | 0.10-0.20 | 12.72 | 18.72 |
| | 0.20-0.30 | 11.71 | 18.45 |
| | mean | 15.66 | 18.80 |
| 2 | 0.0-0.10 | 22.14 | 21.96 |
| | 0.10-0.20 | 13.03 | 19.97 |
| | 0.20-0.30 | 12.37 | 18.61 |
| | mean | 15.85 | 20.18 |

In Rakvice, the content of water in soil was determined by means of gravimetry performed immediately after the sampling (Tab. 4). As one can see, a higher soil humidity was recorded in variants with applied grape marc compost in both experimental years. In all variants under study, a higher content of soil moisture was recorded always in the upper soil layer. Raviv et al. (2004) found out that compost application into the soil increased generally its water retention capacity. In sandy-loamy soils, the hydraulic conductivity of soil showed a tendency to decrease while in clay and clay-loamy soils the application of compost induced an enlargement of soil pores and, thus, increased their hydraulic conductivity.

**Table 4: Soil moisture in different variants with grape marc compost – Rakvice, 2012-2013**

| Variants | Soil depth (m) | Years | |
|---|---|---|---|
| | | 2012 | 2013 |
| | | % wt. | |
| 1 | 0.0-0.10 | 21.70 | 19.82 |
| | 0.10-0.20 | 18.11 | 19.58 |
| | 0.20-0.30 | 16.97 | 18.02 |
| | mean | 18.93 | 19.14 |
| 2 | 0.0-0.10 | 21.34 | 21.03 |
| | 0.10-0.20 | 21.16 | 20.19 |
| | 0.20-0.30 | 21.42 | 19.04 |
| | mean | 21.31 | 20.08 |
| 3 | 0.0-0.10 | 21.10 | 20.90 |
| | 0.10-0.20 | 21.32 | 20.04 |
| | 0.20-0.30 | 22.44 | 19.27 |
| | mean | 21.62 | 20.07 |

## Conclusions

Basing on obtained results it is possible to conclude that the effect of applied grape marc compost was more and more obvious, above all in the locality Troubsko. The applied compost improved soil properties, i.e. its structure, water resistance and content of soil moisture. In the locality Rakvice, a better soil structure was recorded only in the upper soil layer and in the second experimental year. The water stability of soil aggregates was positively influenced by ccmpost application. In variants with applied compost, the content of soil moisture was also higher. These results were influenced not only by a great variability of climatic conditions that existed in 2013 but also by a too shallow application of grape marc compost.

## Acknowledgement

Presented results were supported from financial funds of the project Eureka No. E! 6742 WINEREST LF12006 „Sustainable and innovative use of wastes from grape and fruit processing“.

## References

ANNABI, M., HOUOT, S., FRANCOU, C., POITRENAUD, M., LE BISSONNAIS, Y., 2007: Soil aggregate stability improvement with urban composts of different maturities. Soil Sci. Soc. Am. J., 71 (2): 413-423

BROWN, S., COTTON, M., 2011: Changes in soil properties and carbon content following compost application: Results of on - farm sampling. Compost Science and Utilization, 19 (2): 87-96. ISSN 1065-657X

KODEŠOVÁ, R., ROHOŠKOVÁ, M., ŽIGOVÁ, A., 2009: Comparison of aggregate stability within six soil profiles under conventional tillage using various laboratory tests. Biologia, Section Botany, 64 (3): 550-554.

MORAL, R., PAREDES, C., BUSTAMANTE, M. A., MARHUENDA-EGA, F., BERNAL, M. P., 2009: Utilisation of manure compost by high-value crops: Safety and environmental challenges. Bioresource Technology, 2009, 100: 5454-5460. ISSN 0960-8524

OAKA, Y., YERMIYAHU, U., 2002: Suppressive effects of composts against the root-knot nematode Meloidogyne javanica on tomato. Nematology, 2002, 4: 891-898. ISSN 1388-5545

RAVIV, M., MEDINA, S., KRASNOVSKY, A., ZIADNA, H., 2004: Organic matter and nitrogen conservation in manure compost for organic agriculture. Compost Science and Utilization, 2004, 12 (1): 6-10. ISSN 1065-657X

RENCO, M., 2013: Organic amendments of soil as useful tools of plant parasitic nematodes control. Helminthologia, 2013, 50 (1):3-14. ISSN 0440-6605

WHELAN, A., KECHAVARZI, C., COULON, F., SAKRABANI, R., LORD, R., 2013: Influence of compost amendments on the hydraulic functioning of brownfield soils. Soil Use and Management, 2013, 29 (2): 260-270. ISSN 0266-0032

ZHANG, P., WEI, T., JIA, Z., HAN, Q., REN, X., LI, Y., 2014. Effects of straw incorporation on soil organic matter and soil water-stable aggregates content in semiarid regions of northwest china.
*PLoS One*, *9*(3) doi:http://dx.doi.org/10.1371/journal.pone.0092839

**Contact Address:**

Dipl. Ing. Barbora Badalíková
Research Institute for Fodder Crops, Ltd.
Zahradní 1
664 41 Troubsko, Czech Republic
e-mail: badalikova@vupt.cz
phone: +420 547 138 821

Dump of wine marc

Soil sampling – physical properties

# WATER STABILITY OF SOIL AGGREGATES UNDER DIFFERENT COMPOST DOSES

**J. Bartlová, B. Badalíková**

Agricultural Research Ltd., Troubsko, Czech Republic

**Abstract**

Effects of application of different compost doses on macro structural changes taking place in the ploughing layer were monitored in years 2012 and 2013. The macro structure was evaluated on the base of the water stability of soil aggregates. The pilot experiment was established in Velešovice, Czech Republic in the altitude of 228 m above sea level. The village of Velešovice is situated in the sugar-beet growing region and the long-term average precipitations and temperatures are 490 mm and 8.7 $^{0}$ C, respectively. Experimental variants were as follows: Var. 1 – control (without compost); Var.2 – compost dose of 20 t.ha$^{-1}$ and Var. 3 – compost dose of 40 t.ha$^{-1}$. Obtained results indicate that the application of compost influenced positively the development of soil structure and the water resistance of soil aggregates.

**Keywords:** water stability; soil aggregates; structural coefficient; chernozem

## Introduction

Soil particles form smaller or greater clusters called soil aggregates. The term “soil structure“ characterises the spatial arrangement of these soil aggregates (Kutílek, 1978). The term “aggregate stability“ refers to the resilience of soil structure exposed to external mechanical forces. Many authors consider the soil aggregation to be a parameter that reflects soil health because it is dependent on chemical, physical, and biological factors (Mataix-Solera, 2011). The stability of soil aggregates is a product of interactions between soil environment, management practices, and land use patterns (Zhang *et al.*, 2008). The aggregate stability is dependent on soil type and texture class, content of organic matter (Javůrek & Vach, 2009), biological activity of soil (Oades, 2005), fertilizer application (Anabi *et al*., 2007), soil tillage practices, and also on the vegetative cover.

The use of soil improving organic materials represents an old practice of conventional agriculture that enables to improve physical and chemical properties of soils, soil structure, Soil temperature, soil humidity and also contents of nutrients required for the growth of plants (Renco, 2013).

Brown and Cotton (2011) quantified advantages resulting from the application of compost in agricultural soils. They found out that, as compared with control, this resulted in a triple increase in the content of organic carbon in soil. The soil microbial activity increased twice. The application of compost also increased significantly the content of water in soil and reduced its bulk density and shortened the time interval of water infiltration into the soil. The availability of nutrients was comparable with control. In the variant with the highest dose of compost, the effect of its application into the soil was more positive than in the variant with its lower dose or in the variant with a conventional system of farming. The efficiency of lower compost doses was comparable with that of control.

Annabi *et al.* (2011) compared the efficiency of a repeated application of municipal compost and manure on dusty topsoils with a low stability of soil aggregates and found out that in the majority of cases the application of municipal compost showed a positive effect on the stability of soil aggregates than the application of manure. These authors concluded that compost could be used when trying to increase the resistance of soil against water erosion. Arthur et al. (2010) studied effects of applied compost on the stability of soil aggregates and the resistance of light soils to effects of water erosion. These authors found out that after the application of compost made of garden greenery waste a significant increase in the stability of soil aggregates took place; when applying composts made either of fruit and vegetable waste or waste generated at mushroom producing facilities the differences were statistically not significant. As mentioned by Duong *et al*. (2012), effects of compost application were different and depended on the type of applied compost (i.e. on the original waste and on the compost maturity).

## Materials and methods

In 2012 – 2013, a pilot experiment was established in the cadastre of Velešovice village (Czech Republic). This locality is situated in the sugar-beet-growing region at the altitude of 328 m. Local soils were characterised as clayey-loamy carbonate chernozem with an alkaline soil reaction. Average annual sums of temperature and precipitations were 8.7 °C and 490 mm, respectively. In years 2012 and 2013, only maize (*Zea mays*) were grown in this locality. There were three experimental variants with different doses of compost applead in the autumn of each year.

Experimental variants:
Variant 1: Control – without compost
Variant 2: Compost applied in the dose of 20 t.ha$^{-1}$
Variant 3: Compost applied in the dose of 40 t.ha$^{-1}$

Soil samples were collected every year in the spring and in the autumn, i.e. at the beginning and to the end of the growing season. Sampling was performed in two different depths of the ploughing layer (viz. 0-0.15 m and 0.15-0.30 m) and in three different sampling sites.
The soil structure was evaluated by screening of dry soil through sieves with different mesh size (0.25; 0.5; 1; 5; 10 and 20 mm). The evaluation itself was based on calculated structural coefficients (SC) which expressed the relationship existing between structural element of agronomic value (i.e. 0.25-10 mm) and of a lower of agronomic value (i.e. >10 and <0.25 mm).
Values of water stability of soil aggregates (WSA) were estimated using the method of sieve analysis (Kandeler, 1996). WSA was expressed as the percentage of water stable aggregates in the total amount of aggregates after subtracting the proportion of sand.
Experimental results were statistically processed using the multi-factorial analysis of variance and the Tukey's tests of simple contrasts. The statistical analysis was performed using the software package Statistica 7.

## Results and discussion

WSA values estimated in individual experimental variants are presented in Fig. 1. As compared with Variant 1 (i.e. without compost), WSA values estimated in Variants 2 and 3 (i.e. with different compost doses) were higher. The best WSA values were recorded in Variant 2. Similar results were published also by Paluszek (2010).

CONTENT

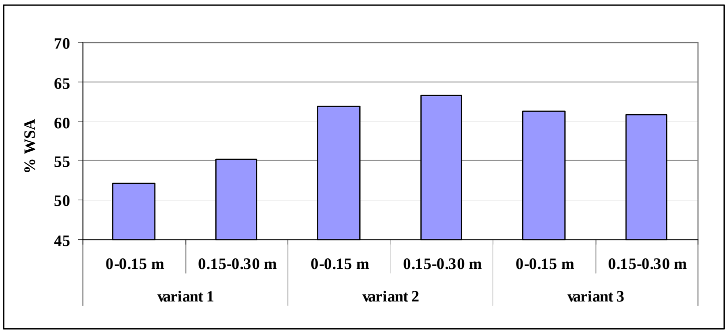



Fig. 1. Average values of water stability of soil aggregates (%) in years 2012-2013

On fields, compost application resulted in an increase in the content of organic matter in soil. According to Kroulík *et al*. (2010), organic matter showed a positive effect on soil fertility, increased the stability of soil aggregates and improved soil structure. As shown in Tabs 1 and 2, there was a statistically significant difference in WSA values recorded in Variant 1 (Control) and Variants 2 and 3 (i.e. with different doses of applied compost).

Table 1. Analysis of variance of water stability of soil aggregates (%) in years 2012-2013

| Effect | d.f. | Mean square |
|---|---|---|
| Variant | 2 | 269.2 ** |
| Error | 33 | 35.6 n. s. |

*** P = 0,001; **P = 0,01; *P = 0,05; n.s. non-significant

Table 2. Tukey HSD test - WSA

| Variant | Average |
|---|---|
| 1 | 53.71[b] |
| 3 | 61.05[a] |
| 2 | 62.57[a] |

Average values indicated by various letters are statistically different

In the experimental locality, the soil structure was not good (Fig.2). Its structure was impaired, especially in the lower soil layer (i.e. in the depth of 0.15-0.30 m). Calculated values of the structural coefficient were lower than 1. A better soil structure was found out only after the application of a higher compost dose (i.e. in Variant 3).

Well-matured compost supplies humus into the soil and this markedly accelerates the process of recovery of its fertility. To assure a good balance and reserves of humus in soil, it is necessary to supply approximately 1.5 $t.ha^{-1}$ of net organic matter per year; this means that it is necessary to apply approximately 9 $t.ha^{-1}$ of medium-quality manure (Badalíková and Bartlová, 2011). Ortas *et al*. (2013) and Pardini *et al.* (2008) also reported that application of compost into the soil improved not only soil structure but also its fertility.

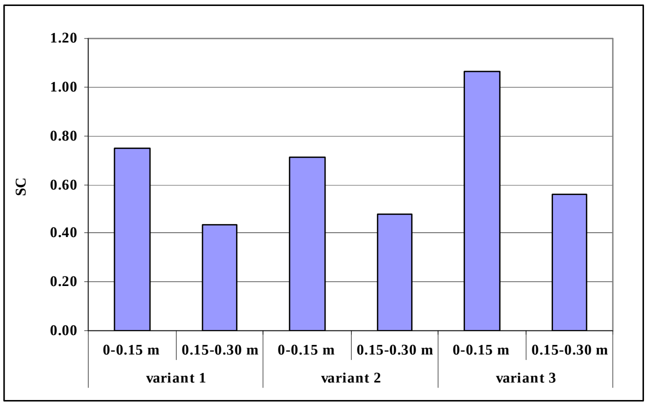



Fig. 2. Average values of structural coefficient in years 2012-2013

**Conclusions**

Results of a two-year study indicated a positive effect of compost application on water stability of soil aggregates. After the application of both compost doses It was out that both compost doses significantly improved values of WSA. The application of a higher compost dose showed a positive effect on soil structure, above all in its upper layer (topsoil). A lower dose of compost did not influence the soil structure.

**Acknowledgement**

Presented results were supported from financial funds of the project of the National Agency of Agricultural Research (NAZV), ministry of Agriculture of the Czech Republic n° QJ 1210263.

**References**

ANNABI, M., LE BISSONNAIS, Y., LE VILLIO-POITRENAUD, M., HOUOT, S., 2011: Improvement of soil aggregate stability by repeated applications of organic amendments to a cultivated silty loam soil, 144 (1): 382-389.

ANNABI M. - HOUOT S. - FRANCOU C. - POITRENAUD M. - LE BISSONNAIS Y., 2007: Soil aggregate stability improvement with urban composts of different maturities. Soil Sci. Soc. Am. J., 71 (2): 413 – 423.

ARTHUR, E., CORNELIS, W. M., VERMANG, J., DE ROCKER, E., 2010: Effect of compost on erodibility of loamy sand under simulated rainfall. Catena, 85: 67-72.

BADALÍKOVÁ, B., BARTLOVÁ, J., 2011: Use of composts made of biologically degradable materials when improving soil environment. In proceedings of the 15th Conference of Environment and Mineral Processing, Part I., VŠB Ostrava, s.143-147 BROWN, S., COTTON, M., 2011: Changes in soil properties and carbon content following compost application: Results of on - farm sampling. Compost Science and Utilization, 19 (2): 87-96.

DUONG, T. T. T., PENFOLD, C., MARSCHNER, P., 2012: Differential effects of composts on properties of soils with different textures. Biology and Fertility of Soils, 48 (6): 699-707.

RENCO, M., 2013: Organic amendments of soil as useful tools of plant parasitic nematodes control. Helminthologia, 50 (1):3-14.

JAVŮREK M., VACH M., 2009: Vliv dlouhodobého uplatňování půdoochranné technologie na sekvestraci uhlíku a dusíku a související charakteristiky ve středně těžké půdě typu luvisol (Effect of a long-term soil-protecting technology on sequestration of carbon and

nitrogen and on related characteristics in a medium heavy of the luvisol type, in Czech). Úroda, A scientific attachment of the journal, 12: 361 - 365.
KROULÍK, M., BRANT, V., MASEK, J., KOVAŘÍČEK, P., 2010: Influence of soil tillage treatment and compost application on soil properties and water infiltration. Trends in agricultural engineering, p. 343-349.
KUTÍLEK M., 1978: Vodohospodářská pedologie. SNTL - ALFA, Praha, 295 s.
MATAIX-SOLERA, J., CERDÀ A., ARCENEGUI V., JORDÁN A., ZAVALA L. M., 2011: Fire effects on soil aggregation: A review. Earth-Science Reviews, 109: 44-60.
OADES, J. M., 2005: Soil organic matter and structural stability: mechanisms and implications for management. Plant and Soil, 76 (1-3): 319 - 337.
ORTAS, I., AKPINAR, C., LAL, R., 2013: Long-term impacts of organic and inorganic fertilizers on carbon sequestration in aggregates of an entisol in Mediterranean Turkey. Soil Science, 178 (1): 12-23.
PALUSTEK, J., 2010: The influence of urban green waste compost on the physical quality of soil exposed to erosion. Archives of Environmental Protection, 36 (3): 97-109.
PARDINI, G., GISPENT, M., JORDANA, R., VELAYOS, J., 2008: Experimental use of composted grape seed and olive mill residues for amelioration of fertility and structural stability of soils. Compost Science & Utilization, 16 (1): 61-68.

**Contact address:**

Dipl. Ing. Jaroslava Bartlová, Ph.D.
Agricultural research, Ltd.
Zahradní 1
664 41 Troubsko, Czech Republic
e-mail: bartlova@vupt.cz,
Phone: +420 547 138 816

Velešovice – spring time 2013

Velešovice – soil sampling

# CURRENT TRENDS IN SOIL TILLAGE SYSTEMS IN PANNONIAN REGION

**M. Birkas[1], M. Mesic[2], V. Smutný[3]**

[1] Szent István University Gödöllő, Hungary
[2]University of Zagreb, Croatia
[3]Mendel University Brno, Czech Republic

**Abstract**

In our region most classical authors held that the primary aim of cultivating soil was to meet crops requirements. In the late 19th century rendering the soil's fertile layer suitable for crop growing was considered to provide a good standing place for plants. The word suitable usually applied to the soil physical state, its favourably loose structure that was to be developed to the required depth. However, it was recognized by some authors back in the late 1800s already, that creating soil condition assumed to be required by plants may even damage the soil, what with the frequent traffic involved in the process. In other words, taking a crop oriented approach will rather do damage than good. In a regime of tillage focusing on conservation the need for protecting the soil is not subordinated to crops demands. Primarily importance is to create a soil condition required by crops takes a lot less energy and causes much less mechanical damage in a soil whose good structure and condition has been carefully preserved. In the second decade of the new millennium the primary goal of tillage is to create and maintain favourable interaction between soil conservation and cropping. The aim of soil conservation and environmental protection should realise depending on the effectiveness of the EU and national soil conservation endeavours and efforts and its duration should be determined by the extent to which such practices are adopted across the farming community.

**Keywords:** adaptability, soil remedying, water conservation, Panonian region

## Introduction

Classical authors emphasised the importance of creating a good site for plants, that of improving the soil fertile layer to make it suitable for cropping (Birkás et al., 1989). In the physical approach tillage was regarded as playing its most important role in controlling soil processes. Consequently the period of several centuries dominated by this approach is referred to as the era of crop oriented tillage (Cannell, 1985). The over-estimation of the importance of crop requirements resulted in damaging the soils, which inevitably led to the recognition, in the mid-1960s, of the need for protecting soils quality hence that was the beginning of the era of soil oriented tillage (Bartalos et al., 1995). Any crop requirements can be met by a soil kept in a good physical and biological condition by soil preserving tillage, with the added benefits of causing less damage and cutting costs. Since the first years of the climate change, as the new trends have raised concern, tillage must be turned into a climate focused effort with the aim of reducing climate-induced losses through improving soil quality (Birkás, 2011).

The various trends of tillage (minimum, reduced, soil conservation) and endeavours (e.g. energy saving, sustaining) can be distinguished in the basis of their aims (Hayes, 1982a,b; Birkás et al, 1989; Edwards et al., 1990). Since the first energy crisis (mid-1970s), the endeavours to reduce tillage have been motivated by a variety of factors. During the next years reduced tillage under the pressure of economic constraints was practised on several hectares in the region promoting physical and biological degradation of the soils (ECAF,

1999; Jug et al., 2010). It had to be made aware that is no possible to adopt techniques of energy saving tillage without improving the condition of the soils. Further challenge was that the methods developed far from this region adapting to the local soil and farming conditions (Birkás and Mesić, 2012; Jug et al., 2006).
The main problem of the ploughing systems is not the soil inversion (however this action is often deteriorates soil quality), but the realisation in the regional sites. Partly to mitigate damage caused by the climate change the plough is probably going to be used less frequently in this region in the future (Bašić et al., 2010; Birkás, 2012). From crops responses and from findings of soil state assessments and studies it has been concluded that tillage without inverting is not disadvantageous to cropping and particularly to environmental protection (Kisić et al., 2010; Birkás et al., 2013). The ploughless systems, on the one hand, are based on soil loosening (by tine or by subsoiler) and on shallow intervention (by disk or rotavator). On the other hand, the variants which can realise in soils are adequately applied to the different site conditions (Birkás, 2010). Namely, subsoiler and tine can be used in the entire surface or in strips, and tine tillage is also applied shallowly (10-15 cm) or deeply (30-35 cm) adopting to the production goals. At the same time, further tillage and sowing technologies have circumspectly been tested since the 1980s e.g. till and plant system for green manure plants, strip-till and plant for wide row crops, ridge-till and plant in sloped sites etc. (Jug and Birkás et al., 2010). It is noteworthy that the first trials of direct drilling in this region were conducted and investigated in the beginning of the 1960s (Birkás et al., 2008). Nowadays this system is often used as a studying variant in the regional soil tillage experiments. The most important questions in adoption of any new tillage and sowing systems are the adaptability to the cropping requirements and site conditions, the yield certainty, good trainability and reasonable investment level (Spoljar et al., 2011). A further important question is the suitability of the new systems to the extreme climate conditions are increasingly afflicted soil in the region (Gajić-Čapka, 2009; Jug et al., 2007; Pospišil et al., 2011, Smutný et al., 2013; Szalai and Lakatos, 2013; Várallyay, 2011).

**Material and methods**

This paper is based on works reviewing the subject (Bartalos et al., 1995; Bašić et al., 2010, Birkás et al., 1989; Birkás and Kisić et al., 2013, Jolánkai et al., 2013; Jug et al., 2009, 2010, Kisić et al., 2010; Šeremešić et al., 2011; Sabo et al., 2006, 2007) and on stating in long term experiments underway in the countries as well as on the conclusions drawn from them (Birkás, 2010, 2012; Jug and Sabo, 2010, Kalmár et al., 2013).

**Results and discussions**

Tillage results in changes in the soil state and in its environment (Jug and Stipešević et al., 2006, 2007). Such changes can be identified at this moment as well as over a longer period of time. It is a crucial question whether tillage carried out ‘in the crops interest’ has effects improving, maintaining or deteriorating the soil’s structure, bearing capacity and biological activity (Birkás et al., 2008; Nikolić et al., 2002).
The development of tillage systems in our region, respect for tillage in general, its position in the system of cropping, the efforts made at conserving the soil along with the acceptance of new approaches, have always been substantially affected by traditions (Birkás et al., 2008). They noted that the foreign trends – e.g. the American Campbell’s dry farming boom between 1905 and 1912 or the German Bippart’s ‘anti-plough’ movement in the 1920s – had little impact on the common tillage practices in this region. The practice of ploughing to depths exceeding 25 cm was increasingly widely adopted in response to the encouragement of sugar beet production (from 1860 on). Economising under the force of necessity has always been a typical response to periods of economic difficulties but the over-tillage of soils cannot be

linked directly to any particular time period (Birkás et al., 1989; Jug et al., 2010; Pejićet al., 2013). Farmers' attitude with respect to rationalising tillage could, in retrospect, be explained by shortage of capital. At the same time the former aversion to the new methods has also lasted despite of the symptoms in soil deterioration that are originated from the long-term traditional tillage (Kovačević and Lazić, 2012). Authors, cited above, have often outlined that adopting new techniques in this region cannot be introduced without remedying the condition of the soils.

Soil protection has been a key subject of research for decades now, and the results achieved so far are taken into account in the development and application of cultivation practices (Jug and Jug et al., 2007; Spoljar et al. 2011). Covering the soil was found to be an effective approach to control dust storms on the Great Plains in the 1930s (Allen and Fenster, 1986). The approach referred to as 'minimum tillage', which was developed in the 1960s, should be regarded as something of a detour, as the objective of soil conservation ranked second to the priorities of reducing tillage operations and costs (Schertz, 1988). The year of change was 1977, and the new concept is called 'soil conservation' tillage, a method that retains protective amounts of residues on the surface throughout the year. Schertz quotes the definition adopted by the authorities in 1983, conservation is any tillage and planting system in which at least 30 % of the soil surface is covered by plant residue after planting to reduce soil erosion by water. Different methods of the soil protection – are listed in Table 1 – have been and are being conducted in areas exposed to erosion by water or wind, in parallel with no-till experiments (Kisić et al., 2003; Soane et al., 2012). According to Soane et al., no-till systems are not applied in Europe as extensively as they could be. At the same time, there is growing interest in other soil conservation techniques e.g. till-plant, mulch-till, and strip-till (Jug et al., 2010), to some extent perhaps as a consequence of the increasingly climate threats. Shifts in the timing and the gradual lengthening of periods that are critical from the aspect of soil conservation are also considered to have been caused by extreme weather patterns (Jolánkai et al., 2013; Várallyay, 2013).

**Table 1. Soil tillage trends, objectives and realisation in the Pannonian region**

| Trends, *systems* | Time and place of developing | Aims of the system | In the Pannonian region | |
|---|---|---|---|---|
| | | | appearance | realisation |
| Minimum tillage | 1950s (USA) | cutting tillage depth, passes and costs | mid-1970s | reduced constraint e.g. disk tillage |
| Reduced tillage | 1960s (USA) | cutting tillage passes and costs | mid/end-1970s | tool/element combination |
| Conservation tillage | 1960s (USA) | effectual soil preserving by surface cover (≥30 %) after sowing | end-1980s, first years of the 2000s | surface cover after stubble tillage and after some types of primary tillage |
| *no-till* | 1950s (USA) | soil and water preserving by minimised soil disturbance | from the 1960s | problems in the first years limited the interests |
| *mulch-till* | 1980s (USA) | soil and water preserving by whole surface disturbance and by fair surface cover | mid-1980s, first years of the 2000s | good: by tine, by loosening, risky: by disking |
| *ridge-till* | 1980s (USA) | soil and water preserving in sloped fields | 1990s | in experiments only |
| *strip-till – 1$^{st}$* | 1970s (USA) | clean sowing strips, covered inter rows – reducing tillage intervention and costs; improved by satellite guidance and automatic positioning | 1990s | tepid interest |
| *strip-till – 2$^{nd}$* | 2000s (USA) | | 2010s | field trials with hope of the extending |
| climate mitigating | mid-1990s (Europe) | all systems are adaptable to site and climate conditions | first years of the 2000s | step by step, however time presses |

It may outline that the first step in the process of adaptation in conservation tillage involves recognition of the risks – wrong practices/habits, poor soil quality, extreme climate phenomena etc. – and an urge for improvement, while the second step involves improvement or conservation of the quality of the soil, in harmony with ecological conditions, mechanisation and the farming and management conditions. Twelve factors are selected to present the fundamental requirements of the conservation soil tillage (Bašić et al., 2010; Birkás and Mesić, 2012): (1) Avoiding the farming and tillage-induced soil damages, that are occurrence and extension of soil compaction, soil structure degradation, water and wind erosion, high CO2 emission, and organic material loss. (2) Maintaining soil moisture transport by improving the water infiltration and storage in wet periods and decreasing the moisture loss in dry and average seasons. (3) Preserving organic material of the soil to increase the water-holding capacity, the structure stability, the loading capacity and the workability and to decrease the soil compactibility and vulnerability. (4) Managing stubble residues by application of harvest and tillage techniques leaving mulch cover. Cover the surface after harvest, as long as possible to remedy soil structure and to preserve soil moisture and to mitigate heat and rain stress outside the growing season. (5) Recycling stubble residues to the soil with the passing of the critical period for the sake of the soil organic matter improvement, promoting the favourable biological activity in soils thus improving the soil workability trough the mellowing processes. (6) Utilizing the possible machinery – tractor, mass of tool, running gear, working speed, energetic relation between tractor and tool, state and construction of tillage tool – and arable site factors to reduce the energy consumption thus to decrease the environmental load. (7) Minimising the soil loading stress from stubble to sowing phase. (8) Applying optimal crop sequence to reduce fertilizer needs and to improve soil biological activity through the crops effect on soil condition. (9) Particular attention is to be paid to maintaining the soil infiltration and storage capacity and the soil aggregation on irrigated soils. (10) Applying tools without pan-creation in any tillage procedures, particularly in wet soils. (11) Assessing the possible risks cautiously prior to establishment of the new tillage and sowing systems. Soil condition assessment will have greater importance before tillage interventions, in the crop stands and after sowing. (12) Selecting the most adaptable soil conservation methods are conformed to the site and crop production requirements.

Crop residues – that can be seen in the foregoing – are considered a possible material for soil conservation. Stubble residues have come under the limelight again, though unfortunately at a time when they have come to be used as a source of ‘bio-energy’ (Lal, 2009). Surface protection during the summer is indisputably important in the Pannonian region (Kalmár et al., 2013). The soil needs to be kept in place and at the same time efforts must be made to alleviate heat and rain stress and to reduce the loss of water (Birkás, 2011; Turk and Mihelič, 2013; Várallyay, 2013). Mulched green manure and chemically treated weeds and volunteers may also provide a protective cover besides crop residues on soils. Two of classic authors (Manninger and Kemenesy) were encouraged first (in the 1930s) to use mulch covering the soil (Birkás et al., 2008). The training of mulch-tillage was laid down 34 years ago by the studying of the soil in fields after harvest (Kalmár et al., 2013). Progress was clearly facilitated by the introduction of flat plate disks and mulch-cultivator tools (Rádics and Jóri, 2010). Where the crop residue is left on the soil surface the level of protection is first affected by the ratio of the cover, and later by the mode and quality of stubble tillage. Kalmár et al. (2013) cited Schertz (1988) that soil conserving tillage is characterized by an at least 30 % cover ratio after sowing, and they recommended a higher – 45-55 % – ratio by evenly chopped straw for surface cover after summer harvest.

The following is a review of possibilities of some tillage and sowing methods to be adaptable to the site conditions. Experiences are sown in the Table 2.

**Table 2. Experiences in soil conservation solutions in the Pannonian region**

| System/method | Crops sown situation | Main advantages | Main considerations | First adoption |
|---|---|---|---|---|
| Mulch-till by subsoiling | Oilseed rape, wide-row crops | Deep rooting, less climate dependence | Same diseases, greater weed infestation in the first years | - mid 1980s<br>- from the 2000s |
| Mull-till by tine | All crops | Soil structure preserving and improvement, less dependence on soil water content | Same diseases, greater weed infestation in the first years | - mid 1980s<br>- from the 2000s |
| Much-till by disk | Mostly winter cereals | Saving time and energy | Shallow loosened layer, higher climate dependence | - from the 1980s |
| Till-plant | Green manure crops/ oilseed rape | Saving time and energy | State of the root zone | - from the 2010s |
| No-till | Mostly w. cereals, secondary crops | Saving time and energy | Continuous: long-term soil conversion; occasional: soil water content | - 1960s, 1990s<br>- 2010s |
| Strip-till | Mostly wide-row crops | Loosened soil to the depth of 27 cm, saving time and energy | Uncrushed maize stalks (good habitat to E. corn borer) | - from the 2010s |
| Composting tillage | All crops | Soil structure preserving and improvement | Depth of the loosened layer | -from the 2010 (Slovenia) |
| Twin-row sowing | Oilseed rape, wide-row crops | Deep rooting (in subsoiled soil only) | Misunderstanding the crop root development and placement | - Kolbai, 1956, Hungary<br>- 2010s (USA) |
| Seedbed preparation and plant | All narrow-row crops | Water conservation for germination | Over-wet soil condition | -mid 1990s |
| Surface cover of undisturbed soil (2-3 months) | Stubble state after cereals | Best water conservation in dry season | Risks at autumnal sowing | - 2010s |
| Improved ploughing | Spring sown crops | Inverting and surface levelling | Pan compaction | - mid 1980s<br>-1990s |

The system based on the use of mulch-till by tine offers the benefit of sparing the soil structure before crops sown. In the year following subsoiling it may use for maintaining the favourable soil conditions. This method is also recommended for gently trans-mixing the upper (0-30 cm) layer of soil after application of 3-4-year strip-till. It causes little – and easily remedied – damage in wet soils. The mulch-till by tine may be a part of modern low intensity and mid-tech land use mode on account of its favourable environmental impact. In a dry year loss of moisture can be reduced by less soil disturbance, gentle crumbling and leaving adequate surface cover.

Disking should not be applied in successive years. The system should only be applied if the soil deeper layers are in a good condition, and the soil should be dry or a little humid. Composting tillage shows similar advantages and risks.

Using a till-plant is one of the modes of low intensity farming. A deeper soil disturbance may be resorted to in a year following the sallow tillage. Strip-till is applied in the mid-tech farming for maintaining good soil state as involves few tillage passes. By covering between

rows with residues this technique meets the expectations in weed free fields. Loosening variant of strip-till may be applied if the aim is to improve the soil condition.
No-till is a mode of the low-intensity farming and offers benefits and entails risks. Being a special cropping method entailing minimised soil disturbance whose application requires modern machinery, a frequently updated technology adapted to the site, the year and the crop concerned and sound expertise. On soils of degraded structure the yields will decline in the first years after adopting the no-till. The risks of applying this particular system may be reduced when the soil physical, biological and chemical parameters have been harmonised.
Twin-row – 55+22 cm row spacing – sowing was developed for optimizing the use of light, water, and nutrients by crops. Special twin-row planter put the seeds in a precise alternating diamond pattern, and distance between plants is also optimised (25.1-29.5 cm). A forced machine selling and method' adoption are really overshadowed the original and possible advantages.
Seedbed preparation and sowing in a single tillage pass in a soil after primary tillage of the depth and mode meeting the crop requirements and adapted to the site conditions, involving or without ploughing and then finishing the surface of the soil with the aid of a combined machine assembled for this purpose.

**Conclusions**
There have been considerable changes in tillage practice in the Pannonian region over the past decades from over-disturbing tillage systems to the adaptable some conservative solutions. The main tasks are to provide scientific proof of the benefits of soil conservation and to stabilize crop yield level and to disseminate various tillage techniques that are suitable for achieving these aims, as widely as possible in the farming community.

**Acknowledgements**
The study was supported by Research was supported by the project No TÁMOP-4.2.A-11/1/KONV, research project No. QJ1210008, financed by the Ministry of Agriculture of the Czech Republic and Research project No. TA02010669, financed by the Technology Agency of the Czech Republic.

**References**
BIRKÁS, M.: 2010. Long-term experiments aimed at improving tillage practices. Acta Agr. Hung. 58(Suppl 1): 75-81.
BIRKÁS, M.: 2011. Tillage, impacts on soil and environment. In: Encyclopedia of Agrophysics. (Glinski, J., Horabik, J., and Lipiec, J., eds.). Springer, Dordrecht, pp. 903-906, 2011.
BIRKÁS, M.: 2012. Challenges faced by the practice of soil tillage in Hungary and in the Pannonian region. In: Soil-School. What to learn from and what to teach about soils. (Birkás, M.,ed.). Szent István Egyetemi Kiadó, Gödöllő, pp. 432-451.
BIRKÁS, M., ANTAL, J., DOROGI, I.: 1989. Conventional and reduced tillage in Hungary – A review. Soil and Tillage Res., 13(3): 233-252.
BIRKÁS, M., MESIĆ, M.: 2012. Impact of tillage and fertilization on probable climate threats in Hungary and Croatia, soil vulnerability and protection. Hungarian – Croatian Intergovernmental S&T Cooperation 2010–2011. Szent István Egyetemi Kiadó, Gödöllő, p. 186.
BIRKÁS, M., KISIĆ, I., JUG, D., SMUTNÝ, V.: 2013. Soil management to adaptation and mitigation of climate threats. Proc. of 2nd Internat. Conference on Soil and Crop

Management: Adaptation and Mitigation of Climate Change (Vukadinović, V. and Đurđevic, B., eds), Osijek, Croatia, 26-28 Sept., 2013, pp. 14-24

BOTTLIK, L., CSORBA, SZ., GYURICZA, CS., KENDE, Z., BIRKÁS. M.: 2014. Climate challenges and solutions in soil tillage. Applied Ecology and Env. Research. 12(1): 13-23.

CANNELL, R.Q.: 1985. Reduced tillage in north-west Europe – A review. Soil and Tillage Res., 5: 129-177.

ECAF: 1999. Conservation Agriculture in Europe: Environmental, economic and EU policy perspectives. European Conservation Agricultural Federation, Brussels, p. 14.

EDWARDS, C.A., LAL, R., MADDEN, P., MILLER, R.H, HOUSE, G.: 1990.Sustainable Agricultural systems. Soil and Water Conservation Society, Ankeny, Iowa, p. 696.

GAJIĆ-ČAPKA, M.: 2009. Global Climate Change – Observed Climate Change in Croatia – Precipitation. In: Fifth National Communication of the Republic of Croatia under the United Nation Framework Convention on the Climate Change. Ministry of Environmental Protection, Physical Planning and Construction, pp. 137-143.

HAYES, W.A.: 1982a. Minimum tillage farming. No-Till Farmer, Inc., Brookfield, Wisconsin, p. 167.

HAYES, W.A.: 2013. No-till farming. No-Till Farmer, Inc., Brookfield, Wisconsin, p. 202.

JOLÁNKAI, M., BALLA, I., PÓSA, B., TARNAWA, Á., BIRKÁS, M.: 2013. Annual precipitation impacts on the quantity and quality manifestation of wheat and maize yield. Acta Hydrologica Slovaca, 14(2): 446-450.

JUG, D., BIRKÁS, M., ŠEREMEŠIĆ, S., STIPEŠEVIĆ, B., JUG, I., ŽUGEĆ, I., DJALOVIĆ, I.: 2010. Status and perspective of soil tillage in South-East Europe. Proceedings of the 1st International Sci. Symposium on Soil Tillage – Open Approach (Jug, I., Vukadinović, V., eds.) Osijek, Croatia, 9-11 Sept, 2010. pp. 50-64.

JUG, D., JUG, I., KOVAČEVIĆ, V., STIPEŠEVIĆ, B., ŠOŠTARIĆ, J.: 2007. Soil tillage impacts on nutritional status of wheat. Cereal Res., Comm., 35(2): 555-558.

JUG, D., SABO, M., JUG, I., STIPEŠEVIĆ, B., STOŠIĆ, M.. 2010. Effect of different tillage systems on the yield and yield components of soybean [Glycine max (L.) Merr.] Acta Agr. Hung., 58(1): 65-72.

JUG, D., STIPEŠEVIĆ, B., ZUGEĆ,. I.: 2006 Effects of conventional and reduced tillage systems in winter wheat – soybean crop rotation on crops biomass development. Cereal Res. Comm., 34: 1137-1143.

JUG, D., STIPEŠEVIĆ, B., JUG, I., SAMOTA, D., VUKADINOVIĆ, V.. 2007. Influence of different soil tillage systems on yield of maize. Cereal Res., Comm., 35(2): 559-562.

JUG, D., STOŠIĆ, M., BIRKÁS, M., DUMANOVIĆ, D., SIMIĆ, M., VUKADINOVIĆ, V., STIPEŠEVIĆ, B., JUG, I.: 2009. Soil trafficking analysis for different reduced soil tillage systems. Proceedings of 2nd International Conference on Agriculture in nature and environment protection (Jug, D. and Sorić, R., eds.), Vukovar, Croatia, 4-6 June, 2009 pp. 51-59.

KALMÁR, T., BOTTLIK, L., KISIĆ I., GYURICZA, C., BIRKÁS, M.: 2013. Soil protecting effect of the surface cover in extreme summer periods. Plant, Soil and Env., 59 (9): 404-409.

KISIĆ, I., BAŠIĆ, F., NESTROY, O., MESIĆ, M., BUTORAC, A.: 2003. Soil erosion under different tillage methods in central Croatia. Die Bodenkultur, 53(4): 197-204.

KISIĆ, I., BAŠIĆ, F., BIRKAS, M., JURIŠIĆ, A., BIĆANIĆ, V.: 2010. Crop yield and plant density under different tillage systems. Agriculturae Conspectus Scientificus, 75(1): 1-7.

KOLBAI, K.: 1956. A gödöllői ikersoros kukoricatermesztés. MTA Agrártudományok Oszt. közleményei, 9 (4): 371-375.

KOVAČEVIĆ, D., LAZIĆ, B.: 2012. Modern trends in the development of agriculture and demands on plant breeding and soil management. Genetika, 44(1): 201-216.

LAL, R.: 2009. Soil quality impacts of residue removal for bioethanol production. Soil and Tillage Research, 102: 233–241.

NIKOLIĆ, R., SAVIN, L., FURMAN, T., GLIGORIĆ, R., TOMIĆ, M.: 2002. Research of problems of the soil compaction. Tractors and power machines, 7(1): 5-13.

PEJIĆ, B., KRESOVIĆ, B., TAPANAROVA, A., GAJIĆ, B., MAČKIĆ, K.: 2013. Effects of water stress on water use and yield of maize. Contemporary Agriculture, 62(1-2): 35-45.

POSPIŠIL, M., BRČIĆ, M., HUSNJAK, S.: 2011. Suitability of soil and climate for oilseed rape production in the Republic of Croatia. Agr. Conspectus Scientificus, 76(1): 35-39.

RÁDICS, J., JÓRI, J. I.: 2010. Development of 3E tillage system and machinery to challenge climate change impacts. Periodica polytechnica-mechanical engineering, 54: 49-56.

SABO, M., JUG, D., UGARČIĆ-HARDI, Ž.: 2006. Effect of reduced tillage on wheat quality traits. Acta Alimentaria, 35(3): 269–279.

SABO, M., JUG, D., JUG, I.: 2007. Effect of reduced tillage on quality traits of soybean [Glycine max (L.) MERR.] Acta Agronomica Hungarica, 55(1): 1-6.

SCHERTZ, D. L.: 1988. Conservation tillage: An analyis of acreage projections in the United States. J. Soil and Water Conservation, 43: 256-258.

ŠEREMEŠIĆ, S., MILOŠEV, D., DJALOVIĆ, I., ZERENSKI, T., NINKOV, J.: 2011. Management of soil organic carbon in maintaining soil productivity and yield stability of winter wheat. Plant Soil and Environment, 57(5): 201-206.

SMUTNÝ, V., NEUDERT, L., LUKAS, V., DRYŠLOVÁ, T., HOUŠŤ, M.: 2013. The effect of different soil tillage on yield of maize and the impact on soil environment. Növénytermelés, 62 (Suppl.): 17-20, 2013.

SOANE, B.D., BALL, B.C., ARVIDSSON, J., BASCH, G., MORENO, F., ROGER-ESTRADE, J.: 2012. No-till in northern, western and south-western Europe: A review of problems and opportunities for crop production and the environment. Soil and Tillage Research, 118: 66–87.

SPOLJAR, A., KISIC, I., BIRKÁS, M., GUNJACA, J., KVATERNJAK, I.: 2011. Influence of crop rotation, liming and green manuring on soil properties and yields. J. of Environmental Protection and Ecology, 12: 54-69.

SZALAI, S., LAKATOS, M.: 2013. Precipitation climatology of the carpathian region and its effects on the agriculture. Növénytermelés, 62(Suppl.): 315-318.

TURK, A., MIHELIČ, R.: 2013. Wheat straw decomposition, N-mineralization and microbial biomass after 5 years of conservation tillage in Gleysol field. Acta agriculturae Slovenica, 101 (1): 69-75.

VÁRALLYAY, G.: 2011. Water-dependent land use and soil management in the Carpathian basin. Növénytermelés, 60(Suppl.): 297-300.

VÁRALLYAY, G.: 2013. Soil moisture regime as an important factor of soil fertility. Növénytermelés, 62 (Suppl.): 307-310.

**Contact address:**
Ing. Vladimir Smutný, Ph.D.
Mendel University in Brno
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: smutny@mendelu.cz
tel.: +420 545133116

# LONG-TERM EFFECT OF DIFFERENT SOIL TILLAGE SYSTEMS ON GRAIN YIELDS OF SPRING BARLEY GROWN IN MONOCULTURE

**T. Dryšlová, B. Procházková, J. Křen, V. Smutný**

Mendel University in Brno, Faculty of Agronomy, Dpt. of Agrosystems and Bioclimatology

**Abstract**
The aim of this study was to assess long-term effect of different methods of soil tillage, straw management and mineral fertilization on grain yields of spring barley grown in monoculture. Long-term experiment is conducted in maize-growing region on heavy gleic fluvisol from 1969. Experiment variants: three variants of straw management (straw harvested-removed, incorporated into soil and burned); two variants of soil tillage (conventional plough tillage to 0.22 m and shallow tillage to 0.12-0.15m) and three variants of mineral fertilization (30, 60 and 90 kg $N.ha^{-1}$). Results of grain yield are presented from period 1975-2013 in this study. Statistically significantly higher grain yield were reached with conventional plough tillage to 0.22 m, straw burned and with the highest nitrogen dose, compared with another level in equivalent factor.

**Keywords:** spring barley monoculture; yield; soil tillage; straw management; N doses

## Introduction

General changes in the Czech Republic in recent years are also reflected in the change of primary agricultural production. Structure of crops (predominance growing of cereal crops) have been changed and also livestock production went through major changes. Today, there is a number of companies currently without animal production at all, i.e. without the need for straw. Arises the question how to use a straw, especially form cereals. Also a general reassessment and subsequent changes in the systems of soil tillage and cropping. In addition to traditional (conventional) practice gradually expanded minimum technologies of soil tillage. This paper offers a brief look at the grain yield results of spring barley grown in monoculture in a long-term experiments where experimental factors were soil tillage and straw management; the third factor is differentiated nitrogen fertilization. Mentioned factors and theirs interactions were studied in different agroecological conditions of the Czech Republic for many years and very important source of information are long-term stationary field experiments. The problem of growing cereals in monoculture, resp. barley, or with combination of different straw management are included in publications of Kos (1977); Vymětal (1982); Kopecký (1988); Hrubý, Dovrtěl and Procházková (1996); Procházková, Málek, Dovrtěl, (2002); Hrubý, et al. (2008, 2009). Effect of different soil tillage technologies on grain yields of cereals, but also other crops (whether in combination with monoculture growing or different straw management) is comprehensively described in publications Hůla, Procházková, et al. (2002) and Hůla, Procházková, et al. (2008). In these publications are frequent sources articles published in the journal Soil & Tillage Research.

**Materials and methods**

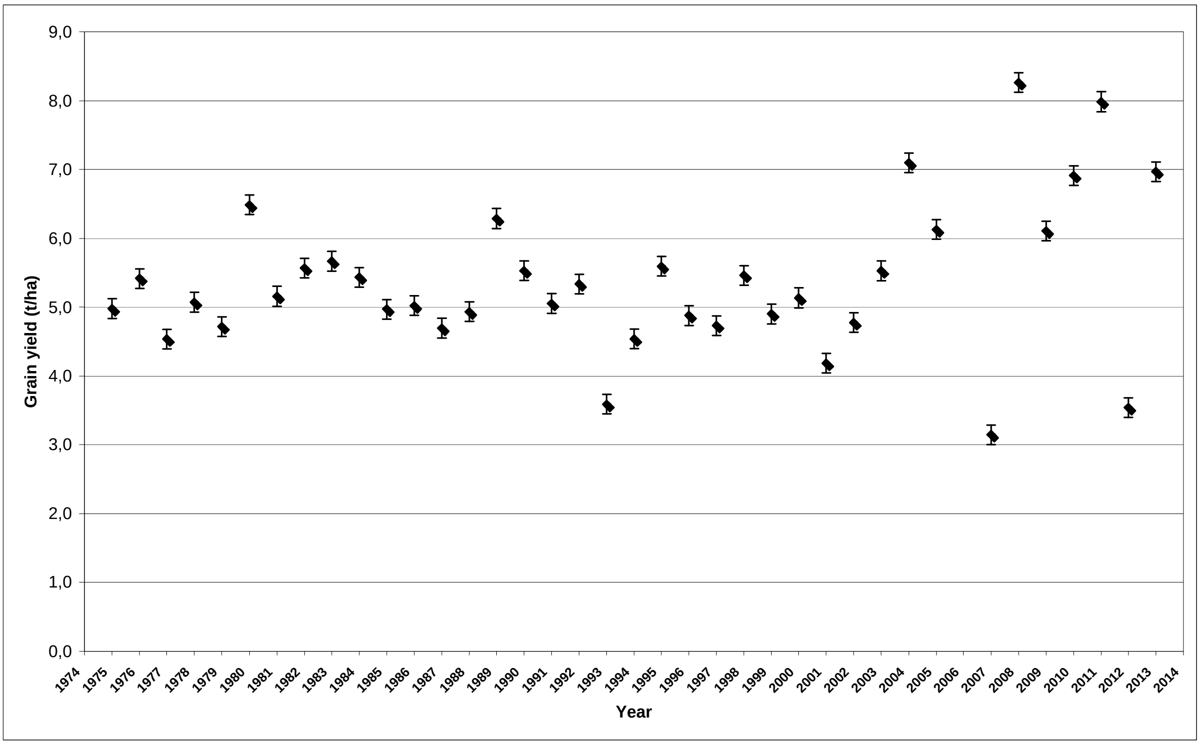
Long-term field experiment of spring barley (*Hordeum vulgare* L.) monoculture was established in 1969 in the maize-growing region in Žabčice. Site characteristics: the altitude is 179 m above sea level, average annual temperature 9.2 °C, average annual sum of precipitation 480 mm; heavy gleic fluvisol (FMG), neutral pH, humus content in topsoil 2.5% and content of available phosphor and potassium good. Experiment variants: three variants of straw management (straw harvested-removed, incorporated into soil and burned); two variants of soil tillage (conventional plough tillage to 0.22 m and shallow tillage to 0.12-0.15m) and three variants of mineral fertilization (30, 60 and 90 kg N.ha-1). Obtained grain yield data were statistically evaluated by a confidence level of 95 %.

**Results and discussion**

Average grain yield over all experimental variants was 5.37 t.ha$^{-1}$ in evaluated period 1975-2013. Effect of assessment years are presented in Figure 1 (with statistical assessment for P ≥ 95 %). Analysis of variance achieved significant effect of all studied factors. The statistically significant highest grain yields were achieved with conventional plough tillage to 0.22 m (5.62 t.ha$^{-1}$), straw burned (5.57 t.ha$^{-1}$) and with the highest nitrogen doses (5.65 t.ha$^{-1}$) compared with another level in equivalent factor.

Results of straw different management show that the best results were generally obtained in the variant with straw burned; the second best was the variant with straw incorporated into soil and the worst with conventional harvest and straw removed. Results of different N doses show that the best results were generally obtained in the variant with 90 kg N.ha$^{-1}$, the second best was the variant with 60 kg N.ha$^{-1}$ and the worst with 30 kg N.ha$^{-1}$.

**Figure 1 Average grain yields of spring barley (t.ha$^{-1}$) - Žabčice (1975-2013; P ≥ 95%)**



CONTENT

**Conclusions**

When we compare long-term effect of straw incorporation into soil and burning on grain yields of spring barley with conventional harvest and straw removed it was found out that in the variant with a shallow incorporating of straw there was a trend toward yield depression and that this adverse effect could be partly compensated by the application of nitrogen.

**Acknowledgement**

This study was supported by the National Agency of Agricultural Research as research project No. QJ1210008 "Innovation of cropping systems of cereals in different agroecological conditions on Czech Republic" and by contract for the implementation of long-term trials from the Ministry of Agriculture (by the VÚRV, v.v.i.).

**References**

HRUBÝ, J, DOVRTĚL, J., PROCHÁZKOVÁ, B., 1996: Effect of different agronomy practices on yileds of continuous spring barley. *Scientific studies*, VÚP Troubsko, 14: 65-71.

HRUBÝ, J., et al., 2008: Vliv různých agrotechnických a fytosanitárních zásahů na výnosy ječmene jarního pěstovaného v dlouhodobé monokultuře (Efffect of different agrotechnical and phytosanitary measures on spring barley yields in long-term monoculture). *Poľnohospodárstvo (Agriculture)*, 54(3):111-118.

HRUBÝ, J., et al., 2009: Protein content and grain yield of malting barley in continuous cropping systems. *Kvasný průmysl (Fermentation industry)*, 55(6): 143-149.

HŮLA, J., PROCHÁZKOVÁ, B., et al., 2002: *Vliv minimalizačních a půdoochraných technologií na plodiny, půdní prostředí a ekonomiku (Effect of minimum and soil conservation soil tillage technologies on the crop, soil environment and economy).* Zemědělské informace (Agricultural information). Praha: ÚZPI, no.3: 104 p. ISBN 80-7271-106-7

HŮLA, J., PROCHÁZKOVÁ, B., et al., 2008: *Minimalizace zpracování půdy (Minimum of soil tillage.* Praha: Profi Press, s.r.o., 248 p. ISBN 978-80-86726-28-1

KOPECKÝ, M., 1988: Vliv dlouhodobé monokultury na tvorbu výnosu a jakost jarního ječmene (The effect of long term continuous growing of spring barley on the yield and its quality). *Acta Univ. Agric. Fac. Agron.*, 36(2–4): 43-45.

KOS, M., 1977: Výzkum fytosanitárních opatření v monokultuře jarního ječmene (Research of phytosanitary practices in spring barley monoculture). *Rostl. Výr.*, 23(4): 405-411.

PROCHÁZKOVÁ, B., MÁLEK, J., DOVRTĚL, J., 2002: Effect of different straw management practices on yields of continuous spring barley. *Rostl. Výr.*, 48(1): 27-32.

SOIL & TILLAGE RESEARCH, an international journal on research and development in soil tillage and field traffic, and their relationship with land use, crop production and the environment. Published in collaboration with the International Soil Tillage Research Organization (ISTRO), print by ELSEVIER. ISSN 0167-1987

VYMĚTAL, M., 1982: Možnosti pěstování jarního ječmene v dlouhodobé monokultuře (The possibilities of spring barley cultivation in long monoculture). *Acta Univ. Agric. Fac. Agron.*, 30(3): 111-115.

**Contact address:**

Ing. Tamara Dryšlová, Ph.D.
Mendel University in Brno
Faculty of Agronomy
Department of Agrosystems and Bioclimatology
Zemědělská 1/1665
613 00 Brno
Czech Republic
e-mail: dryslova@mendelu.cz
Telephone: +420 5 4513 3107

# INFLUENCE OF DIFFERENT TYPE OF FERTILIZATION AND RAINFALL VARIATIONS ON SOIL HYDROPHOBICITY AND LEACHING OF MINERAL NITROGEN

**J. Elbl, A. Kintl, T. Lošák, L. Plošek, E. Pohanková**

Mendel University in Brno, Czech Republic

**Abstract**

This work deals with the influence of different type of fertilization and rainfall variations on soil hydrophobicity and on leaching of mineral nitrogen ($N_{min}$). This influence was tested by the pot experiment. *Deschampsia caespitosa* was used as a model plant. The leaching of $N_{min}$ was measured by application of ion exchange discs and soil hydrophobicity was determined based on the values of saturated hydraulic conductivity ($K_{sat}$). Three groups of the treatments with different regime of irrigation and fertilization were prepared. The significant differences in the detection of $N_{min}$ and values of $K_{sat}$ were found. All variants with addition of compost ($C_p$) showed lower amount of $N_{min}$ loss than variants without. The highest values of $K_{sat}$ were found in variants with addition of $C_p$ in comparison with variants where $N_{min}$ was applied. Low values of $K_{sat}$ in variants with $N_{min}$ addition indicate an increased level of hydrophobicity.

**Key words:** soil hydrophobicity, mineral nitrogen, fertilization, rainfall variations

## Introduction

The issue of extreme fluctuations of soil moisture, in relation to the activity of soil microorganisms and their influence on soil hydrophobicity, was not adequately described in conditions of middle Europe. Various scientific papers (Piccolo et al., 1999; Mataix-Solera&Doerr, 2003; Cosentino et al., 2010) describe only specific or particular aspects. Soil water-repellency or hydrophobicity was first characterized in semi-arid and sub-tropical climatic conditions (Buczko et al., 2005). It was clarified that soil hydrophobicity is caused by organic compounds, which remain on the surface of soil particles after the death of microorganisms.

In general, soil water repellency (SWR) is mostly caused by soil organic matter (SOM), e.g. by coating of plant-derived waxes covering the soil particles, by fungal hyphae or by particles in interstitial pore spaces (Buczko et al., 2005). SWR is a widespread phenomenon, which affects infiltration as well as soil water retention and plant growth. It can be responsible for enhanced surface runoff, erosion and preferential flow. Due to this high relevance, a great number of studies have been conducted on possible causes of water repellency and point to a variety of factors causing and influencing repellency (Schaumann& al., 2007). Soils with high content of hydrophobic compounds show an increase in surface water runoff and the reduction of water available for plants arises here (Mataix-Solera&Doerr, 2003). Buzcko et al. (2005) states that soil water repellency is a function of many factors including the soil water content, the previous wetting and drying of the soil, temperature, relative ambient air humidity, and the amount and quality of the SOM. Cosentino et al. (2010) point to the fact that there is a direct linkage between the amount of hydrophobic compounds and stability of soil aggregates. Therefore, water use efficiency by plants and resistance of soil to erosion can be negatively affected by soil hydrophobicity (soil water repellency = SWR).

The objectives were to test (i) if soil hydrophobicity will be increased under reduced amounts of rainfall, leading to a reduced amount of infiltration, and (ii) if adding anorganic carbon source will increase microbial activities and affect value of soil hydrophobicity while decreasing leaching of mineral nitrogen whereas adding available nitrogen will not.

## Material and methods

*Experimental design*

Effect of organic carbon ($C_{org}$) addition and rainfall variations on soil hydrophobicity and leaching of mineral nitrogen ($N_{min}$) from arable land were tested by a pot experiment, which was carried out in a growth box (phytotron). Twenty seven containers from PVC were used for this experiment. All same size lysimeters were filled with 3 kg of topsoil and 7.5 kg of subsoil. Soil used for the experiment was sampled from the area Březová nad Svitavou. Soil sampling was done on the 25$^{th}$ of May 2013 in accordance with ČSN ISO 10 381-6. Samples of compost ($C_p$) were taken on the 15$^{th}$ of March 2013 in accordance with ČSN EN 46 5735. Before using soil and compost, samples were sieved through a sieve (grid size of 2 mm). Before application, the soil samples were preincubated at laboratory temperature for 30 days. *Deschampsia caespitosa* was used as a model plant (1 plant per pot). During the whole experiment, experimental containers with indicator plant were kept in phytotron at 24°C day temperature, 20°C night temperature, 65 % humidity (for all 24h) with a day length of 12 h. Light intensity was 380 μmol·m$^{-1}$·s$^{-1}$. To demonstrate effect of drought on soil hydrophobicity and leaching of mineral nitrogen from arable soil, three groups of experiment A, B and C with different regime of irrigation (simulation of rainfall variations) were prepared according Elbl et al. (2014). The complete overview is shown in the Table 1.

**Table 1: Overview of the laboratory experiment**

| Group | | Variants | Characteristic |
|---|---|---|---|
| A | 70 % WHC | A1 | Control |
| | | A2 | 0.140 Mg N/ha |
| | | A3 | 50 Mg $C_p$/ha |
| B | 40 % WHC | B1 | Control |
| | | B2 | 0.140 Mg N/ha |
| | | B3 | 50 Mg $C_p$/ha |
| C | Wilting point | C1 | Control |
| | | C2 | 0.140 Mg N/ha |
| | | C3 | 50 Mg $C_p$/ha |

*Soil properties*

The basic soil properties (available nutrients, soil reaction and salinity) were determined in homogenized sample of topsoil (arable soil) and subsoil, which were sampled from the area of our interest. Analysis of soil samples was performed according to Mehlich III.

*Determination of saturated hydraulic conductivity*

Saturated Hydraulic Conductivity ($K_{sat}$) was calculated based on the measured volume of water that infiltrated into the soil. Cumulative infiltration was measured using a Mini Disk Infiltrometer. The calculation was performed by Šindelář et al. (2008), Lichner et al. (2007a, 2007b). This method of determining the $K_{sat}$ is based on the recording of the infiltrated volume of water over the time. High soil hydrophobicity slows water infiltration, i.e.: hydraulic conductivity is lower, and vice versa. Therefore, $K_{sat}$ may indicate a degree of soil hydrophobicity (Doerr et al., 2000; Buzcko et al., 2005 and Robichaud et al., 2008).

*Measurement of the leaching of mineral nitrogen*

Measurement of the leaching of mineral nitrogen was performed using ion exchange discs according Elbl et al. (2013) and Novosadová&Záhora (2011). The results obtained from the Ion Exchange Discs were expressed in mg of $N_{min}$ per $m^2$ of soil.

*Statistical analysis*

Potential differences in values of $K_{sat}$ and leaching of $N_{min}$ were identified by one-way analysis of variance in a combination with the Tukey´s test. All analyses were performed using Statistica10 software. The results were processed graphically in the program MS Excel.

**Results and discussion**

The experiment was divided into three parts: (i) from July to August; (ii) from September to October and (iii) from November to December 2013.This study presents the first results of a long-term pot experiment from first period of experiment.

*Soil properties*

The basic soil properties are summarized in Table 2 and 3. These data show differences in content of plant available nutrients between topsoil (higher content of K, Ca, Mg) and subsoil (higher content of P). Conversely, differences in soil reaction are minimal. Based on these data, authors conclude that properties of topsoil and subsoil did not have directly affected the main objectives of experiment.

**Table 2: Agrochemical characteristics – plant-available nutrient content of soil samples used for establishment of experiment (the luvisol modal; sandy loam soil)**

| Soil sample | mg/kg | | | | K:Mg |
|---|---|---|---|---|---|
| | **P** | **K** | **Ca** | **Mg** | |
| Topsoil | 139,2 | 366,3 | 3683 | 189,6 | 1,9 |
| | high | high | high | good | suitable |
| Subsoil | 232,3 | 65,1 | 2133 | 57,1 | 1,14 |
| | very high | low | good | low | good |

**Table 3: Agrochemical characteristic – soil reaction and salinity of soil samples used for establishment of experiment (the luvisol modal; sandy loam soil)**

| Soil sample | **pH ($CaCl_2$)** | **pH ($H_2O$)** | **EC (mS/cm)** | **TDS (mg/l)** |
|---|---|---|---|---|
| Topsoil | 5,49 | 6,4 | 2,63 | 1683 |
| | acid | weakly acidic | saline | saline |
| Subsoil | 6,05 | 6,6 | 0,00339 | 21,7 |
| | weakly acidic | neutral – weakly acidic | non-salinity | non-salinity |

*Leaching of mineral nitrogen*

The loss of $N_{min}$ from agricultural land represents a major problem for agriculture in the Czech Republic, because it is one of the main factors responsible for the decline in soil fertility. The Figure 1 shows a significant difference ($P<0.05$) of leaching of $N_{min}$ between the variants with addition of $C_p$ and without $C_p$. The graph shows how values of leaching of $N_{min}$ are increased in variant without $C_p$ addition (in individual groups “A, B and C”). The highest detection of $N_{min}$ was found in variant C1 (28.6 mg/$m^2$). Conversely, the lowest detection of $N_{min}$ was measured in variant C3 (8.01 mg/$m^2$). The measured values indicate important influence of method of fertilization on loss and availability of $N_{min}$ in arable soil. Moreover this data indicated that drought (rainfall variations) did not have directly affected the leaching of $N_{min}$. The effect of rainfall variations was secondary, because the primary influence was the method of fertilization.

Consider Figure 1: the highest loss of $N_{min}$ was found either in variant with addition of $N_{min}$ (A2; B2) or in variant (C1) without addition of $C_{org}$. This is an evidence of influence of fertilization method on leaching of $N_{min}$.

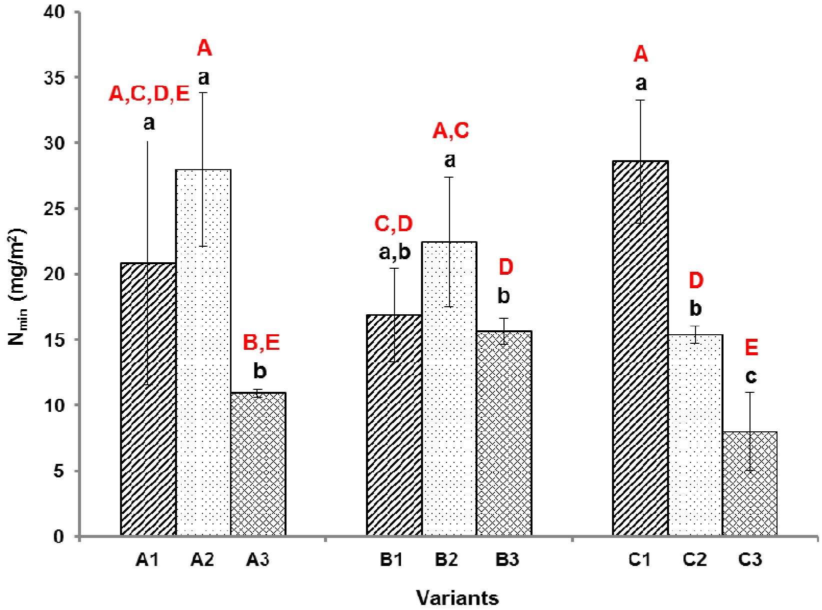



**Figure 1: Leaching of mineral nitrogen. Different small letters indicate a significant differences (P<0.05) between individual variants within the same group and different uppercase letters indicate a significant differences between all variants (regardless groups).**

Loss of $N_{min}$ was significantly decreased by application of $C_p$. All variants with addition of $C_p$ showed lower amount of nitrogen than variants without (in individual groups; P<0.05). This status confirms the positive impact of $C_p$ addition on leaching of $N_{min}$. Various scientific studies (Decau et al., 2003 and Diaz&Bertoldi, 2007) confirm that addition of $C_{org}$ has a positive impact on microbial activity in soil, because $C_{org}$ it is a source of energy for soil microorganisms. Development of microorganism activity is an essential prerequisite for the retention and use of excessive nitrogen in soil (Sutton, 2011). The increase in microbial activity has a direct impact on retention of $N_{min}$ in soil because soil microorganisms may enable the $N_{min}$ to be available for plants or they immobilize it (Elbl et al., 2013).

*Soil water repellency*

Soil hydrophobicity (or soil water repellency = SWR) is caused by organic compounds, which remain on the surface of soil particles after the death of microorganisms. Consider Table 4, the highest values of $K_{sat}$ were found in variants with addition of $C_{org}$. Conversely, the lowest values of $K_{sat}$ were found in variants with addition of $N_{min}$ (A2 and B2). Low values of $K_{sat}$ indicate an increased level of hydrophobicity. These data indicated that there is an association between method of fertilization (caused by rainfall variations) and formation of SWR. Moreover, based on these results we can conclude that the application of $C_p$ contributes to the development of microbial activity and thus to the development of soil organic - mineral complex, which allows better uptake and utilization of soil water. This theory was confirmed by Doerr et al. (2000), Solera&Doerr (2004) and Robichaud et al. (2008).

SWR reduces the affinity of soil for water (Solera&Doerr, 2004). The relationship between hydraulic conductivity and soil hydrophobicity was confirmed by Bens et al. (2007) and Wahl et al. (2003), but accurate quantification of this relationship has not been described yet. Soils with high content of hydrophobic compounds show an increase in surface water runoff and the reduction of water available for plants arises here (Mataix-Solera&Doerr, 2003).

**Table 4: Impact of method of fertilization and rainfall variations on SWR. Different small letters indicatea significant differences (P<0.05) between individual variants within the same group and different uppercase letters indicate a significant differences between all individual variants (regardless groups).**

| Group | Variants | $K_{sat}$ (cm/s) | ±SD | Differences within same group | Differences between all variants |
|---|---|---|---|---|---|
| | A1 | 0.000395 | 0.00012 | a | A |
| A | A2 | 0.000352 | 0.00017 | a | A |
| | A3 | 0.000441 | 0.00031 | a | A,C |
| | B1 | 0.000147 | 0.00004 | a | B |
| B | B2 | 0.000139 | 0.00006 | a | B |
| | B3 | 0.000481 | 0.00024 | b | A |
| | C1 | 0.000725 | 0.00026 | a | A,C |
| C | C2 | 0.000483 | 0.00023 | a | A,C |
| | C3 | 0.000918 | 0.00026 | a | C |

Moreover, Cosentino et al. (2010) point to the fact that there is a direct linkage between the amount of hydrophobic compounds and stability of soil aggregates. This indicates that the optimal degree of SWR is desired to increase soil fertility and resistance against soil erosion.

**Acknowledgements**

This work was supported by the grant IP 19/2014 - Internal Grant Agency of Agronomy faculty; Mendel University in Brno. Moreover, this work was supported by the National Agency for Agricultural Research (NAZV), project: *The possibilities for retention of reactive nitrogen from agriculture in the most vulnerable infiltration area of water resources*, registration no.: QJ 1220007.

**References**

BENS, O., WAHL, N. A., FISCHER, H., HÜTTL, R. F., 2007: Water infiltration and hydraulic conductivity in sandy cambisols: impacts of forest transformation on soil hydrological properties.*European Journal of Forest Research*. 126 (1): 101-109.

BUCZKO, U., BENS, O., HÜTTL, R. F., 2005: Variability of soil water repellency in sandy forest soils with different stand structure under Scots pine (Pinussylvestris) and beech (Fagussylvatica). *Geoderma*. 126 (3-4): 317-336.

COSENTINO, D., HALLET, P. D., MICHEL, J. C., CHENU, C., 2009: Do different methods for measuring the hydrophobicity of soil aggregates give the same trends in soil amended with residue?.*Geoderma*. 159 (1-2): 221-227.

DECAU, M. L., SIMON, J. C., JACQUET A., 2003: Fate of urine nitrogen in three soils through a grazing season. Journal of Environmental Quality, 32 (4): 1405-1413

DIAZ, L.F., BERTOLDI M., 2007: Compost science and technology. Elsevier:Boston,364p.

DOERR, S. H., SHAKESBY, R. A., WALSH, R. P. D., 2000: Soil water repellency: its causes, characteristics and hydro-geomorphological significance. *Earth-Science Reviews*, 51 (1-4): 35-65.

ELBL, J., FRIEDEL, J. K., PLOŠEK, L., KINTL, A., PŘICHYSTALOVÁ, J., HYNŠT, J., DOSTÁLOVÁ, L., ZÁKOUTSKÁ, K., 2013: Leaching of mineral nitrogen and phosphate from rhizosphere soil stressed by drought and intensive rainfall. *World Academy of Science and Technology*. 7 (11): 324-330.

ELBL, J., PLOŠEK, L., KINTL, A., HYNŠT, J., JAVOREKOVÁ, S., ZÁHORA, J., KALHOTKA, L., 2014: Effects of drought on microbial activity in rhizosphere, soil hydrophobicity and leaching of mineral nitrogen from arable soil depending on method of fertilization. *World Academy of Science, Engineering and Technology* (in press).

LICHNER, L., HALLETT, P. D., FEENEY, D. S., ĎUGOVÁ, O., ŠÍR M., TESAŘ M., 2007a: Field measurement of soil water repellency and its impact on water flow under different vegetation. *Biologia* (Section Botany), 62: 537-541.

LICHNER, L., ORFÁNUS, T., NOVÁKOVÁ, K., ŠÍR M., TESAŘ, M., 2007b: The Impact of vegetation on hydraulic conductivity of sandy soil. *Soil & Water Resources*, 2: 59-66.

MATAIX-SOLERA, J., DOERR, S. H., 2004: Hydrophobicity and aggregate stability in calcareous top soils from fire - affected pine forests in southeastern Spain. *Geoderma*.118 (1-2): 77-88.

NOVOSADOVÁ, I., ZÁHORA, J., 2011: The availability of mineral nitrogen in mediterranean open steppe dominated by *Stipatenacissima* L. *ActaUniversitatisAgriculturae et SilviculturaeMendelianaeBrunensis*, 59 (5): 187-192.

PICCOLO, A., SPACCINI, R., HABERHAUER, G., GERZABEK, M. H., 1999: Increased Sequestration of Organic Carbon in Soil by Hydrophobic Protection. *Naturwissenschaften*.10: 496-499.

ROBICHAUD, P. R., LEWIS, S. A., ASHMUN, L. E., 2008: New procedure for sampling infiltration to assess post-fire soil water repellency. *Res. Note. RMRS-RN-33*. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 14 p.

SCHAUMANN, G. E., BRAUN, B., KIRCHNER, D., ROTARD, W., SZEWZYK, U., GROHMANN, E., 2007: Influence of biofilms on the water repellency of urban soil samples. Hydrological processes, 21 (17): 2276-2284.

SOLERA, J. M., DOERR, S. H., 2004: Hydrophobicity and aggregate stability in calcareous topsoils from fire-affected pine forests in southeastern Spain. *Geoderma*. 118 (1-2): 77-88.

SUTTON, M. A., 2011: The European nitrogen assessment: sources, effects and policy perspectives. New York: Cambridge University Press.

ŠINDELÁŘ, R., KOVAŘÍČEK, P., VLÁŠKOVÁ, M., HŮLA, J., KROULÍK, M., 2008: Measurement of water infiltration into soil using round infiltrometer mini disk. *Agritech-Science*.2: 1-6.

WAHL, N. A., BENS, O. SCHAFER, B., HÜTTL, R. F., 2003: Impact of changes in land-use management on soil hydraulic properties: hydraulic conductivity, water repellency and water retention. *Physics and Chemistry of the Earth*. 28 (33-36): 1377-1387.

**Contact address:**

Ing. Jakub Elbl
Mendel University in Brno
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: jakub.elbl@mendelu.cz

# COMPACTION PARAMETERS AND SOIL TILLAGE QUALITY IN SYSTEM WITH PERMANENT TRAFFIC LANES

**D. Gutu[2], J. Hůla[1], P. Kovaříček[1], M. Vlášková[1]**

[1]Research Institute of Agricultural Engineering, p.r.i., Czech Republic
[2]ZAS Podchotucí, a.s., Křinec, Czech Republic

**Abstract**
In the field experiment were all machines passages concentrated in permanent traffic lanes at the module of machine working width 6 metres. The paper contains results of measurement of soil porosity in variants with traffic lanes and outside the traffic lanes. The results confirm a benefit of wheel traffic concentration to permanent traffic lanes aimed at protection of the most part of the field from soil compaction. Another confirmed advantage of concentration of passages into permanent tracks is an increase of soil tillage quality in the most part of the field. After a medium deep tillage in November 2012 were clods hardness and shearing strength of clods lowest outside the traffic lanes, in traffic lanes of wheels of a tractor during sowing, combine harvester and soil tillage were acceptable.

**Keywords:** traffic on fields; porosity of soil; clods hardness

## Introduction
Contemporary technologies of field crop cultivation are connected with wheel traffic on fields that causes undesirable soil compaction. In past years intensive researches on problems of undesirable soil compaction have been conducted (Håkansson, 1995; Unger, 1996). The wheel load may cause different reactions in the soil profile, first of all in relation with soil moisture and degree of preceding soil loosening or compaction. At present, there are great efforts to decrease the wheel traffic of machines in fields to permanent tracks in order to maintain a major part of the area under crops without negative influence of wheel traffic (Chamen et al., 2003; Tullberg, 2007). The system of controlled traffic farming (CTF) is now regarded as prospective also because satellite navigation systems are available that make it possible to ensure the required accuracy of passes during all field operations. In the farm, which has a high-performance agricultural machinery was established field experiment with CTF system. The influence of wheel traffic restriction to permanent lanes on soil properties and on soil tillage quality was tested.

## Material and methods
A field trial on a land of 10 ha in size was established in the spring 2010. Soil conditions in the field: loamy soil (content of particles smaller than 0.01 mm in the topsoil layer: 38.3% by weight). Content of combustible carbon in topsoil: 3.8%.
In 2011 after forecrop harvest (winter wheat) the field was worked by a sweep cultivator to a depth of 80 mm, in autumn the soil tillage by a combined cultivator to a depth of 200 mm followed. 18.10.2011 were sown winter wheat. All wheel traffic was organised within the CTF system using OutTrac (Chamen, 2006) – Fig. 1. It is typical of this wheel traffic system that the wheel tracks of a combine harvester that has a wider wheel gauge than tractors are on the outer side of common permanent traffic lanes.
Tab. 1 gives an overview of farm machines used for field operations in the field in 2012. Those machines were chosen whose working width corresponded to the basic module of 6 m. The field operations of soil tillage and sowing were performed at the working width of 6 m. The wheel rows established during sowing were used for the application of chemicals for plant protection while the working width of a sprinkler was 18 m. The same wheel rows were also used for the application of mineral fertilisers.
On this field the soil properties were evaluated in four variants of wheel effect:

1 Traffic lanes of tractors during sowing, application of chemicals for plant protection, application of mineral fertilisers, lanes of a combine harvester and during soil tillage.

2 Traffic lanes of wheels of a tractor during sowing, lanes of a combine harvester and lanes of a tractor during soil tillage (without lanes of tractors at chemicals for plant protection and mineral fertilizers application).
3 Outside the traffic lanes.
4 Part of the field with uncontrolled wheel traffic (area of 3 ha) - Random.

In the variants of the field trial measurements basic physical properties of soil were evaluated in the spring season. After soil tillage in autumn, the indicators of soil tillage quality were assessed. To measure the shearing strength of soil a CL-100 vane probe (Terratest) was used. Clods hardness was measured by pocked penetrometer. By sieving on sieves has been clods size detected after soil tillage in autumn 2012.
For the navigation of machines during soil tillage, sowing, application of chemicals for plant protection, application of mineral fertilizers and during harvest a GPS satellite system with the correction signal of RTK VRS was used. For machines steering an assisted steering system AgGPS EZ-STEER (Trimble) was used. The vehicles for transport during the operation of a combine harvester did not pass across the field the grain tank of a combine harvester was emptied to a tractor semi-trailer on the edge of the field near the road.
This paper contains the results of evaluation of wheel traffic impacts on the soil in a field trial in 2012 (the third year of the consistent application of controlled traffic farming in a field). In that year winter wheat was grown in the field concerned, after its harvest soil tillage for spring pea followed.

**Tab. 1 Field operations in 2012 and machines**

| Field operation | Time | Machines | Working width [m] | Distance of tracks [mm] | Tyre width [mm] |
|---|---|---|---|---|---|
| Sowing of winter wheat | 18.10.2011 | CASE 7140 + VÄDERSTAD Rapid 600P | 6 | 2000 | 500x2 |
| Mineral fertilizers application | 18.3.2012 | By airplane | - | - | - |
| Herbicide application | 27.4.2012 | CASE JX 1100U + AGRIO NAPA 18 | 18 | 1800 | 320x2 |
| Pesticide application | 11.6.2012 | CASE JX 1100U + AGRIO NAPA 18 | 18 | 1800 | 320x2 |
| Winter wheat harvest | 2.8.2012 | CLAAS Lexion 460 | 6 | 2750 | 650x2 |
| Shallow loosening (depth 120 mm) | 20.8.2012 | CASE 335 + FARMET Hurikan 600 | 6 | 2220 | 720x2 |
| Mineral fertilizers application | 20.8.2012 | ZETOR 10145 + AMAZONE 1000 | 18 | 1800 | 300x2 |
| Repeated shallow loosening | 19.9.2012 | CASE 335 + FARMET Hurikan 600 | 6 | 2220 | 720x2 |
| Medium deep loosening (200 mm) | 15.11.2012 | CASE 335 + Simba SLD 600 | 6 | 2220 | 720x2 |

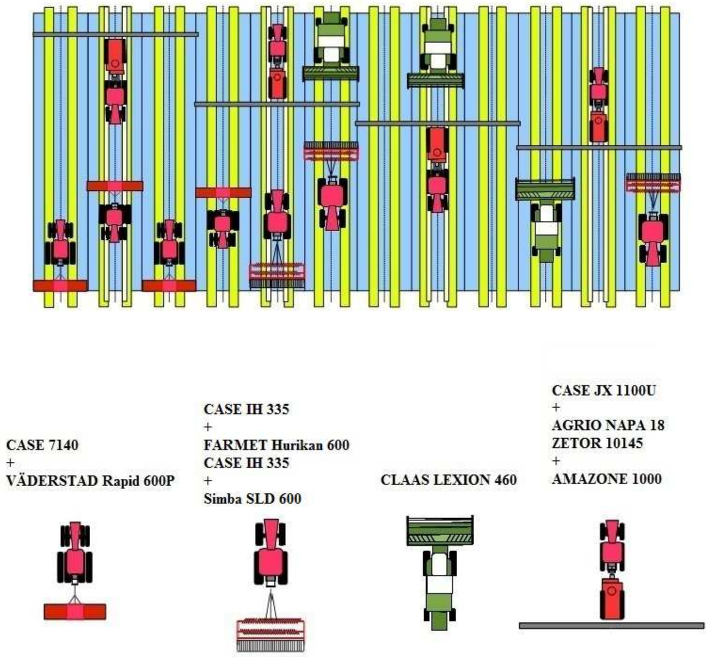



**Fig. 1Wheel ruts of tractors and combine harvester on the field**

**Results and discussion**

The Fig. 2 and 3 illustrates the average values of soil total porosity on 26th April 2012. At a depth of 0.15-0.20 m the highest total porosity of soil was in variant 3 (Fig. 2). Among other variants, the differences of soil porosity were statistically insignificant. Statistically insignificant differences were in the depth of 0.25-0.30 m (Fig. 3). Because the wheel traffic in 2012 were after the collection of soil samples, these results indicate a relatively balanced soil porosity values. The increase of soil compaction due the tractor passes at winter wheat sowing (18.10.2011) was observed only in the surface layer of soil (Fig. 2).

In 2012 the field was run over a total of seven times, as in previous years passes were concentrated in permanent rolling tracks. After a medium deep tillage in November 2012 were measured shear stress in clods and hardness of clods on the soil surface. Measurements with vane probe on 15th November 2012 showed increasing differences between variants 1 (wheel rows) and 4 and the other variants (Fig. 4). Values of the shearing strength of clods in variant 1 were more than six times higher than in the variant 3 (outside wheel tracks), these differences were statistically significant. Highest values of the shearing strength of clods were found on variant 4 (Random).

The Fig. 5 documents the values of penetration resistance of clods in the surface layer of soil in November 2012 after autumn soil tillage. The highest penetration resistance of clods was on variants 1 and 4 (2.9 times more than on variant 3).

Average soil moisture of clods was 17.2% of the weight in variant 1 and 17.6% of the weight in variants 2, 3 and 4.

Graph in Fig. 6 documents the size clods after medium deep loosening (200 mm) on November 2012. The best size clods fractions were on variant 3. On all other variants were in the soil surface layer clods too big (over 100 mm). Too big clods make difficult the seedbed preparation for winter crops.

The existing results of pilot field trial show that the system CTF is useful in conditions of agricultural enterprises with good technical equipment and good organize of work operations. The system of controlled traffic farming with permanent separation of wheel tracks of machines from the production area of the field without traffic is used in the ZAS Podchotuci, a.s. agricultural enterprise in Krinec for 4 years on the land of 10 ha. Although the wheel gauge of combine harvester is wider than the wheel gauge of tractors, a relatively good situation was reached when the total area of wheel tracks in the field (with the exception of headland) accounted for 32% of the land area if the module of the 6-metre working width of machines was used. But it is realistic to decrease the area of wheel tracks to 20-25%

CONTENT

of the field area when the module of working width be wider (8 or 9 m). In conditions of the Czech Republic the monitoring of wheel traffic in fields showed that the wheel tracks accounted for 86% of the field area in the production system of winter wheat when conventional soil tillage was used (Kroulik et al., 2011).

Other decrease of the proportion of wheel tracks in the area of fields could be reached by unification of the wheel gauge of tractors and harvesting machines - these adaptations of machines for the CTF system are already implemented in some countries (Tullberg, 2010).

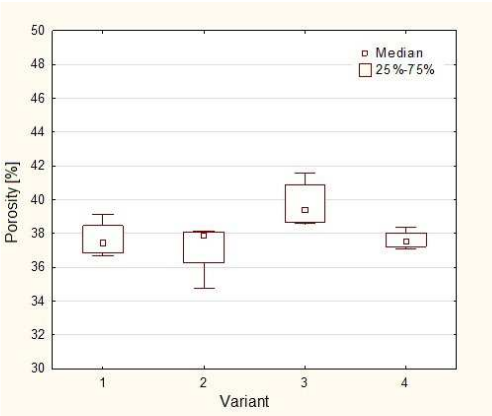



**Fig. 2 Soil total porosity on 26th April 2012 – 0.15-0.20 m**

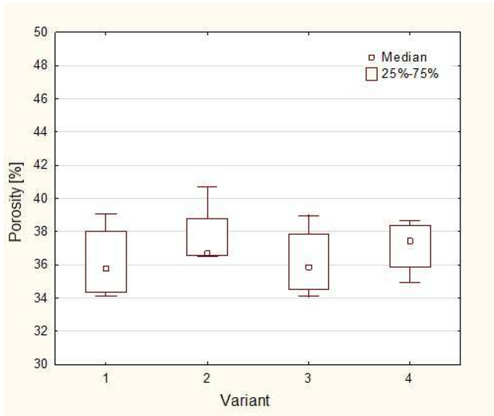



**Fig. 3 Soil total porosity on 26th April 2012 – 0.25-0.30 m**

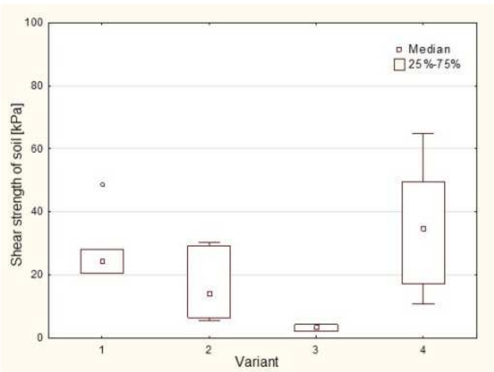



**Fig. 4 Shear strength of clods in the surface layer of soil after soil tillage (15th November 2012)**

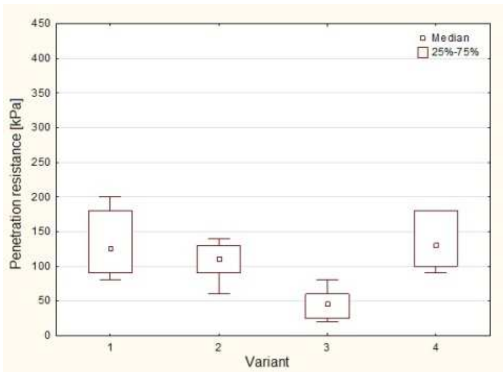



**Fig. 5 Penetration resistance of clods in the surface layer of soil after soil tillage (15th November 2012)**

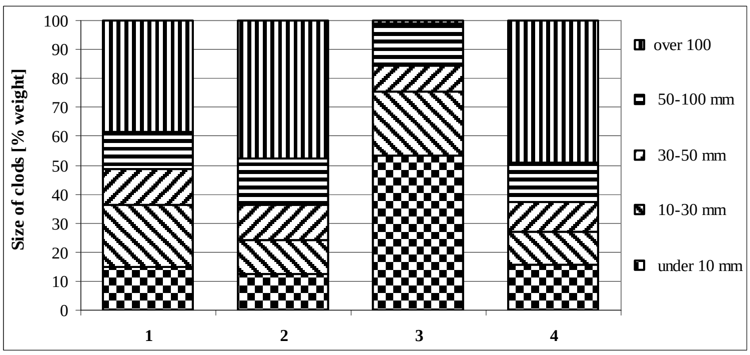



**Fig. 6 Size of clods after medium deep loosening (200 mm) on November 2012**

**Conclusions**

The research results of a pilot field trial obtained in 2012 show that the controlled traffic farming system can be realized in agricultural enterprise. The requirement is the use of a precise navigation satellite system with the correction signal with the assisted or automated steering of tractors and combine harvesters. The controlled traffic farming system can be used in minimum tillage and soil conservation technologies for the production of crops harvested by combine harvesters.

**Acknowledgements**

Supported by the Ministry of Agriculture of the Czech Republic under the institutional support for long-term strategic development of RIAE, p.r.i.

**References**

CHAMEN W.C.T., ALAKUKKU L., PIRES S., SOMMER C., SPOOR G., TIJINK F., WEISSKOPF P., 2003: Prevention strategies for field traffic - induced subsoil compaction: a review, Part 2. Equipment and field practices. *Soil & Tillage Research*, 73: 161–174.

CHAMEN W.C.T., 2006: Controlled traffic farming on a field scale in the UK. In: Horn, R. - Fleige, H. - Peth, S. - Peng, X.H., (Eds.): Soil Management for Sustainability. *Advances in geoecology*, 38: 251-260.

HÅKANSSON I., 1995: Compaction of arable soils. Uppsala, SLU Uppsala, No. 109, 153 p.

KROULÍK M., KVÍZ Z., KUMHÁLA F., HŮLA J., LOCH, T., 2011: Procedures of soil farming allowing reduction of compaction. *Precision Agriculture*, 12 (3): 317-333.

TULLBERG J.N., YULE D.F., MCGARRY D., 2007: Controlled traffic farming - From research to adoption in Australia. *Soil & Tillage Research*, 97: 272-281.

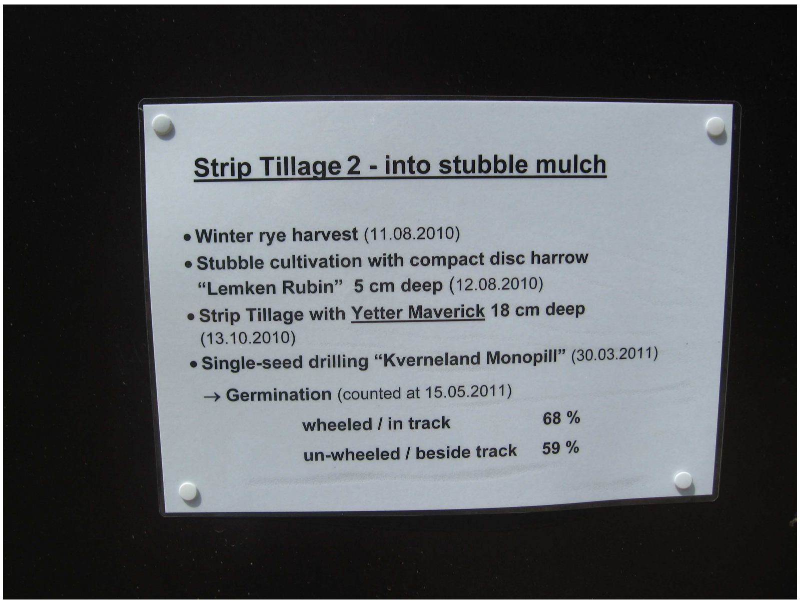
TULLBERG J., 2010: Tillage, traffic and sustainability - A challenge for ISTRO. *Soil & Tillage Research*, 111: 26-32.

UNGER P.W., 1996: Soil bulk density, penetration resistance, and hydraulic conductivity under controlled traffic conditions. *Soil & Tillage Research*, 37: 67-75.

**Contact address:**

prof. Ing. Josef Hůla, CSc.
Research Institute of Agricultural Engineering, p.r.i.
Drnovská 507
161 01 Prague
Czech Republic
e-mail: josef.hula@vuzt.cz
tel.: +420 233022263

## Controlled Traffic Farming from workshop in Freising




# POSSIBILITY OF GROWTH REGULATOR APPLICATION IN SPRING BARLEY

**M. Houšť, I. Baráyiová, J. Křen**

Mendel University in Brno, Czech Republic

**Abstract**

The field experiment testing various growth regulators in spring barley was founded in 2012. The growth regulators were applied such as Retacel extra R68 (chlormequat chloride 720 g/l), Moddus (trinexapac-ethyl 250 g/l), Optimus (trinexapac-ethyl 175 g/l), Medax Top (prohexadione 42 g/l, mepiquat 228 g/l), Cerone (ethephon 480 g/l). They were applied in different development phases, various doses per hectare, and their combinations. The aim of the experiment was to determine the impact of the pesticides on the growth, development and yield of spring barley. Specifically, the factors affecting the lodging of plants - plant height, straw strength (width and length) should be evaluated. The field experiment should also be focused on the possibility of negative effects of growth regulators on yield (ear length, the number of grains in the ear, thousand grain weight).

**Keywords:** barley, growth regulators, lodging

## Introduction

Currently, spring barely belongs to the crops providing good economic result in suitable growing conditions. The success of cultivation of spring barley is to make the highest possible yield at an acceptable cost. In the most suitable growing conditions, spring barley is able to achieve the yield in the range of 8-9 t.ha$^{-1}$. The yield requires sufficient number of productive tillers per m$^2$. High yields can be reached by vegetation having the density of about 1.000 productive tillers per m$^2$. In such vegetation, the competition among plants or offshoots about space may occur, and therefore the strength and thickness of the stem are lower than in the vegetation with lower density. This fact results in susceptibility of denser vegetation to lodging. One of the tools to prevent crop lodging is the application of growth regulators.

The use of growth regulators in cereals may have three different objectives. The regulators are most often applied to reduce lodging. During the process, the effect of shortening and strengthen stem is put. The applications are carried out depending on the crop and used product from the beginning of the stem elongation till the time exactly before the inflorescence emergence. Another possibility is to use for the support of tillering and thickening stands. The application is taken throughout the duration of tillering. The last possibility of putting growth regulators is to increase the certainty of overwintering of overgrowing winter cereals in the autumn. For agricultural purposes, the growth regulators are substances influencing physiological processes in plant metabolism by the required way. It also positively affects crop yields and the quality of production. This is mainly to increase the resistance to winter, lodging limitation, straightening of offshoots, to reduce apical dominance, higher fitting of generative organs, more efficient use of nutrients, decreasing harvest losses, and facilitating the harvest (Vašák et al., 1997). The application of growth regulators is the important factor in the intensification of cereal cultivation, and currently it is also a necessary measurement. Therefore, the proper use of plant growth regulators forms the integral part of the intensive cultivation technology relating to modelling vegetation, harvest, and then the economy of growing (Bezdíčková, 2011). The primary objective is to use plant growth regulators to prevent lodging of vegetation causing in strong cases the damaging

previous inputs such as decreasing harvest and its quality and increasing the costs for harvesting. The application of growth regulators can affect the straightening of productive tillers and prolongation of the activity of leaf surface.
The greenhouse research confirms that the growth regulators can reduce the evapotranspiration by up to 29 % (Green et al., 1990). Some studies confirm that growth regulators may actually increase rooting (Cooper et al., 1987). The previous studies have shown that the plants with slow growth can survive prolonged drought than the fast growing plants (Kondoh et al., 2006). The use of growth regulators is accompanied by many positive effects especially in conditions of water deficit. The application of growth regulator Trinexapac – ethyl promotes the formation of the root system, to ensure the increasing of stem stability, and to improve the transport of water and nutrients. The using of the CCC product can be achieved better regulation of stomata, stimulating root growth and the increasing of using of water efficiency. The application of fungicides of strobilurin type is provided higher photosynthetic rate and the reduction of stomata conductivity. The Ethephon product and its effect on the plant allows increasing of water potential. The use of phytohormones or synthetic regulators can be accomplished by the partial elimination of environmental stress, respectively, to alleviate the effect of stress or to facilitate plant regeneration after the stress action. It can be theoretically assumed that the controller itself causes the increase or decrease crop. Despite of its effect which is correlating with the influence of all other environmental parameters. It is not possible to stabilize the optimal conditions in which the regulator would cause to the crop to reache a higher crop because the interactive variable external conditions influence the conditions of the crop development at the same time. Drought belongs then to the most important environmental factors adversely affecting vegetation. The application of growth regulators can be achieved the partial elimination of the impacts of environmental stress. Growth regulators can improve the efficiency of water use in the case of closing of stomata. It also causes the increase in the root proportion. The above ground biomass may affect the accumulation of antioxidants protecting the plants during stress conditions.

**Material and methods**

The experiment was carried out on the experimental field station in Žabčice. Various options of treatment by growth regulators in spring barely were evaluated there. The experiment was established in 2012, variety Bojos seeded on 6$^{th}$ March in 2012. Seed quantity was 5 MGS. The previous crop was winter wheat. N fertilization using LAV fertilizer at the dose of 100 kg N/ha was once performed before sowing spring barley. The crop was treated using the herbicide Sekator OD + Mero against dicotyledonous weeds and Axial product against *Apera spica venti*. Pest control against *Oulema* was carried out using the Proteus product at the stage of BBCH 33. The protection against fungal diseases was done using Archer turbo at the stage of BBCH 33. The growth regulators were applied in three periods: T1 - BBCH 28-30 , T2 - BBCH 31-32 , T3 - BBCH 37 – 39. In laboratory analyzes, eight plants of each variant were selected for the analysis. Each plant had at least two productive tillers. It means that at least 16 productive tillers (stems) were analyzed. During the analyzes, the subsequent parameters were assessed, such as the length of ear, stem height, the total plant height, the number of grains per ear, the length of internodes, the internodes thickness and the carrying capacity of the internodes. The values were measured in the first three internodes. The carrying capacity of internodes was tested by the method of loading internodes. In 2013, the experiment was continued. Some new formulations and combinations were included into the variants.

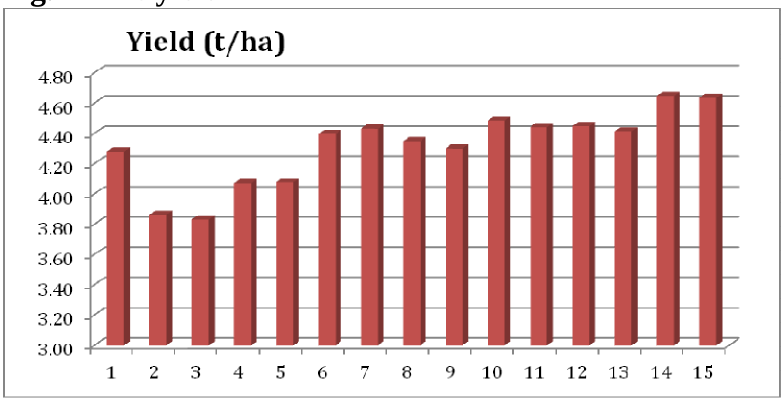
CONTENT

## Results and discussions

**Tab. 1 The variants of treatment of growth regulators in barley in 2012**

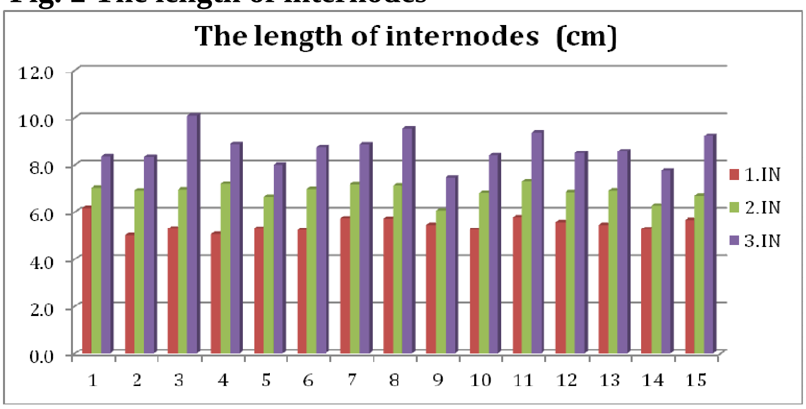
| BBCH | | Growth regulators 2012 BBCH 28 - 30 | BBCH 31 - 32 | BBCH 37 - 39 |
|---|---|---|---|---|
| variants | | | | |
| 1 | | Kontrola | | |
| 2 | | | Moddus 0,4 l/ha | |
| 3 | | | Moddus ME 0.4 l/ha | |
| 4 | | Moddus 0,4 l/ha | | |
| 5 | | | Moddus 0,3 l/ha + CCC 0,5 l/ha | |
| 6 | | CCC 1 l/ha | Moddus 0,4 l/ha | |
| 7 | | | Moddus 0,3 + Archer turbo 0,8 l/ha | |
| 8 | | | Moddus ME 0.4 l/ha + Archer turbo 0.8 l/ha | |
| 9 | | | | Cerone 0,7 l/ha |
| 10 | | | Moddus ME 0.3 l/ha + CCC 0.5 l/ha | |
| 11 | | | | Moddus ME 0.4 l/ha |
| 12 | | | | Moddus 0.2 l/ha + Cerone 0.3 l/ha |
| 13 | | Moddus 0,2 l/ha + CCC 0,5 l/ha | | Cerone 0,5 l/ha |
| 14 | | | Moddus 0,3 l/ha + CCC 0,5 l/ha | Moddus 0.2 l/ha + Cerone 0.3 l/ha |
| 15 | | CCC 1 l/ha | Moddus 0,4 l/ha | Cerone 0,7 l/ha |

**Fig. 1 The yield**



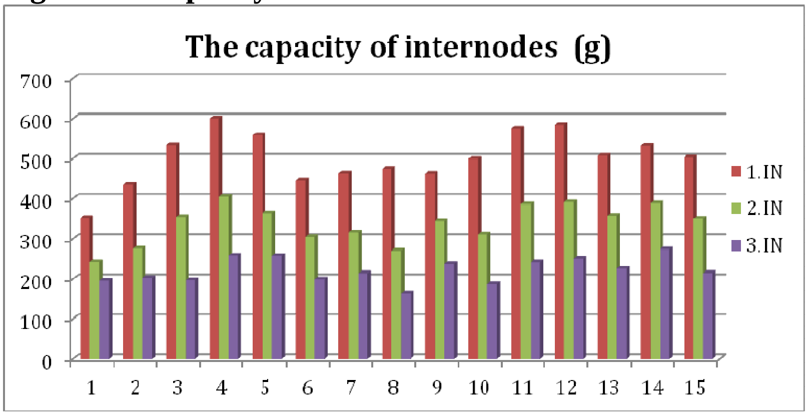

The best yields were achieved by the variants 14 and 15. More products were applied in various stages of development. Conversely, the lowest yield was reached in the variants 2 and 3 using products Moddus respectively Moddus ME in the development stages of BBCH 31-32 at the dose of 0.4 $l.ha^{-1}$. The decrease of yield was probably caused by the stopping of the development of weaker and later period offshoots of spring barley.

**Fig. 2 The length of internodes**



From the graph, it can be seen that the length of internodes increasing by 1 after the third internode. The differences between the versions are minimal. The graph shows that the control had the longest internode 1. Conversely, the shortest first internode was the possibility 2 coming from Moddus at the rate of 0.4 $l.ha^{-1}$ in the growth of BBCH 31-32. The most curtailed by the last internode was in later of the developmental stage of BBCH 37-39 by Cerone at the dose of 0.7 $l.ha^{-1}$.

**Fig. 3 The capacity of internodes**




The control particularly showed the lowest capacity in the first and second internodes in some cases. The high capacity was showed by the variations of 4, 5, 11 and 12. The variants 4 and 5 are based on the application of the products in the growth of BBCH 31-32. The products Moddus and the combination of Moddus and CCC were used. The other way round, the variants 11 and 12 were based on the application of growth regulators in the last possible stage of development of BBCH 37-39. In this case the product Moddus or the combination of Moddus and Cerone were used.

**Conclusions**

The use of growth regulators is highly dependent on the weather conditions. In 2012, there was dry vegetation period at experimental location Žabčice corresponding to the experimental results. The growth regulators will have to strengthen and shorten the stem, as prevention malt barley lodging. In 2012, the average yield of the experiment achieved 4 $t.ha^{-1}$, what is in relation with drought during vegetation. In such growth and its structure, the conditions for lodging were not provided. It was showed in the conditions before harvest. The lodging of vegetation was at the level of 0%. To offer the lodging potential of spring barley vegetation, the crop yield level should be at least 6 $t.ha^{-1}$.

Despite of the results of the vegetation not offering the potential for lodging, it can be observed that the growth regulators adjusting the morphology of the stem development. The height, strength and the stem resistance to lodging can be regulated using them. It is always important to consider the dose and the combination of products with respect to the structural condition of vegetation, soil moisture, variety, and the assumed course of weather after the application. Spring barley has lower lodging resistance according to previous suggestion. Two applications are usually carried out during vegetation. The first application is in the stage of BBCH 30-32. One of the suitable possibilities is the application of Moddus product at the dose of 0.1 to 0.3 $l.ha^{-1}$ + CCC from 0.3 to 0.8 depending on the application conditions. The second phase is followed in the development of BBCH 37-43 (from the appearance of the last leaf to the leaf sheath distention). It is most often used in the Cerone products at the dose of 0.4-0.7 $l.ha^{-1}$. The suitable combination is also based on 0.4 $l.ha^{-1}$ Cerone + 0.2 $l.ha^{-1}$ Moddus.

The current state of vegetation, variety, location, weather are always necessary to take into account for the dose establishment and the combination of the products. Generally speaking, the higher amount of precipitation of vegetation are more susceptible to lodging. They tolerate higher doses of morforegulators better than the growths less density of ear per unit area.

**Acknowledgements**

This paper was prepared with financial support of the project QJ1210008, titled: "Innovation cereal production systems in different agro-ecological conditions of the Czech Republic".

**References**

BEZDÍČKOVÁ, A., 2011: Ako správne používať regulátory pri pestovaní obilnín. In: Ako udržať ziskovosť pestovania obilnín. Praha, s.59-63

COOPER, R.J. et al., 1987: Root growth, seedhead production and quality of annual bluegrass as affected by mefluidide and a wetting agent. Agronomy Journal 79:929-934

GREEN, R. L., K. S. KIM and J. B. BEARD., 1990: Effects of flurprimidol, mefluidide, and soil moisture on St. Augustinegrass evapotranspiration rate. HortScience 25:439-441

KONDOH, S. et al., 2006: Interspecific variation in vessel size, growth and drought tolerance of broad-leaved trees in semi-arid regions of Kenya. Tree Physiol. 26:899–904

RADEMACHER, W. (2000): Growth Retardants: Effect on giberelin biosynthesis and other metabolit pathways. Annu. Rew. Plant. Physiol. Plant Mol. Biol. 2000, 51: 501–531.

RAJALA, A., Peltonen-Sainio P. (2001): Plant growth regulator effects on spring cereal root and shoot growth. Agronomy Journal, Vol: 93, Issue: 4, Pages: 936–943, 2001

VAŠÁK, J., FÁBRY, A., ZUKALOVÁ, H., MORBACHER, J., BARANYK, P. et al., 1997: Systém výroby řepky - česká a slovenská pěstitelská technologie ozimé řepky pro roky 1997 - 1999. Praha: Svaz pěstitelů a zpracovatelů olejnin, 1997, 116 s

**Contact address:**

Ing. Martin Houšť
Ústav agrosystémů a bioklimatologie
Mendelova univerzita v Brně
Zemědělská 1, 613 00 Brno
e-mail: houst.martin@seznam.cz

# THE INFLUENCE OF TILLAGE TECHNOLOGY ON WEEDS IN MAIZE

**S. Chovancová, J. Winkler**

Mendel University in Brno, Czech Republic

---

## Abstract
Field trial was established in cadastre Branisovice (South Moravia, Czech Republic), in autumn 2000. It was used five crops rotation system, like winter oilseed rape, winter wheat, winter wheat, corn (for grain), spring barley. Three different ways of tillage are utilized to each crop, as CT (conventional tillage), MT (minimum tillage) and NT (no-tillage). The species *Convolvulus arvensis* were more frequently observed in no-tillage variant. *Amaranthus* spp. occurred most often in option of minimum tillage. Conventional tillage system was frequently weeded by species *Chenopodium album*, *Fallopia convolvulus* and *Echinochloa crus-galli*.

**Keywords:** weeds, maize, soil tillage

## Introduction
Cultivation of corn faces many problems, especially on soils threatened by erosion. Reductions of soil erosion is also dependent on soil surface layer structure, water infiltration into the soil and water resistance of soil aggregates, which are generally better at reduced tillage (Azzoz and Arshad, 1997; Tippl et al., 2005).
Corn is crop, in which is usually relatively small weed spectrum (Jursík and Soukup, 2006). Typical weeds are goosefoot, pigweed, bistorta and barnyardgrass. Foxtail may occur in some locality (*Setaria pumila, S. verticillata, S. viridis*) and other late spring weeds such as mercuries annual and datura. In view of the fact that datura germinates at higher temperature, it avoids mostly to herbicidal intervention and is capable to create considerable biomass in very short time. Subsequently datura degrades silage maize thanks to its toxicity. Knotweed is typical weed species occurring in maize, primarily in consequence its high resistance against wide number of soil and foliate herbicide. Perennial species such as couch grass, creeping thistle, mugwort enforce relatively easy in maize. The aforementioned spectrum of weed is characteristic for typical corn region of Czech Republic. Hanf (1982), Kohaut (2001) and Dvořák, Smutný (2003) confirm in their publications the occurrence of these weed species in maize. The cosmopolitan species are mainly from group of overwintering weeds (shepherd's-purse, field penny-cress). Their occurrence is affected by course of wheather in given year. There is a range of authors, who have dealt with the intensity of weed infestation in maize and its subsequent impact on yield. (Cavero et al., 1999; Harrison et al., 2001; STRAHAN et al., 2000; Yong et al., 1984). The results of these works showed that it may lead to reduction of yield by 12-37 % thanks to different weed infestation intensity by various weed species. Soil protective cultivation technology create new framework for cultivation of maize as well as for weeds (Procházka et al., 2009).

**Material and methods**

The experimental field is located on lands of Branisovice. Cadastre lies in the geomorphological area Dyjsko-svratecký úval (South Moravia, Czech Republic). The altitude is in range 185 to 210 m a.s.l. The area of interest belongs to the basin of Thaya river. The land pertains to corn production area and to the very hot and dry climatic region. The ten-year average annual rainfall is 456.6 mm, the long-term average temperature is 9.8 °C. Chernozem and clay-loam soil occur on the experimental land.

The field attempt was established by Monsanto ČR Ltd. company in autumn 2000. The experiment was designed as a pilot plant, parcel size is 50 m x 36 m. Five crops rotation system is used, winter oilseed rape, winter wheat, winter wheat, **maize (for grain)**, spring barely respectively. Three different types of soil tillage were utilized to each crop:

**CT (conventional tillage):** it means stubble breaking, plowing at 0.22 m and seedbed preparation with loosening .

**MT (minimum tillage):** plowing was exchanged for dual stubble breaking and classic seedbed preparation (soil is treated up to 5 cm) in the second tillage variant.

**NT (no-tillage):** soil tillage is completely omitted in the third variant. There is used the technology of direct seeding.

The evaluation of weed infestation was held in growths of maize (for grains) in 2001 and 2002 (in June). The individuals of particular weed species were counted by numerical method. The numbers of weed individuals were detected in an area of 1 $m^2$ in 25 repetitions after herbicide applications. Roundup forte before and Guardian together with Atrazin, Grid and Trend after sowing were applied for weed control in maize.

The computer program Canoco 4. 0. (Ter Braak, 1998) was used for further data processing. Collected data were evaluated by using multivariate analysis of ecological data. Redundancy analysis was used, which is based on a linear model response (linear response). 499 permutations was calculated in Monte-Carlo test. Data were centered and standardized.

**Results and discussions**

In growth of maize were found 27 species. 6.96 pcs $1m^{-2}$ were determined in no-tillage option, 8.08 pcs $1m^{-2}$ were set in variant of minimization tillage and 7.72 pcs $1m^{-2}$ were in conventional tillage. The average numbers of weed species individuals in particular tillage options are shown in Table 1.

The results of evaluation were processed by redundancy analysis (RDA). On the basis of frequency of occurrence and weed density in individual monitoring, the spatial arrangement of particular weed species and different tillage options was created by RDA and graphically displayed in the ordination diagram. Weed species are presented by vectors (arrows). Tillage options are shown as points. In case the vector of relevant weed species tends to the concrete point of tillage variant, its occurrence is more bounded to this type of tillage. Figure 1 represents results of redundancy analysis, which are significant at the significant level $\alpha$ = 0.002 for all canonical axes and explain 7.3 % of the total variability in the data.

**Conclusions**

Species *Convolvulus arvensis* was more often observed on the variant without tillage. Plants of *Amaranthus* spp., *Sambucus nigra* and *Conyza canadensis* species occurred mostly on the variant with usage of minimum tillage. The variant with conventional tillage was more frequently weedy by species as *Chenopodium album*, *Fallopia convolvulus* and *Echinochloa crus-galli*. As the results show, tillage technology significantly affects more weed species composition, than number of weed individuals. It means, we must expect some changes in the weed species compositions, in case of tillage technology change in cultivation of corn.

**Tab. 1: The intensity of weed infestation of particular tillage variants (average number pcs.m$^{-2}$)**

| Species | Tillage technology | | |
|---|---|---|---|
| | NT | MT | CT |
| *Amaranthus* spp. | 2,12 | 3,52 | 2,52 |
| *Chenopodium album* | 0,28 | 1,44 | 2,4 |
| *Anagalis arvensis* | 0,76 | 0,68 | 0,64 |
| *Convolvulus arvensis* | 1,72 | | 0,04 |
| *Chenopodium hybridum* | 0,48 | 0,64 | 0,16 |
| *Capsella bursa-pastoris* | 0,48 | 0,52 | 0,08 |
| *Echinochloa crus-galli* | 0,2 | 0,28 | 0,44 |
| *Fallopia convolvulus* | 0,04 | 0,12 | 0,48 |
| *Cirsium arvense* | 0,36 | 0,2 | |
| *Sambucus nigra* | | 0,24 | 0,08 |
| *Sonchus oleraceus* | 0,04 | 0,08 | 0,2 |
| *Anagalis arvensis f. azurea* | 0,12 | 0,08 | 0,04 |
| *Euphorbia helioscopia* | 0,04 | | 0,16 |
| *Persicaria maculosa* | 0,04 | 0,04 | 0,08 |
| *Kickxia spuria* | | | 0,16 |
| *Microrrhinum minus* | 0,08 | 0,04 | |
| *Carduus acanthoides* | 0,08 | | |
| *Silene noctiflora* | 0,04 | | 0,04 |
| *Veronica polita* | 0,04 | 0,04 | |
| *Conyza canadensis* | | 0,08 | |
| *Medicago sativa* | | | 0,08 |
| *Stachys palustris* | | 0,04 | |
| *Tripleurospermum inodorum* | | | 0,04 |
| *Urtica dioica* | | | 0,04 |
| *Sonchus arvensis* | | 0,04 | |
| *Thlaspi arvense* | 0,04 | | |
| *Fumaria officinalis* | | | 0,04 |

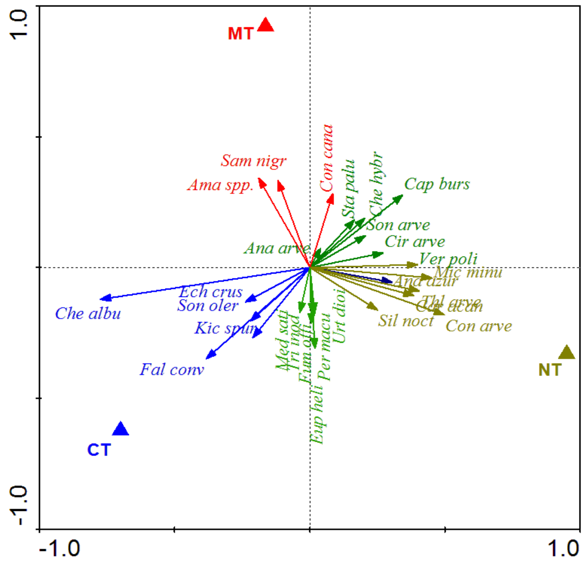



**Figure 1: Ordination diagram expressing the relation between tillage technology and found weed species**

Explanatory notes: CT – conventional tillage, MT – minimum tillage, NT – no-tillage. *Ama spp.* – *Amaranthus* spp., *Ana arve – Anagalis arvensis, Ana azure – Anagalis arvensis* f. *azurea, Cap burs – Capsella bursa-pastoris, Car acan – Carduus acanthoides, Cir arve – Cirsium arvense, Con arve – Convolvulus arvensis, Con cana – Conyza canadensis, Ech crus – Echinochloa crus-galli, Eup heli – Euphorbia helioscopia, Fal conv – Fallopia convolvulus, Fum offi – Fumaria officinalis, Che albu – Chenopodium album, Che hybr – Chenopodium hybridum, Kic spur – Kickxia spuria, Med sati – Medicago sativa, Mic minu – Microrrhinum minus, Per macu – Persicaria maculosa, Sam nigr – Sambucus nigra, Sil noct – Silene noctiflora, Son arve – Sonchus arvensis, Son oler – Sonchus oleraceus, Sta palu – Stachys palustris, Thl arve – Thlaspi arvense, Tri inod – Tripleurospermum inodorum, Urt dioi – Urtica dioica,Ver poli – Veronica polita.*

**Acknowledgements**

This work arose as project output of Internal Grant Agency AF MENDELU, number: IP 12/2014 „ The influence of different tillage technologies on weeds in maize monoculture“

**References**

AZZOZ, R. H., ARSHAD, M. A., 1997: Soil in filtration and hydraulic conductivity under long-term no-tillage and conventional tillage systéme. *Can. J. Soil Sci.*, 76, 143-152

TIPPL, M., JANEČEK, M., KAČER, M., 2005: Vliv zpracování půdy na velikost povrchového odtoku a ztrátu vody erozí. *Průběžná výzkumná zpráva projektu NAZV 1G57042*, 63-82.

JURSÍK, M., SOUKUP, J., 2008: Možnosti herbicidní regulace zaplevelení v kukuřici. *Agromanuál 4*, 10-13. ISSN 1801-767.

HANF, M., 1982: Ackerunkräuter Europas mit ihren Keimligen und Samen. *BASF Aktiengesellschaft, Ludwigshafen, Klambt-Druck GmbH, Speyer*, 496.

KOHAUT, P., 2001: Buriny Slovenska určovanie podľa klíčnych listov. *Naše pole*, Nitra, 99.

DVOŘÁK, J., SMUTNÝ, V., 2003: Herbologie-Integrovaná ochrana proti plevelům. *Skriptum MZLU v Brně*, 186. ISBN 80-7157-732-4.

CAVERO, J., ZARAGOZA, C., SUSO, M.L., PARDO, A., 1999: Competition between maize and Datura stramonium in an irrigated field under semi-arid conditions. *Weed Research* 39, 225-240.

HARRISON, S.K., REGNIER, E.E., SCHMOLL, J.T., WEBB, J.E., 2001: Competition and fecundity of giant ragweed in corn. *Weed Science*, 49, 224-229

STRAHAN, R.E., GRIFFIN, J.L., REYNOLDS, D.B., MILLER, D.K., 2000: Intenference between Rottboelllia cochinchinensis and Zea mays. *Weed Science* 48, 205-211

YONG, F.L., WYSE, D.L., JONES, R.J., 1984: Quackgrass (Agropyron repens) interference on corn (Zea mays). *Weed Science* 32, 226-234.

PROCHÁZKOVÁ, B., DRYŠLOVÁ, T., ILLEK, F. 2009: Vliv různého zpracování půdy na výnosy kukuřice a obsah organického uhlíku v půdě. *Úroda*. [CD-ROM]. In Úroda. 2009. sv. LVII, č. 12, s. 457--460.

TER BRAAK, C., J., F. 1998: CANOCO – A FORTRAN program for canonical community ordination by [partial] [detrended] [canonical] correspondence analysis (version 4.0.). Report LWA-88-02 *Agricultural Mathematics Group*. Wageningen, 1998.

**Contact address:**

Ing. Světlana Chovancová
Mendel University in Brno
Zemedelska 1
613 00 Brno, Czech Republic
e-mail: svetlana.chovancova@mendelu.cz, tel.: +420 545133115

# EVALUATION OF SOIL SEED BANK IN THE VINEYARD IN THE AREA OF ŽABČICE

**L. Jakabová, J. Winkler**

Mendel University in Brno, Czech Republic

---

**Abstract**
Evaluation of total number of seeds in the soil is an essential part of herbology and environmental studies of weeds. The potential weed infestation was evaluated in 2013 in a selected area of the vineyard in Žabčice. Twenty four weed species were identified in the soil samples. Pigweed (*Amaranthus* sp.), Purslane (*Portulaca oleracea*) and Chickweed (*Stellaria media*) were the most frequent species. A statistically proven difference was detected between their positions.

**Key words:** vineyard, weeds, soil seed bank

**Introduction**
Growth of weed populations is the conditional entry of seeds into the soil. Seeds are received into the soil via ´seed rain´ or the uncontrolled supply from transportation by wind or wild animals. Weed species, which are capable of gradation in a relatively short time, deserve our attention. Weed seeds and weed fruits of competitively weaker species are likely to lead to a reduction in the soil seed bank (Dvořák, Smutný, 2011).

**Material and methods**
Soil samples were taken in autumn 2013, from the vineyard in Žabčice. Pinot Blanc grape variety is grown here. The vineyard is located in the geological formations, which represent four furlongs of partially alluvial gravels and silts. The soil pH is neutral to slightly acidic with a lack of humus. The altitude of Žabčice is 185 meters above sea level. The average annual temperature was 9.2 °C; average annual rainfall was 480 mm. This area is situated in a rain shadow. Rainfalls are distributed unevenly during the growing season.
The soil seed bank was evaluated using a modified methodology from Smutný & Křen (2002). The vineyard was divided into 3 sections, grassed space between rows, part close to the base of the vine trunk and the cultivated soil space between the rows. Five mixed samples were taken from each part. Each sample was consisted of three partial taking of soil via spade. The soil samples were collected 0-30 cm from the surface. Samples were collected in identified plastic bags, where the soil was homogenized and then dried at room temperature. When the soil was completely dry, 100 g was taken from each sample for further processing. The next step was to process the samples using a vibratory Sieve Shaker ANALYSETTE 3, which consists of a set of sieves. Weed seeds were picked using tweezers from the residual sample under a binocular magnifier. The weed seeds were identified and counted.
The obtained soil seed bank data were processed by Multivariate Analysis of Ecological Data. The optimal analysis was guided by Lengths of the Gradient, which was obtained by Detrended Correspondence Analysis (DCA). Redundancy Analysis (RDA) was used for further processing. This analysis was based on a Linear Response model. The data were processed by a computer program CANOCO 4.0. (Ter Braak, 1998). A significant difference was retrieved by the Monte-Carlo test. It was converted into 499 permutations.

**Results and discussions**

Twenty four weed species were identified in the soil seed bank from the selected area of the vineyard. A general overview of seeds is shown in *Tab. 1*.

**Tab. 1 The total number of weed seeds in the individual parts of vineyard**

| **Species** | **Cultivated space** | **Part close to the trunk** | **Grassed space** | **SUM** |
|---|---|---|---|---|
| *Amaranthus* sp. | 2 832 | 5 241 | 2 977 | 11 |
| *Portulaca oleracea* | 2 988 | 1 071 | 1 486 | 5 545 |
| *Stellaria media* | 283 | 408 | 183 | 874 |
| *Tripleurospermum inodorum* | 23 | 85 | 30 | 138 |
| *Digitaria sanguinalis* | 20 | 76 | 41 | 137 |
| *Lamium purpureum* | 48 | 38 | 9 | 95 |
| *Lamium amplexicaule* | 44 | 14 | 14 | 72 |
| *Poa annua* | 1 | 2 | 52 | 55 |
| *Galium spurium* | 8 | 30 | 11 | 49 |
| *Polygonum aviculare* | 7 | 15 | 7 | 29 |
| *Plantago* sp. | 1 | 25 | 3 | 29 |
| *Echinochloa crus-galli* | 4 | 4 | 9 | 17 |
| *Thlaspi arvense* | 1 | 3 | 8 | 12 |
| *Holosteum umbellatum* | 2 | 8 | 0 | 10 |
| *Taraxacum officinale* | 3 | 2 | 0 | 5 |
| *Malva neglecta* | 4 | 0 | 0 | 4 |
| *Erodium cicutarium* | 1 | 0 | 2 | 3 |
| *Betula pendula* | 0 | 0 | 3 | 3 |
| *Senecio vulgaris* | 0 | 2 | 0 | 2 |
| *Ranunculus repens* | 1 | 1 | 0 | 2 |
| *Cirsium arvense* | 2 | 0 | 0 | 2 |
| *Cardaria draba* | 2 | 0 | 0 | 2 |
| *Arctium* sp. | 1 | 0 | 1 | 2 |
| *Veronica polita* | 0 | 0 | 1 | 1 |
| **SUM** | **6 276** | **7 025** | **4 837** | **18** |

The resultant weed seeds the from different parts were processed using DCA analysis. The Length of the Gradient was 1.418. RDA was selected for further statistical processing. RDA has created the layout based on the frequency of fruit and weed seeds (Fig. 1). Weed species are shown as vectors, the points display the different parts of vineyard. If the vector of the species is heading to the point, this species occurred more frequently in this part. Results of RDA analysis are significant with a significance level $\alpha = 0.002$ for all canonical axes.

Seeds of species, which occurred most frequently in samples from the grassed space between rows, are marked in green colour. These kinds are *Arctium* sp., *Betula pendula*, *Echinochloa crus-galli*, *Erodium cicutarium*, *Poa annua*, *Thlaspi arvense* and *Veronica polita*.

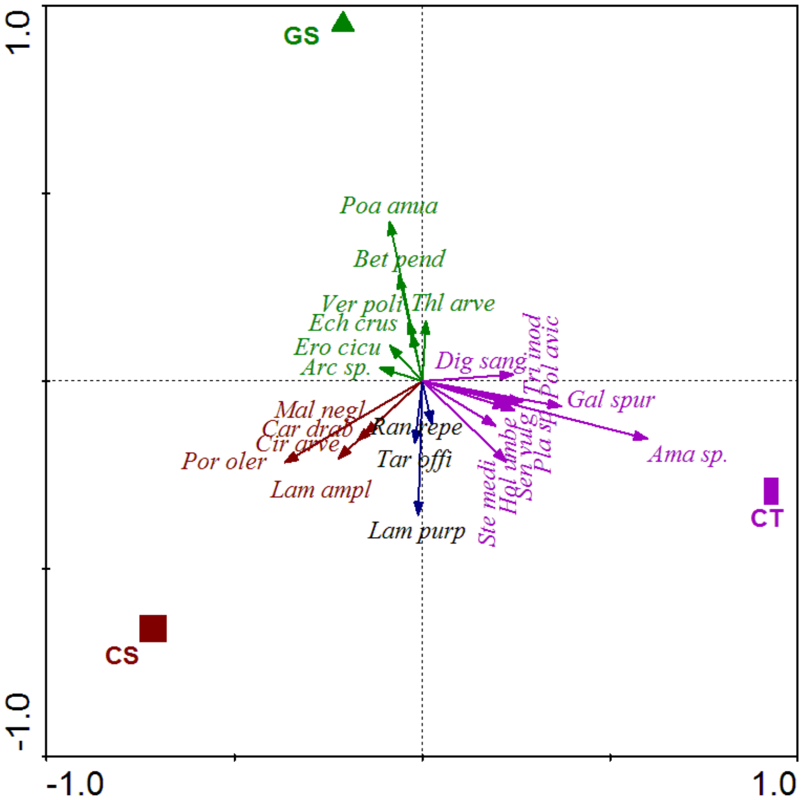
Seeds of species, which occurred most frequently in samples from part close to the base of vine trunk, are marked in violet colour. These kinds are *Amaranthus* sp., *Digitaria*

CONTENT

*sanguinalis*, *Galium spurium*, *Holosteum umbellatum*, *Plantago* sp., *Polygonum aviculare*, *Senecio vulgaris*, *Stellaria media* and *Tripleurospermum inodorum*.

Seeds of species, which occurred most frequently in samples from the cultivated soil space between rows, are marked in red colour. These kinds are *Cardaria draba*, *Cirsium arvense*, *Lamium amplexicaule*, *Malva neglecta* a *Portulaca oleracea*.

Species whose occurrence is affected by other factors are marked in black. This group includes species *Lamium purpureum*, *Ranunculus repens* and *Taraxacum officinale*.




Glossary: *Ama* sp. (*Amaranthus* sp.), *Arc* sp. (*Arctium* sp.), *Cir arve* (*Cirsium arvense*), *Dig sang*, (*Digitaria sanguinalis*), *Ech crus* (*Echinochloa crus-galli*), *Ero cicu* (*Erodium cicutarium*), *Hol umbe* (*Holosteum umbellatum*), *Lam ampl* (*Lamium amplexicaule*), *Lam purp* (*Lamium purpureum*), *Mal negl* (*Malva neglecta*), *Pla* sp. (*Plantago* sp.), *Poa anua* (*Poa anua*), *Pol avic* (*Polygonum aviculare*), *Por oler* (*Portulaca oleracea*), *Ran repe* (*Ranunculus repens*), *Sen vulg* (*Senecio vulgaris*), *Ste medi* (*Stellaria media*), *Tar offi* (*Taraxacum officinale*), *Thl arve* (*Thlaspi arvense*), *Tri inod* (*Tripleurospermum inodorum)* and *Ver poli* (*Veronica polita*).

**Fig. 1 Ordination diagram relates the occurrence of weed seeds and fruits and the sample areas parts in the vineyard**

The highest number of weed seeds and fruits were in samples from the part close to the base of vine trunk. Most often, there occurred seeds of the genus *Amaranthus* sp. It grows up in late spring and it´s resistant to herbicides. Chemical control may not have an impact on this species. The publications from Dvořák & Smutný (2011) said that the number of seeds in areas where herbicides are applied is increasing, because the competitiveness of other species is a secondary reduction in these areas. *Amaranthus* produces many seeds, so that the quantity in the soil can dynamically increase, as confirmed by Mikulka (1999). Seeds of *Portulaca oleracea* were often occurred in the soil samples from this part, but compared to the other parts was number of seeds the lowest. The reason is probably its sensitivity to chemical control (Mikulka, 1999) and the competition of other annual species.

A slightly smaller number of weed seeds occurred in samples from cultivated space between rows. *Portulaca oleracea* was the most common species, which is probably related to its biological requirement. This kind hates overgrown surface and cultivated space has enough sp

Twenty-four kinds of weed seeds were identified in soil samples from the vineyard. Seeds of the genus *Amaranthus* were the most common in the soil samples from the vineyard. The content of weed seeds in the soil is a reflection of our success in the regulation of weeds. We must pay enough attention to the regulation of species that produce large quantities of seeds, or are tolerant or resistant to chemical control. Otherwise, the number of seeds in the soil seed bank will rise and weed infestation will increase in the vineyard.

**Acknowledgements**

ace for growth and development. The genus of *Amaranthus* sp. was often in the soil samples from the cultivated soil space between the rows. The quantity was lower than in the area close to the base of the vine trunk, probably *Amaranthus* does not like repeated tillage.

The lowest number of seeds in the samples was from the grassed space between rows. A high proportion of seeds of *Amaranthus* sp. were in this space. *Amaranthus* germinate from the surface of the soil and grows well in dry areas (Mikulka, 1999). Dvořák & Smutný (2011) add that the plants have a high competitive ability, because its high stature overshadows the surrounding lower species. However, it may also be an old soil seed bank. Seeds of *Portulaca oleracea* often occurred, but the content of the seeds was lower here than in samples from cultivated space between rows. This fact is probably related to the low competitiveness in the involved space, as wrote Mikulka (1999).

**Conclusions**

The results in this paper are the output from project NAZV QI111A184 „Optimization of weed control in the precision farming system".

**References**

DVOŘÁK, J., SMUTNÝ, V., 2011: *Vlivy osevních postupů a herbicidů na zaplevelení ornice semeny plevelů: The effects of crop rotation and herbicides on weed seed bank in the soil.* Vyd. 1. Brno: Mendelova univerzita v Brně, 120 s. Folia Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. ISBN 978-80-7375-504-1.

MIKULKA, J. a kol. (1999): Plevelné rostliny polí, luk a zahrad. Vyd. 1. Praha: Farmář - Zemědělské listy, 160 s. ISBN 80-902413-2-8.

SMUTNÝ, V., KŘEN, J., 2002: *Improvement of an elutriation method for estimation of weed seedbank in the soil*. Rostlinná výroba 48, (6): 271-278.

TER BRAAK, C., J., F., 1998: CANOCO – A FORTRAN program for canonical community ordination by [partial] [detrended] [canonical] correspondence analysis version 4.0.). Report LWA-88-02 *Agricultural Mathematics Group*. Wageningen.

**Contact address:**

Ing. Lenka Jakabová
Mendelova univerzita v Brně
Zemědělská 1
613 00 Brno
Česká republika
e-mail: xjakabo1@node.mendelu.cz
tel.: +420 545 133 110

# SOIL TILLAGE MANAGEMENT IN MITIGATION OF CLIMATE CHANGE

**D. Jug[1], I. Jug[1], M. Birkás[2], V. Vukadinović[1], B. Đurđević[1], B. Stipešević[1], B. Brozović[1]**

[1]Faculty of Agriculture in Osijek, Croatia
[2]Szent Istvan University, Hungary

**Abstract**

Climatic factors (especially temperature and precipitation) in any significant extent, directly or indirectly, affect crop production. Soil water deficit or over-saturation (water-logging) directly affects on the amount of grain yields, and also many other elements. Adapted tillage systems are among the one of the most important ways to mitigate adverse climatic implications. The paper evaluates different tillage systems in climatically very different years, in the period from 1999-2009 year, and evaluations are based on the amount of average grain yields of maize, winter wheat and soybean. The conclusion is that besides the total annual rainfall, more important is a proper distribution of precipitation (especially in vegetation season). The proper and adapted application of reduced or conservation soil tillage systems can significantly mitigate the negative impact of adverse weather conditions.

**Keywords:** climate changes, extreme weather conditions, soil tillage, crop production

## Introduction

According IPCC (2014) climate models projected further warming all over Europe, with strongest warming in South, South-East and East Europe in summer. Projections of precipitation vary regionally and seasonally with decrease amount in same region of Europe (Kjellström et al., 2011). As a respond to climate changes, depends on world region, investigation of reduced or conservation soil tillage are more intensified in the last few decades (Jug et al., 2010). Finding a satisfactory agricultural measures, primarily soil tillage, which can mitigate climate aberrations (precipitation and temperature) between years, but also within the same production year, is increasingly becoming an imperative of modern crop production. Reduced/conservation tillage systems, with various measures and procedures, provide a significantly better ability to alleviate the soil deterioration affected by climate impact (Birkás et al., 2013) and possibility of better water distribution, especially in drought conditions (Vukadinović et al., 2013). Above average air temperature, despite the soil water saturation, can significantly affect the plants response to the heat stress (Jug et al., 2013), soil fertility, nutrient supply and water regime (Várallyay, 2013) and finally causing the yield decrease (Đurđević et al., 2013)

## Material and methods

Influence of different soil tillage systems in mitigation of climate changes was studied on stationary experimental sites in long-term period (1999-2009) in eastern part of Croatia. The experiment was set-up for w. wheat, maize and soybean (depend on experimental year) with four soil tillage systems: CT-Conventional tillage with ploughing up to 25-35 cm depth, followed by diskharrowing up to 10-15 cm and sowing preparation; CH-Chiselling on up to 25-35 cm depth, diskharrowing and sowing preparation as for CT; DH-Diskharrowing and sowing preparation as for CT; NT- No-Tillage sowing without any tillage operation. No-till planter was used for all tillage systems. The size of basic experimental plot was 900 $m^2$ set-up as complete randomised block design in four repetitions. The fertilization and plant protection was uniform across treatments for each crop. Observations were in aspects of some soil states and occurrences (e.g. surface coverage, penetrometer resistance, tillage pan, earthworm population etc.), plant reactions (morphological and physiological) and yields.

**Results and discussions**

The total average rainfall for the period from 1965-2009 year is 647 mm, with a range from 359 to 954 mm, from which it is clearly observed large variations in annual precipitation regime. From aspects of crop production, average precipitation variations on a monthly basis during the same year, are more important. Average annual air temperature for the period from 1965-2009 year was 11.0°C, with significant yearly variations for more than 2°C, and with the temperature aberrations within the same crop year, and with a large number of extremely hot or cold days. Based on the amount and distribution of precipitation and air temperatures, during the research period (a period of eleven years), only three years can be classified as average, and six years as an extreme (dry or humid)

**Table 1. Influence of soil tillage system on grain yields (t ha$^{-1}$) and seasons weather marks for 1999-2009 period**

| Year | Crop | Yield (t ha$^{-1}$) | | | | Average | Weather mark |
|---|---|---|---|---|---|---|---|
| | | CT | CH | DH | NT | | |
| 1999 | WW | 5.95 | 5.85 | 6.11 | 4.87 | 5.70 | A |
| | MZ | 10.53 | 10.65 | 10.44 | 9.55 | 10.29 | |
| 2000 | WW | 6.36 | 6.60 | 6.60 | 5.64 | 6.30 | D(E) |
| | MZ | 7.81 | 5.94 | 5.26 | 0.76 | 4.94 | |
| | SB | 2.33 | 2.28 | 2.02 | 0.90 | 1.88 | |
| 2001 | WW | 6.30 | 6.17 | 6.57 | 5.78 | 6.21 | H(E) |
| | MZ | 9.53 | 8.50 | 8.50 | 7.60 | 8.53 | |
| | SB | 2.87 | 2.77 | 2.94 | 2.74 | 2.83 | |
| 2002 | WW | 6.68 | 6.96 | 6.71 | 7.01 | 6.84 | A |
| | SB | 3.46 | 3.47 | 3.43 | 3.07 | 3.36 | |
| 2003 | WW | 2.73 | 2.77 | 2.64 | 2.20 | 2.59 | D(E) |
| | SB | 2.54 | 2.31 | 2.15 | 1.32 | 2.08 | |
| 2004 | WW | 6.81 | 7.05 | 6.80 | 6.49 | 6.79 | H(E) |
| | SB | 3.13 | 3.01 | 3.07 | 2.30 | 2.88 | |
| 2005 | WW | 6.24 | 6.25 | 6.21 | 5.90 | 6.15 | H(E) |
| | SB | 2.56 | 2.84 | 2.47 | 1.99 | 2.47 | |
| 2006 | WW | 7.08 | 6.47 | 6.52 | 6.17 | 6.56 | A |
| | SB | 5.09 | 5.13 | 5.14 | 4.99 | 5.09 | |
| 2007 | WW | 6.75 | 6.78 | 6.70 | 4.73 | 6.24 | D(E) |
| | SB | 1.44 | 1.49 | 1.44 | 1.45 | 1.46 | |
| 2008 | WW | 8.82 | 8.88 | 8.75 | 8.69 | 8.79 | H |
| | SB | 3.80 | 3.60 | 3.60 | 3.39 | 3.60 | |
| 2009 | WW | 7.65 | 7.69 | 7.45 | 7.35 | 7.54 | D |
| | SB | 2.50 | 2.30 | 2.29 | 2.41 | 2.38 | |

CT-Conventional tillage; CH-Chiselling; DH-Diskharrowing; NT-No-tillage
WW-Winter Wheat; MZ-Maize; SB-Soybean
A-average; D-dry; H-humid; D(E)-extreme dry; H(E)-extreme humid

The impact of weather conditions in the growing area is usually higher than other vegetation and production factors (Murdock, 2000; Birkas and Gyuricza, 2004), and so it was in this eleven years study. On the yields the highest significance had weather conditions, then tillage system. According to the average yield of investigated crops, regardless of tillage system, it can be seen that the amount of crop yields is largely influenced by regular annual distribution of precipitation, and less with total annual rainfall (Birkas et al., 2013). High crop yields on investigated soil tillage systems (Table 1) varied depending on the amount of rainfall and depending on the cultivation period (winter or spring crop), which points to the fact that the distribution of precipitation during the year significantly impacts success of the production (Komljenović et al., 2013). In average years, even with dry weather, all investigated tillage systems were with similar average yields. Small differences in the amount of yield between tillage systems are observed in extremely humid years, while the differences much more significant in the years that are characterized as extremely dry (Birkas et al., 2013; Komljenović et al., 2013). The strongest reaction to the extreme drought conditions, regarding the tillage system, had the maize, soybean had a weaker reaction, while winter wheat had the weakest respond to adverse climatic conditions. In extremely dry conditions the most stabile was CT tillage system and crop yields were decreased in inverse proportion to the reduction of the intensity of soil tillage (Jug et al., 2010).

## Conclusions

In accordance with research (1999.-2009.) of influence of different soil tillage systems in crop production (winter wheat, maize and soybean) within unfavourable weather conditions in eastern Croatia, the following conclusions can be stated:

- the most significant influence at the yield of winter wheat, corn and soybeans the most significant influence had the weather conditions, primarily rainfall and air temperature, while the influence of soil tillage was of lesser importance,
- except total amount of rainfall and average air temperature, the more importance has their regular annual distribution,
- stronger reaction to the unfavourable weather conditions expressed spring crops.

## Acknowledgements

This study has been financially supported by the science projects, granted by Ministry of Science, Education and Sports and Ministry of Agriculture of Republic of Croatia for the period 1999-2014.

## References

BIRKAS, M., GYURICZA, C., 2004: Relationship between land use and climatic impacts. *Talajhasználat Műveléshatás Talajnedvesség*, pp.10-45.

BIRKÁS, M., KISIĆ, I., JUG, D., SMUTNÝ, V., 2013: Soil management to adaptation and mitigation of climate threats. *Proceedings & Abstract of 2nd International Scientific Conference Soil and Crop Management: Adaptation and Mitigation of Climate Change* / Jug, I., Vukadinović, V., Đurđević, B. (ed.). CROSTRO – Croatian Soil Tillage Research Organization, Osijek, 26-28 September 2013, Osijek, pp.14-24.

ĐURĐEVIĆ, B., VUKADINOVIĆ, V., JUG, I., VUKADINOVIĆ, V., JUG, D., ŠEREMEŠIĆ S., 2013: Preliminary research of soil water availability and heat stress *Proceedings & Abstract of 2nd International Scientific Conference Soil and Crop Management: Adaptation and Mitigation of Climate Change* / Jug, I., Vukadinović, V., Đurđević, B. (ed.). CROSTRO – Croatian Soil Tillage Research Organization, 26-28 September, Osijek, pp.209-215

IPCC, 2014: "Climate Change 2014: Impacts, Adaptation, and Vulnerability. *Working Group II Contribution to the IPCC 5th Assessment Report — Changes to the Underlying Scientific/Technical Assessment"*, Ch 23-Europe.

JUG, D., BIRKÁS, M., ŠEREMEŠIĆ, S., STIPEŠEVIĆ, B., JUG, I., ŽUGEC, I., DJALOVIC, I., 2010: Status and perspectives of soil tillage in South-East Europe. *1st International Scientific Conference-CROSTRO, Soil tillage-Open approach*, Osijek, 09-11 September, pp.50-64, Osijek, Croatia.

JUG, I., JUG, D., ĐURĐEVIĆ, B., STIPEŠEVIĆ, B., ŠEREMEŠIĆ, S., DRAGIČEVIĆ, V., PEJIĆ, B., ĐALOVIĆ, I., 2013: Influence of climate variations on some physiological and morphological characteristics of winter wheat. *Proceedings & Abstract of 2nd International Scientific Conference Soil and Crop Management: Adaptation and Mitigation of Climate Change* / Jug, I., Vukadinović, V., Đurđević, B. (ed.). CROSTRO – Croatian Soil Tillage Research Organization, 26-28 September 2013, Osijek, pp.229-236.

KJELLSTRÖM, E., NIKULIN, G., HANSSON, U., STRANDBERG, G., ULLERSTIG, A., 2011: 21st century changes in the European climate: uncertainties derived from an ensemble of regional climate model simulations. *Tellus*, 63A(1), pp.24-40.

KOMLJENOVIĆ, I., JUG, D., MARKOVIĆ, M., KOVAČEVIĆ, V., MIŠIĆ, M., 2013: Reduced tillage as the agricultural techniques in agricultural productivity and to mitigate climate change in Croatia and Bosnia and Herzegovina: *Proceedings Scientific-professional Conference*, *Environment protection between science and practice – status and perspectives*, Institute of protection, ecology and informatics, scientific-research institute, Banja Luka, Republika Srpska, Bosna i Hercegovina, pp.401-412.

MURDOCK, L., 2000: Yield Potential and Long Term Effects of No-Tillage on Wheat Production. *University of Kentucky*. 1999-2000 Report.

VÁRALLYAY G., 2013: Soil moisture regime as an important factor of soil fertility. *Növénytermelés*, 62: Suppl. pp.307-310.

VUKADINOVIĆ V., JUG D., VUKADINOVIĆ V., 2013: Geostatistical model evaluation for soil tillage suitability II. *Proceedings & Abstract of 2nd International Scientific Conference Soil and Crop Management: Adaptation and Mitigation of Climate Change* / Jug, I., Vukadinović, V., Đurđević, B. (ed.). CROSTRO – Croatian Soil Tillage Research Organization, 26-28 September, Osijek, pp.341-351

**Contact address:**

Danijel Jug
Full professor
University of J.J.Strossmayer
Faculty of Agriculture in Osijek
e-mail: djug@pfos.hr
web: http://www.pfos.hr/~jdanijel/
tel.: ++385(0)31554833
Kralja Petra Svačića 1d
31000 Osijek
Croatia

# EVALUATION OF THE RELATIONSHIP BETWEEN THE CONTENT OF CHLOROPHYLL IN LEAF AND SIZE OF ROOT SYSTEM IN INTERCROPS AND SOLE CROPS

**A. Kintl, J. Elbl, L. Plošek, J. Kovárník, E. Pohanková**

Mendel University in Brno, Czech Republic

**Abstract**

The aim of this study is to describe relationship between concentration of leaf chlorophyll and active root zone of Winter Wheat - *Triticum aestivum* (Sole crops - SC) and Winter Wheat (Intercrops - IC) with Winter Pea – *Pissum sativum var. Speciosum*. The size of the root system was evaluated during flowering using the ELC-131D LCR Meter. At the same time, content of chlorophyll in leaves was measured using chlorophyll meter SPAD-502. The significant differences in values of SPAD were not detected between all variants, but the size of root system was different in individual variants. The significant highest value was found in variant with SC (6.1 nF). Conversely, the significant lowest values were found in variant with IC (0.8 nF at Winter Wheat and 2.3 nF at Winter Pea). Measured values indicate a positive effect of mixed culture on deposition of nitrogen in plant biomass, notwithstanding plants in mixed culture had a smaller size of root system than plants in SC.

**Key words:** winter wheat, winter pea, mixed culture, root system, SPAD

## Introduction

Intercropping can be broadly defined as a system where two or more crop species are grown in the same field and at the same time during a growing season (Hauggaard-Nielsen *et al.*, 2008 and Ofori & Stern, 1987). Mixing species in cropping systems may lead to a range of benefits that are expressed on various space and time scales from a short-term increase in crop yield and quality to longer-term agroecosystem sustainability (Malezieux *et al.*, 2009). For farming systems to remain productive, it will be necessary to replenish the reserves of nutrients which are removed or lost from the soil. In the case of nitrogen (N), inputs into agricultural systems may be derived from atmospheric $N_2$ via biological $N_2$ fixation (Peoples *et al.*, 1995). Biological nitrogen fixation is an important aspect of sustainable and environmentally friendly food production and long-term crop productivity (Kessel and Hartley, 2000). Grain leguminous can cover their nitrogen demand from biological fixation of atmospheric $N_2$ (Hauggaard-Nielsen *et al.*, 2001; Trenbath, 1976 and therefore, they compete less for soil Nmin in intercropping with cereaals (Jensen, 1996). The success of intercrop farming systems depends initially on effective nitrogen fixation and more importantly, on subsequent transfer of nitrogen to the non-legume (Stern, 1993). The root system is necessary for a plant's nutrients and water intake. Dalton (1995) demonstrated a good correlation between plant root capacitance and root mass. Root hairs can make up 70 – 80 % of the root surface area and are thought to play an important role in nutrient uptake (Marschner 1995). Crop yield depends on extracting sufficient nutrients and water from the soil (Bengough, 2009).

**Material and Methods**

*Field Experiment*

Area of our interest is the agricultural region located 8 km north from the city Prostějov. Experimental site is situated in the protection zone of underground drinking water source “Kvartér řeky Moravy”. This site is located, according Quitt (1975), in the climatic region T2, where annual climatic averages are 350-400 mm of precipitation in growing season, 200-300 mm of precipitation in winter and 8-9 °C of annual air temperature mean. The experiment was based on the black earth, moderate, loess without skeleton (BPEJ 30100).

Seeds were sown mixed in the rows in the same depth on the 10$^{th}$ of October 2012 at both variants. Three replicates of 2 x 10 m plots per treatment were arrayed in blocked design. These variants were prepared: Winter Wheat (WS) - 140 kg of N ha$^{-1}$ yr$^{-1}$; mixed culture of Winter Wheat + Winter Peas (IC) without fertilization.

*Determination of electrical capacitance of root system*

The electrical capacitance of root system was measured “in situ” by Dalton (1995) with ELC-131D LCR Meter at measuring frequency of 1 kHz in units of nF (nanoFarad). LCR meter measures the amount of electric charge stored by the root system for a given electric potential, which is dependent on the active root surface area and root length (Dalton, 1995). Electrical contact with the plant was established by connecting the negative electrode to the plants stem via a battery clamp at 6 cm above ground level.

*Determination of chlorophyll content in leaves*

The content of chlorophyll in leaves was determined using “chlorophyll meter Minolta SPAD 502” during the flowering time of winter pea. The electrical capacitance of root system and content of chlorophyll in leaves were measured on the same day and with the same plants. Minolta SPAD – 502 meter readings were taken on upper side of leaves of 10 plants per plot and average values were recorded for each plot. Determination of chlorophyll content was performed according to Dray *et al*. (2012) and Lukas *et al*. (2012). Relative values, which were measured with a Minolta SPAD 502, represent chlorophyll content in SPAD values (g·kg$^{-1}$). This relationship was confirmed by Wood et al. (1992). The SPAD-502 chlorophyll meter (Konica-Minolta Sensing, Inc.: Osaka, Japan) measures the absorbance of two distinct wavelength regions in a 2×3 mm area of the leaf and uses these data to generate a (unit-less) value representing the relative amount of chlorophyll present in the leaf (Dray *et al.,* 2012).

**Statistical Analysis**

Potential differences in values of corn yield in the mixed culture were analyzed by the one-way analysis of variance (ANOVA) in combination with the Tukey´s test. All analyses were performed using Statistica 10 software.

**Results and Discussion**

This work presents the first results from the long-term field experiment which is focused on possibilities of IC cultivation. This experiment was established in 2012 and will continue for the next three years. The study “Evaluation the relationship between leaf chlorophyll concentration and active root zone” presents results of chlorophyll content in leaves and size of root system measured during growing season 2013.

The content of chlorophyll and size of root system were measured during flowering growth stages of Winter Wheat (GS 61-69) and Winter Pea (GS 61- 69). The electrical capacitance of root system is presented in the Figure 1. The significant (ANOVA, $P > 0.05$) highest values were found in variant of winter wheat SC (6,19 nF) and the significant lowest values were found in variant of winter pea IC (0,85 nF). These values show that the winter pea IC had the

CONTENT

smallest root system in comparison with other variants. Consider the Figure 1 and 2, these data indicate that winter pea and winter wheat with small root system in IC can absorb and store the same amount of nitrogen as winter wheat SC with greater root system. Based on these results, we can conclude that crops in IC do not need to invest nutrients (carbon) in growing of excessive root system because they can use their root system together in order to obtain water and nutrient from soil. However, sole crops have to invest their nutrients in development of root system because they need great root system to obtain essential compounds from soil. The relationship between content of nutrients (nitrogen) in soil, plants ability to uptake of nutrients and content of chlorophyll in leaves were confirmed by Kulig *et al*. (2010), Škarpa (2011) and Středa *et al.* (2012).

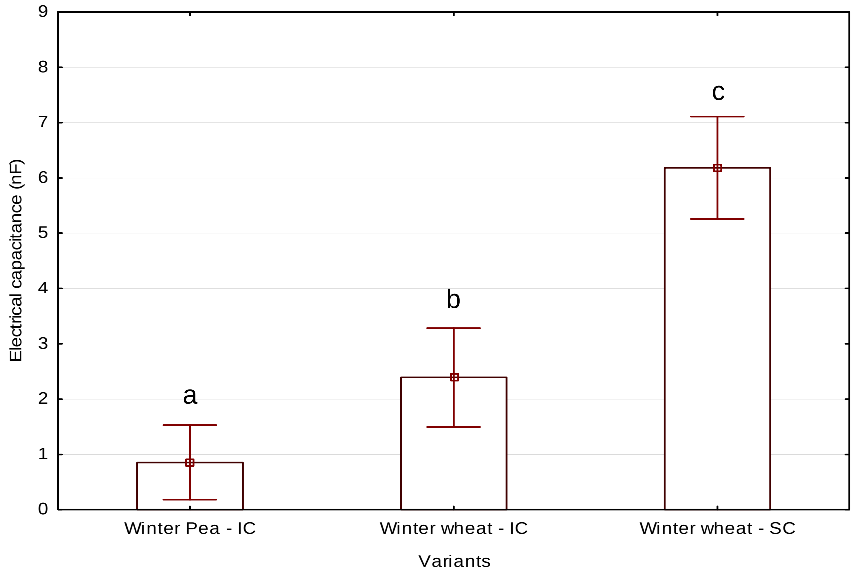



**Figure 1: Root system size. Small letters indicate significant differences at level P > 0.05, data are presented as means ± standard error (n = 23).**

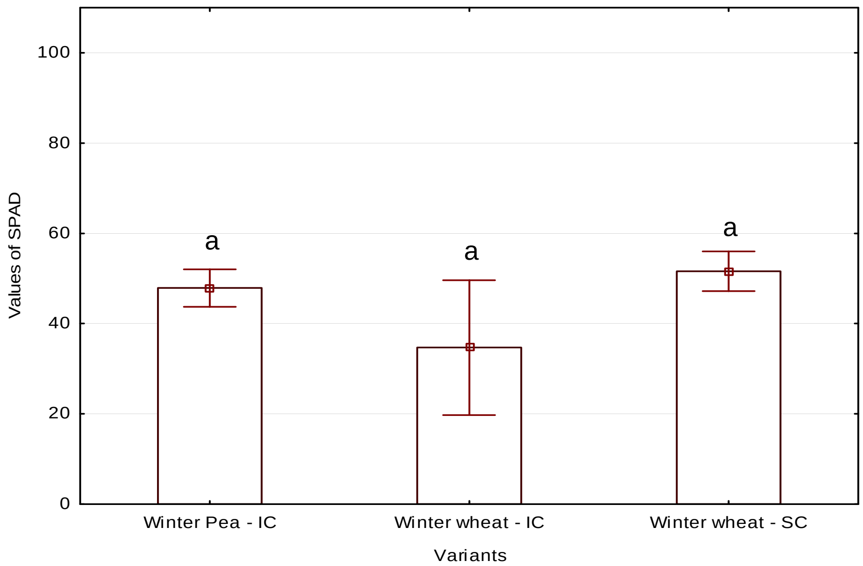



**Figure 2: Spad readings of individual variants. Small letters indicate significant differences at level P > 0.05, data are presented as means ± standard error (n = 23).**

CONTENT

## Conclusions

This contribution presents the first results of a long-term field experiment. Therefore, these results must be interpreted with caution. The measured values indicate the relationship between leaf chlorophyll concentration and active root zone. We assume that the crops in IC have the advantage because they can cooperate with each other.


## Acknowledgments

This work was supported by the project NAZV No.: QJ1220007 and company SELGEN a.s.


## References


DALTON, F. N., 1995: In-situ root extent measurements by electrical capacitance methods. *Plant and Soil*. 173 (1): 157-165.

DRAY, F. A., CENTER, T. D, MATTSON, E. D., 2012: In situ estimates of waterhyacinth leaf tissue nitrogen using a SPAD-502 chlorophyll meter. *Aquatic Botany*. 100: 72-75.

HAUGGAARD-NIELSEN, H., JØRNSGAARD, B., KINANE, J., JENSEN, E. S., 2008: Grain legume–cereal intercropping: The practical application of diversity, competition and facilitation in arable and organic cropping systems. *Renewable Agriculture and Food Systems*. 23 (1): 3-12.

HAUGGAARD-NIELSEN, H., AMBUS, P., JENSEN, E. S., 2001: Interspecific competition, N use and interference with weeds in pea-barley intercropping. *Field Crops Research*, 70: 101–109.

JENSEN, E. S., 1996: Grain yield, symbiotic $N_2$ fixation and interspecific competition for inorganic N in pea-barley intercrops. *Plant and Soil*. 182 (1): 25-38.

KESSEL VAN, C., HARTLEY, C., 2000: Agricultural management of grain legumes: has it led to an increase in nitrogen fixation?. *Field Crops Research*. 65 (2-3): 165-181.

KULIG, B., LEPIARCZYK, A., OLEKSY, A., KOLODZIEJCZYK, M., 2010: The effect of tillage system and forecrop on the yield and values of LAI and SPAD indices of spring wheat. *European Journal of Agronomy*. 33 (1): 43-51.

LUKAS, V., RYANT, P., NEUDERT, L., DRYŠLOVÁ, T. GNIP, P., SMUTNÝ, V., 2012: Stanovení optimalizace diferencovaných dávek dusíkatých hnojiv v precizním zemědělství: metodika pro praxi. Brno: Mendelova univerzita v Brně, 48 p.

MALEZIEUX, E., CROZAT, Y., DUPRAZ, C., LAURANS, M., MAKOWSKI, D., OZIER-LAFONTAINE, H., RAPIDEL, B., TOURONNET, S., VALANTIN-MORISON, M., 2009: Mixing Plant Species in Cropping Systems: Concepts, Tools and Models. LICHTFOUSE, E. *Sustainable Agriculture*. New York: Springer Verlag, pp. 329-353.

MARSCHNER, H., 1995: 15 – The Soil-Root Interface (Rhizosphere) in Relation to Mineral Nutrition. Mineral Nutrition of Higher plants (Second edition), pp. 537-595

OFORY, F., STERN, W. R., 1987: Cereal-legumes intercropping system. California: Academic Press, pp. 41-85.

PEOPLES, M. B., D. F. HERRIDGE, LADHA J. K., 1995: Biological nitrogen fixation: An efficient source of nitrogen for sustainable agricultural production?. *Plant and Soil*. 174 (1-2): 3-28.

STERN, W. R., 1993: Nitrogen fixation and transfer in intercrop systems. *Field Crops Research*, 34 (3-4): 335-356.

STŘEDA, T., DOSTÁL, V. HORÁKOVÁ, V., CHLOUPEK, O., 2012: Effective use of water by wheat varieties with different root system sizes in rain-fed experiments in Central Europe. *Agricultural Water Management*. 104: 203-209.

ŠKARPA, P., 2011: The effect of insufficient nutrition on the development of the sunflower (Helianthus annuus, L.) root system. In 46th Croatian and 6th International Symposium on Agriculture Proceedings, pp. 695-699.

TRENBATH, B. R., 1976: Plant interactions in mixed crop communities. ASA Special Publication (USA), No. 27: 129-169.

WOOD, C. W., REEVES, D. W., DUFFIELD, R. R., EDMISTEN, K. L., 1992: Field chlorophyll measurements for evaluation of corn nitrogen status. *Journal of Plant Nutrition.* 15 (4): 487-500.

**Contact address:**

Ing. Antonín Kintl
Mendel University in Brno
Zemědělská 1
613 00 Brno
Czech Republic
e-mail: antonin.kintl@mendelu.cz

# EFFECT OF HIGH COMPOST RATES ON PHYSICAL AND HYDRAULIC PROPERTIES OF SOIL

**P. Kovaříček, J. Hůla, M. Vlášková**

Research Institute of Agricultural Engineering, p.r.i., Prague, Czech Republic

**Abstract**
In small-scale field trial there was assessed the effect of graded high compost rates on physical and hydro-physical properties of soil in the long period. The compost was incorporated into the soil in single operation and the soil in experimental variants was held for a period of four years without tillage and vegetation. Statistically significant decrease of soil bulk density by the compost incorporation was proved in the course of two years only in case of extremely high rates 165 and 330 $t.ha^{-1}$. In the case of variants without vegetation there was proved an increase of soil moisture and increase of soil retention capacity owing to high compost rates incorporated into the soil. The compost incorporation into the soil influenced favourably hydro-physical properties of soil albeit with timing interval, however with long-term effect. After a longer time from compost incorporation there was found out a linear dependence of increase of soil moisture on growing compost rate. The soil tillage had a considerably greater effect on physical than on hydraulic properties of soil.

**Keywords:** field trial, compost, reduced bulk density, rain simulation, surface runoff

**Introduction**
The monitoring of compost influence on soil properties in view of soil water regime stabilization is current issue. The use of compost on agricultural land gains also importance in relation to the necessity of effective handling with biologically degradable waste (Lalande et al., 2000; Masciandaro et al., 2000; Váňa, 2003). The necessity of preservation of soil environmental functions is particularly important, therefore it is necessary to deal with an effect of organic substances application into the soil on its properties (Bazzoffi et al., 1998).
The compost use leads thanks to an increase of organic matter in soil and enhancement of medium pores content to the improvement of soil retention ability (Mayer, 2004; Ahmad et al., 2008, Gil et al., 2008). Effect of soil tillage, vegetation and spontaneous or by man supported variability of structure and compaction of soil (in particular humus layer) is usually more considerable, than effect of organic matter addition. For example Hangen et al. (2002) mentioned that differences in infiltration are caused by the various ways of soil tillage as a possible cause of. In our contribution we are dealing with effect of single high rate of compost incorporated into the topsoil on reduced bulk density, soil moisture and surface water runoff during the rain simulation.

**Material and Methods**
For the realization of field trial with small plots there was selected an area in the premises of VÚRV, v.v.i. Praha – Ruzyně (Research Institute of Agricultural Engineering, p.r.i. Prague – Ruzyně). The climatic region of trial plot can be characterized as mildly warm, dry, with mild winter. The average annual temperature makes 8.2°C, average annual rainfalls makes 526 mm, the maximum of monthly rainfalls is recorded in July; average number of days with snow cover range from 35 up to 40; average layer of snow is 50 mm and altitude above sea level of trial plot is 330 m. The soil type is chernozem and pedogenic substrate is loess on chalk spongilite. The soil kind can be characterized by transition between loam soil and clay-

loam soil (standard ČSN 46 5302) – average content of particles smaller than 0.01 mm is 44.2 %.
The trial was designed as small plot field trial with repetitions of variants (see scheme on fig. 1). The particular plots had the dimensions of 3x3 m, gaps between trial squares were 0.5 m. Each variant had six repetitions. On measured plots there were withdrawed before incorporation of compost rates and during the existence of trial from autumn 2008 up to spring 2012 so-called „Kopecký´s small rings“ from the depth of 50-100 mm. The withdrawal was taken place always in spring at the beginning of vegetation period and in autumn. From all soil parameters the reduced volume weight was selected for evaluation of physical changes in soil caused by compost incorporation.
On the trial plot there was applied compost in determined rates in April 2008 (tab. 1). The compost was incorporated into the soil during the overall tillage of trial area by rotary tiller equipped by horizontal knife rotor. The topsoil was cultivated during this work operation into the depth of 150 mm.

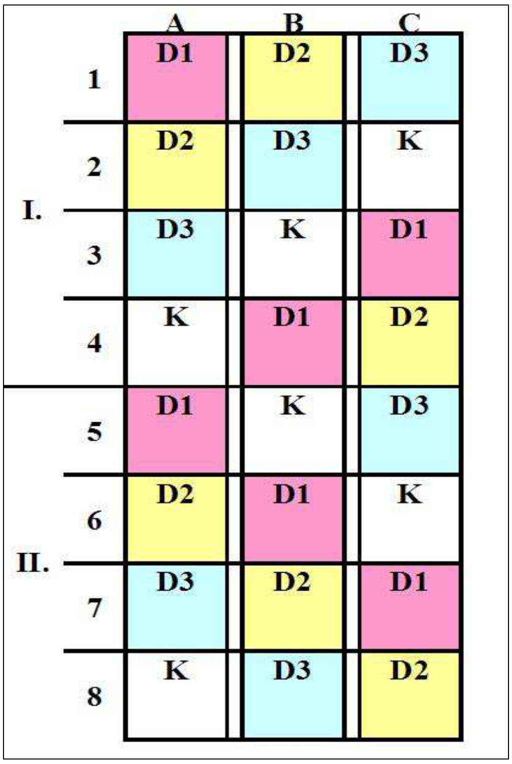



**Fig. 1 Scheme of arrangement of trial variants with compost dosing, 6 repetitions (square plots 3x3 m)**

**Table 1 Variants of compost dosing in Ruzyně trial**

| **Variant** | **Compost rate in dry matter** (t.ha$^{-1}$) |
|---|---|
| K (control) | 0 |
| D1 | 85 |
| D2 | 165 |
| D3 | 330 |

Since 2010 there was evaluated the surface water runoff by means of rain simulator in dependance on compost rate (Šindelář et. al., 2008). Before every measurement of infiltration

CONTENT

there was determined volume soil moisture in topsoil 50-100 mm by means of the probe Theta Probe ML2x, always 6 stabs around every measuring area. During the rain simulation there was used the nozzle Lechler 466788 and spraying pressure 100 kPa. At the height of nozzle 1m over ground the intensity of simulated rainfall was constant during the whole time of measurement 1.46 $l.m^{-2}.min$. The rainfall intensity was kept in the course of all realized measurements. The surface slope of measuring areas was between 2 and 3°.

## Results

After compost incorporation into the soil, the mechanic operation of soil tillage decreases significantly reduced bulk density. Changes caused by compost rate were smaller. Differences among values of reduced bulk density on control variants without compost before establishment of trial in spring 2008 and in autumn, 5 months after compost incorporation (fig. 2), we can explain with mechanical tillage and spontaneous subsiding of soil. The differences in reduced bulk density among variants of compost dosing in the following years are caused by changes in soil structure, which started after addition of organic matter. In spring 2010 the reduced bulk density on control variant without compost has returned to the original level before soil tillage. Statistically significant decrease of reduced bulk density by influence of supplied compost was recorded only in case of the dose 330 $t.ha^{-1}$. However, compost dose was several higher than doses used in practice.
On the trial variants there was evaluated since 2010 in regular spring and autumn deadlines volume soil moisture in topsoil layer 0 up to 100 mm. In spring 2012 the soil moisture was different owing to the weather conditions. In dependence on rate of incorporated compost the soil moisture was rising linearly (fig. 3). This dependence was slight, gradient of line 1.5 % of compost rate. In previous years the correlation between soil moisture and compost rate wasn´t statistically significant.

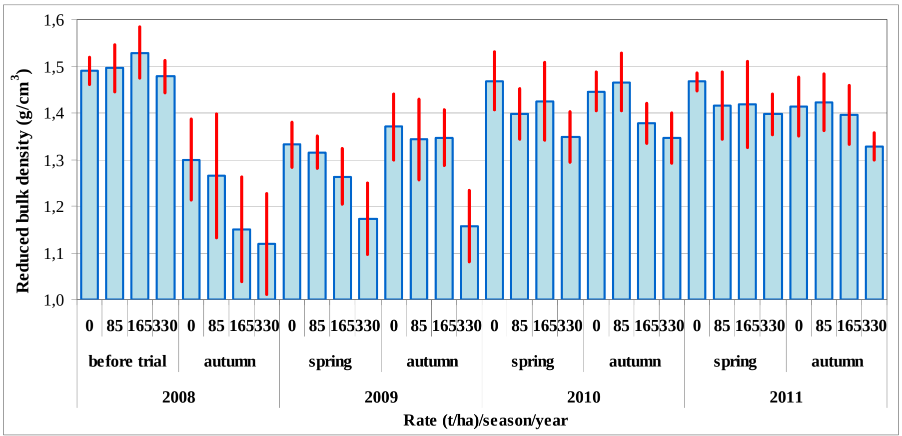



**Fig. 2 Changes of reduced bulk density after incorporation of high compost rates**

CONTENT

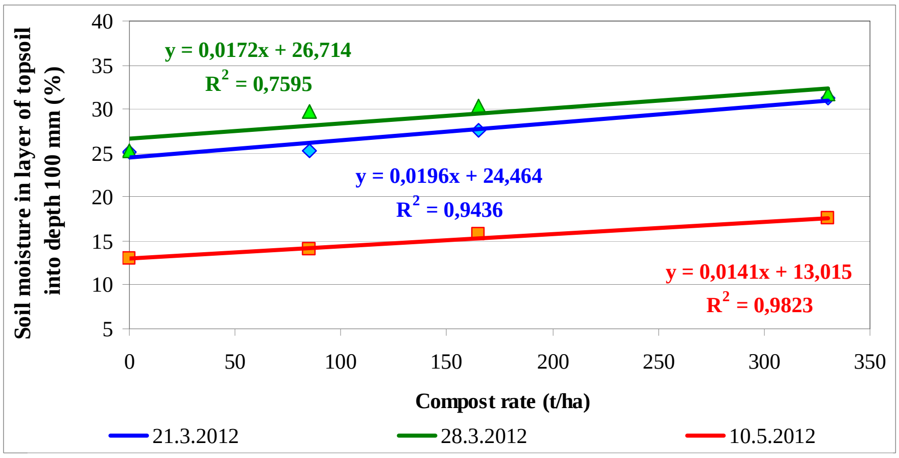



**Fig. 3 Volume soil moisture on trial variants in spring months 2012**

In 2010 we determined during the measurement of surface water runoff at simulated sprinkling the significant correlation with compost rates. The highest cumulated surface runoff was recorded on control plot without compost application (fig. 4). In variants with incorporated compost there was clear inversely proportional trend with compost rate, but difference between variants was minimal. The results of measurements realized by rain simulator in the end of trial on March 21, 2012, confirmed the hypothesis of positive effect of compost incorporation into the soil on water infiltration (fig. 5), dependence on compost rate was already distinct.

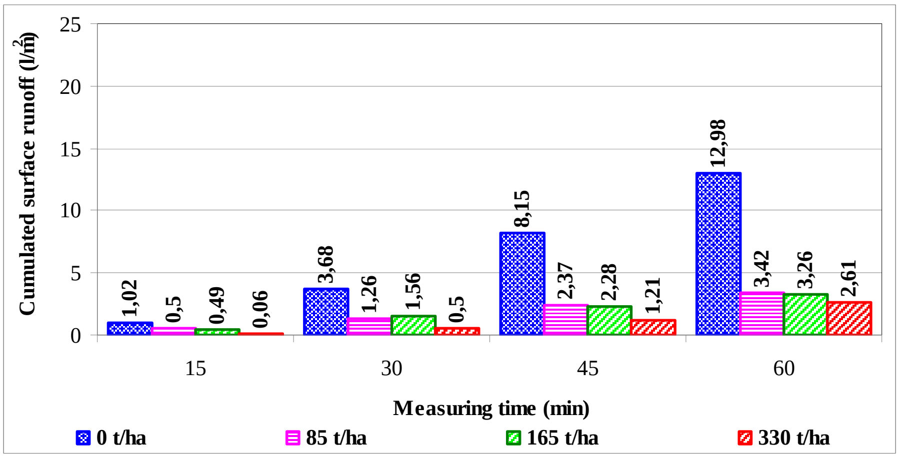



**Fig. 4 Cumulated surface water runoff in 15 minutes lasting interval at simulated sprinkling, Ruzyně 12.5.2010**

CONTENT

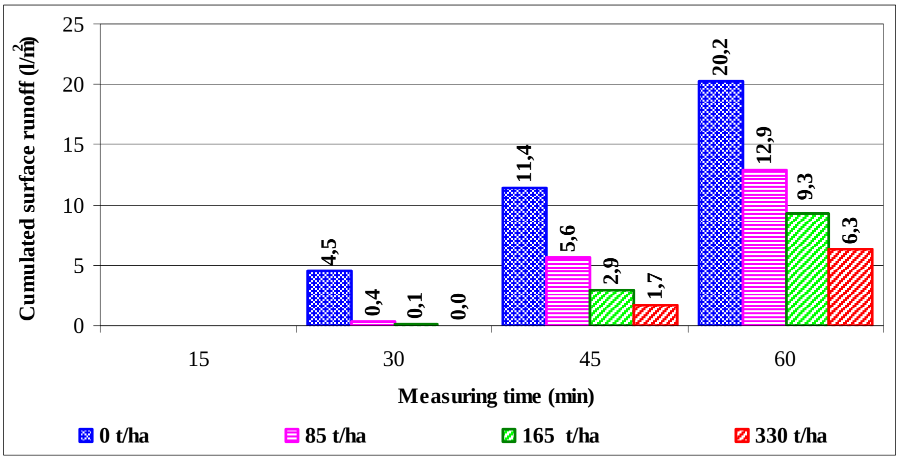



**Fig. 5 Cumulated surface runoff in 15 minutes lasting interval at simulated sprinkling, Ruzyně 21.3.2012**

## Conclusion

Due to mechanical tillage of topsoil by tiller equipped by horizontal rotor in the depth of 150 mm there was recorded a decrease of reduced bulk density for 2 years. The change of reduced bulk density owing to the incorporated compost in the rate of 85 $t.ha^{-1}$ was seven times smaller than owing to the mechanical soil tillage. Three years after the compost incorporation there was a demonstrable change in reduced bulk density only in case of the variant with highest compost rate of 330 $t.ha^{-1}$.

Incorporation of compost into the soil influenced favourably hydraulic soil properties, but after longer time. In areas without vegetation after incorporation of high compost rates into topsoil there was demonstrated an increased soil moisture, it means also its increased water holding capacity. Two years after compost incorporation the surface water runoff during the simulated sprinkling decreased at all variants of dosage practically without depending on compost rate. The progressive dependency on compost rate was proved in spring 2012, it means 5 years after compost incorporation.

## Acknowledgements

This research and outcomes were supported by research project NAZV QJ1210263 and research project NAZV QH82191.

## References

AHMAD R., KHALID A., ARSHAD M., ZAHIR Z.A., MAHMOOD T., 2008: Effect of compost enriched with N and L-tryptophan on soil and maize. Agronomy for Sustainable Development, 28 (2):299-305.

BAZZOFFI P., PELLEGRINI S., ROCCHINI A., MORANDI M., GRASSELLI O., 1998: The effect of urban refuse compost and different tractors tyres on soil physical properties, soil erosion and maize yield. Soil and tillage research, 48 (4): 275-286.

GIL M.V., CALVO L.F., BLANCO D., SANCHEZ M.E., 2008: Assessing the agronomic and environmental effects of the application of cattle manure compost on soil by multivariate methods. Bioresource Technology, 99 (13):5763-5772.

LALANDE R., GAGNON B., SIMARD R.R., COTE D., 2000: Soil microbial biomass and enzyme activity following liquid hog manure in a long-term field trial. Canadian Journal of Soil Science, 80: 263-269.

MASCIANDARO G., CECCANTI B., GARCIA C., 2000: ''In situ'' vermicomposting of biological sludges and impacts on soil quality. Soil Biology & Biochemistry, 32: 1015-1024.
MAYER J., 2004: Einfluss der landwirtschaftlichen Kompostanwendung auf bodenphysikalische und bodenchemische Parameter. 43-58. In: Fuchs, J.G., Bieri, M., Chardonnens, M. (eds), 2004. Auswirkungen von Komposten und von Gärgut auf die Umwelt, die Bodenfruchtbarkeit sowie die Pflanzengesundheit. Zusammenfassende Übersicht der aktuellen Literatur. FiBL-Report. Forschungsinstitut für biologischen Landbau (FiBL), Frick, Schweiz.
ŠINDELÁŘ R., KOVAŘÍČEK P., KROULÍK M., HŮLA J., 2007: Hodnocení povrchového odtoku vody metodou simulace deště. Agritech Science, http://www.agritech.cz/, 7 (2) 5:1-7.
VÁŇA J., 2003: Sdělení odboru odpadů MŽP ke specifikaci skupin kompostovatelných odpadů s výjimkou kompostovatelných odpadů v komunálním odpadu podle přílohy č. 8 vyhlášky č. 383/2001 Sb., o podrobnostech nakládání s odpady. Sdělení 29, Věstník MŽP.

**Contact address:**

Ing. Pavel Kovaříček, CSc.
Research Institute of Agricultural Engineering, p.r.i.,
Drnovská 507
161 01 Prague
Czech Republic
e-mail: pavel.kovaricek@vuzt.cz
tel.: 233022236

# SOIL PROTECTION AND SUSTAINABLE UTILISATION OF SOIL THROUGH MODERN TECHNOLOGIES

**M. Kroulík**

Department of Agricultural Machines, Faculty of Engineering,
CULS Prague, Czech Republic

**Abstract**
GPS has become a synonym for precision farming and modern farming systems. Nowadays, the agriculture technologies using guidance systems during field operations are more and more common all around the world. GPS together with sophisticated machinery guidance systems represents great benefits concerning precise production inputs, minimizing machine errors in fields and therefore lower costs for agriculture.
There are introduced the possibilities how to use the position of the machines to reduce the risk factors with minimal additional cost of agriculture machine equipment.

**Keywords:** GPS guidance, machinery passes, soil compaction, soil erosion, route planning

## Introduction

The development of precision agriculture in the nineties of the last century opened up a whole new ways in attitude to mechanization for plant production. A new range of terms in agriculture were added, many of them werenot brandnew and unfamiliar, but practically meant a change in farming and in the view of the land. GPS navigation has become a synonym for precision farming and modern agricultural technology. On the other hand, the introduction of precision farming expected, to some extent, high degree of expertise and technical skills of the users. However, most farmers see this approach as too complicated. As also shoved studies from USA, Great Britain, Denmark and Germany it is one of the reasons why precision farming is used less than was expected (Reichardt et al., 2009).
With expansion of satellite navigation it is possible to see renewed interest in precision farming technology. Application of precision farming technology is often based on difficult and expensive monitoring of land. As shows some of our results and studies, the mere knowledge of the position of the machines together with deployment of navigation devices can help to minimize the negative impacts of intensive agricultural activities mainly on the soil environment.
The GPS navigation can also be used to collect the data about the operation of machines. These data can be used in soil conservation technologies and measures. Very frequently discussed topics relating to the soil protection and landscape is excessive soil compaction which is related to other negative symptoms, whether economics (increased energy requirements for tillage, decreased crop yields) or environmental (decreased soil infiltration capacity and increased risk of erosion, greenhouse gas emissions). Soil compaction is primarily most frequently been associated with the field operations of heavy machines. Soil compaction caused by machinery traffic in agriculture is a well-recognised problem in many parts of the world (Chan et al., 2006; Gysi, 2001). Subsoil compaction has been acknowledged by the European Union as a serious form of soil degradation, which is estimated to be responsible for degradation of an area of 33 million ha in Europe (Akker and Canarache, 2001). The continuing trend of using larger and more powerful machines for the fieldwork further increases the risk of soil compaction.

**Results and discussions**

**Current issues of the intensive management and its influence on agricultural land and remedial measures**

In today´s agriculture the machinery passes are inevitable. An example is the research conducted in our department which quantifies the amount of passes of agricultural machinery on the field and the area which were influenced by tyres of agricultural machinery. For detection of areas where there are multiple passes by machines sets was used the tractor equipped by the GPS receiver. Each movement of all agricultural machines that entered the land during the season was tracked at regular intervals. By this way the movement of machinery was monitored on the ploughed fields, on thefield where the conservation technology was applied and also grassland areas intended for silage. The following figures show the situation of the current method of organization of the machinery passes. These monitoring measurements have broughtmanydisturbing information.The sequence and frequency of field operations corresponded with the real farm conditions and dependent only to decision of farmer and common practice. Thus the passes organization has significant reserves. Plough technology showed 86.1 % coverage of the soil surface by tracks of the whole plot. In the case of conservation technology run over area was 63.8 % of the whole plot.The same way were recorded passes at the headlands of plots (Fig. 1).

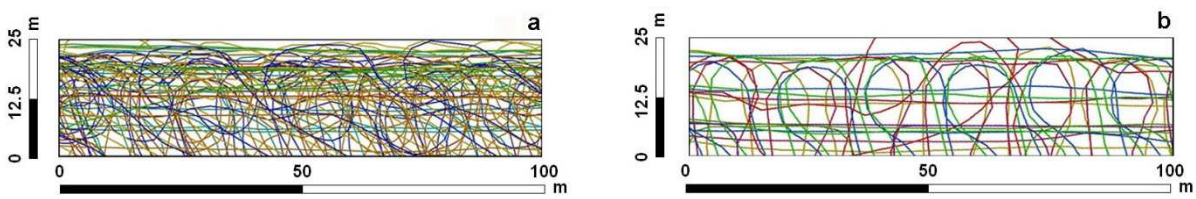



**Figure 1: The trajectories of machines sets on the headlands for plow technology (a) and conservation technology (b)**

The headlands of the field were evaluated concerning repeated passes. Wheeled area on headlands was always higher than 80 %.

The results showed that the less intensity of field operations leads todecreaseof soil loadsby the machinery passes. Despite the fact that intensity of machinery passes is reducedwhen using conservation tillage, the loading ofthe soil profile caused by machine tyres was still quite high.

A problem of intensive and random passes also affects other crops such as fodder grown on the arable land or perennial crops. Figure 2a and 2b shows all machinery passes during harvest of grass for silage. In case of self-propelled forage chopper was run over 63.8 % of 1 ha area. In case of round baler the run over areawas 63.4 %. The double passes are the most frequent repetitive.

CONTENT

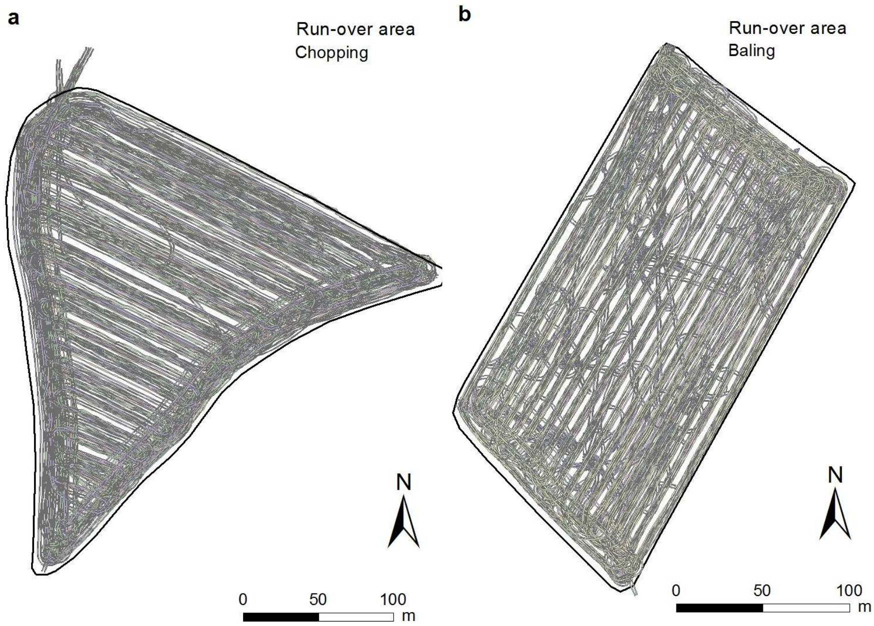



**Figure 2: Graphical representation of machinery passes for chopping (a),graphical representation of machinery passes for baling (b).**

It is clear from the aerial photography howthe quality of vegetation is reflected onthe state of the soil. Especially on the headlands occurseven absence of vegetation (Fig. 3).

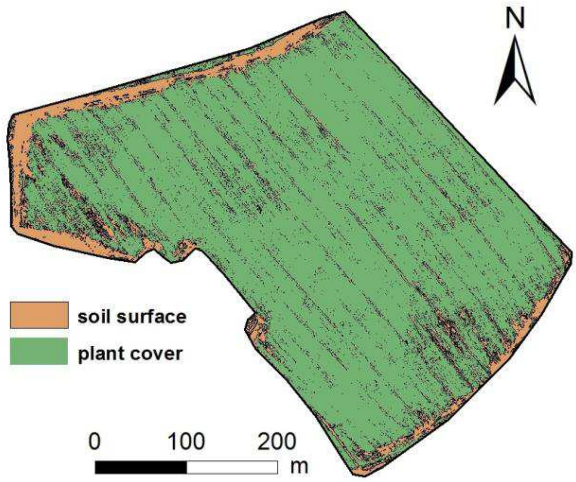



**Figure 3: Image analysis of the area of interest which documents the damage of the crop**

**Proposals of remedial measures focused to reduce intensity of passes and optimize the work of machine sets**

Purpose of the project is a proposal of usage GPS navigation for agricultural machinery sets, which on one hand will optimize the economic aspects (consumption of fuel, seeds, herbicides, pesticides, water technology, time, simple operation, crop yields) and on the other hand, significantly reduce the environmental impact of farming (soil compaction, soil degradation, formation of surface runoff, soil erosion, overlays or omissions in the application of fertilizers or chemicals, sediment transport). Though the project is divided into several separate points the problems are intertwined and complement each other.

**Optimization of deep loosening**

Record of passes shows how intensively the land is burdened by traversing mechanisms of machines. Figure 4 interprets the statement: "Soil compaction phenomenon is connected with number of machinery passes but also with time exposure of contact pressureto soil surface". Figure shows places with different traffic intensity and also with different time of machinery load exposure to the soil. The map was created from the sum of machinery position records in time at a particular place – in selected squares 6x6 m (the field was divided by square grid with the cells 6x6 m). It means, the more times a machine entered each square the more records for the square and also the more time a machine spent in the square the more records there are as well (dependence on working speed and even machine stops).

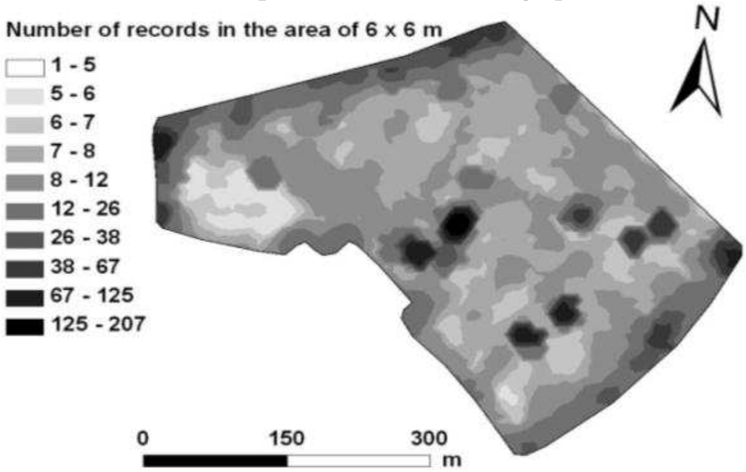



**Figure 4: Map characterising intensity of traffic and time spent at a certain area**

As a remedial measure against undesirable compaction is often applied deep loosening or sub soiling. This is extremely energy demanding intervention. Based on knowledge of the load intensity is possible to optimize the depth of loosening pursuant maps of passes. From figure most exposed areas by loads are headlands and areas where the machines were weaned.

**Restriction of passing frequency by combining of working sets**

A significant reduction of wheeled area allows adoption of fixed track system for machinery traffic.

The results from the fixed track system for machinery traffic measurements on the experimental plots (only conservation tillage) are as follows. Intensity of wheeled area decreased when using a 4 m system up to 37 % total run-over area. With the 4 m machinery working width system, it was possible to concentrate all tyre passes into two permanent tracks due to almost the same machine wheel spacing. Generally, the wheel spacing could be the major obstacle for fixed track application because there are no standards for agriculture machinery manufacturers. Therefore there are usually different machines and implements with different wheel spacing on farms. On the other hand, it is possible to use fixed track despite not having all machines with the same wheel spacing. Then more than two (usually three) tyre tracks are used when using significantly wide or narrow wheel-spaced machines. This exception is usually a combine harvester with much wider wheel spacing than tractors and other tools.

The experimental arrangement with 8 m machinery working width was exactly this case. All machine tracks were concentrated into two tracks except the combine harvester. Therefore, the combine harvester passes were organized in the way that one wheel of the harvester ran on the existing fixed track and the second wheel made an additional third track. Finally, three track systems resulted from this case. Intensity of wheeled area decreased when using the 8 m

system with three tracks up to 31 % total run-over area (Fig. 5). This value is not too much different from the value of total run-over area for a 4 m system (37.38 %) when taking into account half the number of passes for the 8 m system. This was caused by the third track made by the combine harvester with wide tyres. With 6 m machinery working width system the wheeled area was 33 %.
On the other hand, it is obvious from the results that repeatedly run-over areas increases in comparison with random traffic. A detailed description for 4 m and 8 m working widths is in Table 1.

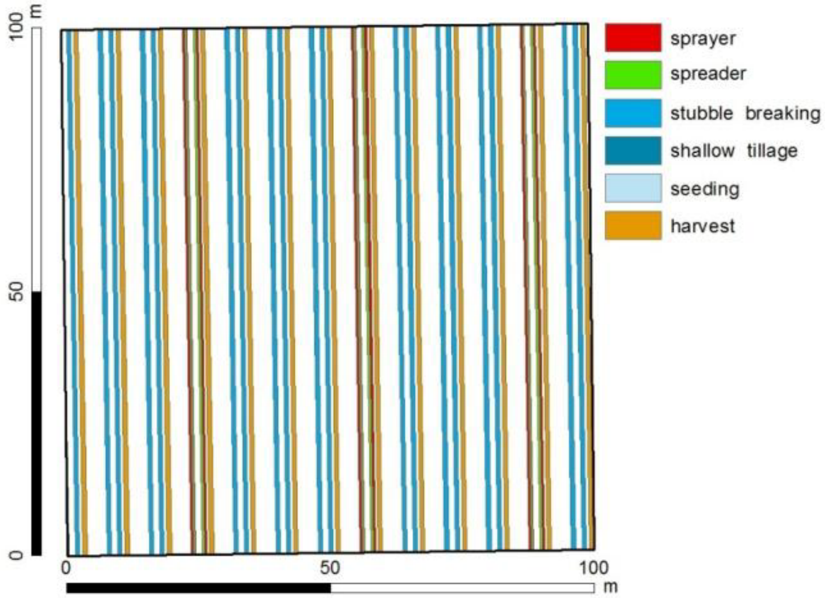



**Figure 5: Area which was run over by tyres during organized passes of machinery (working width 8 m)**

**Table 1: Frequency of machinery passes across a field where fixed tracks were used.**

| Conservation tillage 4 m working width | Run-over area (%) | Conservation tillage 8 m working width | Run-over area (%) |
|---|---|---|---|
| Number of passes repetitions | | Number of passes repetitions | |
| 1x | 4.58 | 1x | 10.38 |
| 2x | 3.24 | 2x | 0.00 |
| 3x | 5.18 | 3x | 8.46 |
| 4x | 16.51 | 4x | 7.65 |
| 5x | 0.16 | 5x | 1.36 |
| 6x | 7.71 | 6x and more | 3.03 |
| Run-over area (total) (%) | 37.38 | Run-over area (total) (%) | 30.88 |

Significant finding is that there is no necessary to solve wheelbase of tractors and harvesting machinery for larger working widths. Technical solution of the same wheelbase or tracks could be a major obstacle. Without costly measures in the form of expansion of wheelbases and likewise can be achieved at the same intensity of the work which was described by conservation technology in Table 1 as a significant reduction in the frequency of passes.

**Optimizing production areas of land**

With regard to the shapeof the land is necessary to highlight another fact. With irregular shapes of the fields or with curved sides; increases the number of passes, turns, overlaps or

CONTENT

omissions. Even minimal curvature side of the field is the source of repeated passes. How the shape of the fieldis reflected in the work of the sprayer is shown in the Figure 6. On figure thefield of 22.2 ha areais illustrated. It shows a record of work of the sprayer and places where has been boom section turned on or off. The evaluation of the record was found that the spray was applied on 23.6 ha.

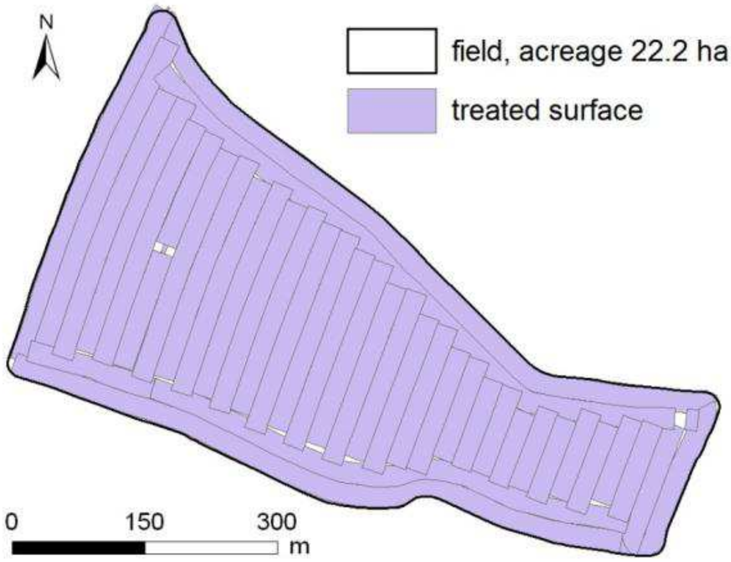



**Figure 6: Record of sprayer work with manual control of sprayer arms**

The driver has to make a greater effort to treat or process these marginal areas and corners of the field. Especially the headlands, as seen in the previous images, are exposed to increased intensity of passes. Yet these are the areas treated with the same or higher intensity than in other production areas. However, a sustained effort of farmers often does not bring the expected results. To obtain economic nature information about the field or information about the operation of machines is relative simple. Today the crop yield monitoring is one of the most widespread applications of precision farming. Monitoring of process parameters of working machines especially during tillage (fuel consumption, tensile strength or slippage) is easy due to modern tractors and electronic equipment. Modern tractors are equipped with the sensors that provide useful information about the operation of machines, with minimal additional cost of additional equipment. The use of these data is supported by the introduction of telemetry. To identify areas that are, in terms of crop yield,lossy or profit is thus quite simple. From this perspective are preferably used aerial photographs which are nowadays relatively easily accessible and valuable information for a comprehensive assessment of the land. The following figures confirm this claim. Figure 7a shows the fuel consumption during ploughing. Followed by Figure7b which divide reference field into the profitable area and loss-making area. This division takes into account the purchase price of inputs and commodity prices. The question is, to what extent it is appropriate intensively cultivate these areas or deal with remedial measures?For example, establishment of grassland on these areas would allow better pass ability during turns or the placement of conveyance that enters to the field minimally. It would also coped the curvature of the field and thereby minimize overlaps or omissions during establishment or maintenance of vegetation. Grassy vegetation would also form a barrier against water runoff from the sloping fields. Suitable mixture of seeds sown on the surface would also expand the food supply for wild species. Defined areas can be prepared in the form of polygons with which the navigations can operate and, for example, control sowing sections. Today´s multi-chamber tanks ofseeders are also able to combine the seed, according to predetermined settings.

CONTENT

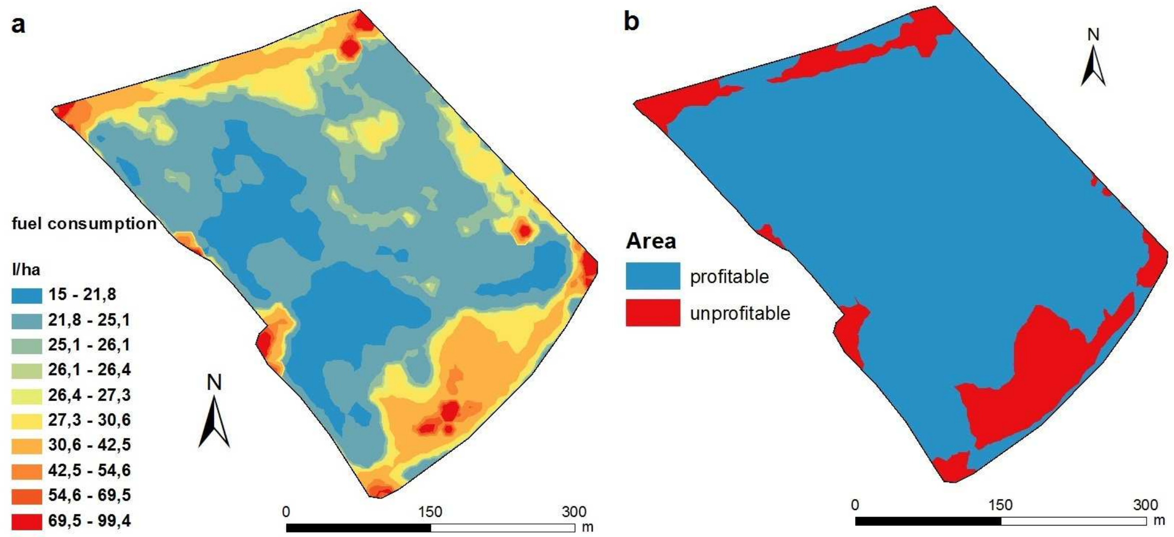



**Figure 7: Map of fuel consumption during ploughing (a),distribution of land to profitable and unprofitable areas (b)**

**Route planning and optimization of machine sets for land**

Merging of tracks is shown as a suitable way how to reduce the burden of soil by traversing mechanisms. In terms of immediate practical use and expected benefits of guidance the proposal of guidance lines trajectories is introduced and presented. At present, it is based especially on the experience of drivers or usual habits of farmers. There are many factors that affect the efficiency of machine sets. Shape of the land, its size, slope, obstacles and working widths of machines play a significant role in this case. In our conditions applies that the land on which two opposite sides are not parallel can be considered as standard.

Figure 8 represents the real situation and the optimal trajectory which respects the shape of the field. A comparison of the lengths of driving distances for different directions brings Figures 9. The direction of lines graduated at 5° during the modelling.Real trajectory direction during the work, according to the Figures 10a, was approximately 90°. It is evident from the Figure 9 that transports distance significantly increased in comparison with optimal trajectory.

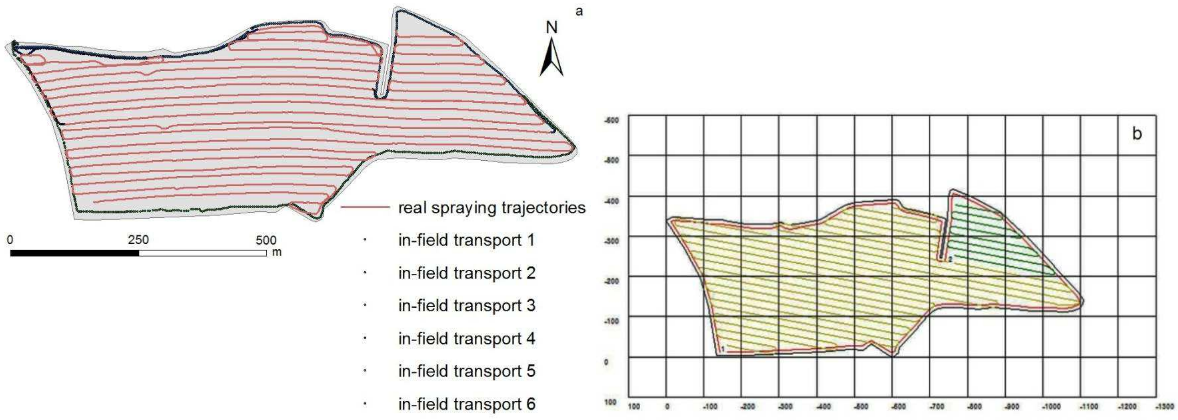



**Figure 8: Spraying. Real example (a) and example of optimal trajectory of guidance line for field (b)**

CONTENT

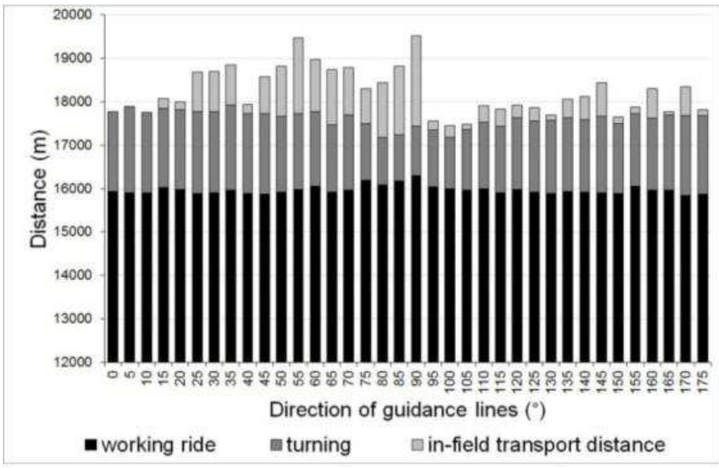



**Figure 9: Length of driving distance for the different directions of trajectories**

As illustrated in Figure 9, even minimum deviation from optimal route can lead to, in proportion, a significant increase of non-working trips and passes. Trajectory model can be, quite easily, transferred into the navigation device. On the other hand, the model does not respect the slope of the land.The slope of the land is the essential prerequisite for the plan of erosion measure. Here arises a significant scope for further suggestions because question of slope of the land is not sufficiently addressed for traction performance and suggestions of routes. Substantial weight transferred between drive wheels, especially when operating on steep slopes, can alter the traction and braking. The effect of slope could be explained mainly through the poorer tractive performance as a result of increased wheel slip. From this perspective it is necessary to focus further work on development of working models of route trajectories that would also take into account the shape of the land with emphasis on erosion mitigation and with the possibilities of agricultural machinery pass ability. The outcome of the proposal will be the trajectories corresponding to a particular land which is farmed. These trajectories should be available from relevant websites for the navigation devices.

**Delimitation of areas with increased risk of erosion**

The purpose of the presented task is to try to find ways of using the knowledge of erosion models and transport processes on the land to reduce risks through navigation devices. The need to eliminate the above risks is legally enshrined in the documents of the European Communities (Council Regulation (ES) No. 73/2009). These societal requirements for the performance of agriculture in the framework of the common agricultural policy applied in the individual EU state members are implemented in the GAEC standards (Good Agricultural and Environmental Conditions). The condition for the individual farmer to be able to draw financial subsidies, in the caseof erosion risk land management; they have to meet the requirements of GAEC standard. Improved navigation system will help them to meet these requirements.

Every farmer in the Czech Republic has an overview of their lands on the web portal LPIS of the Ministry of Agriculture. Figure 10 shows the viewport screen of current land state in LPIS system.

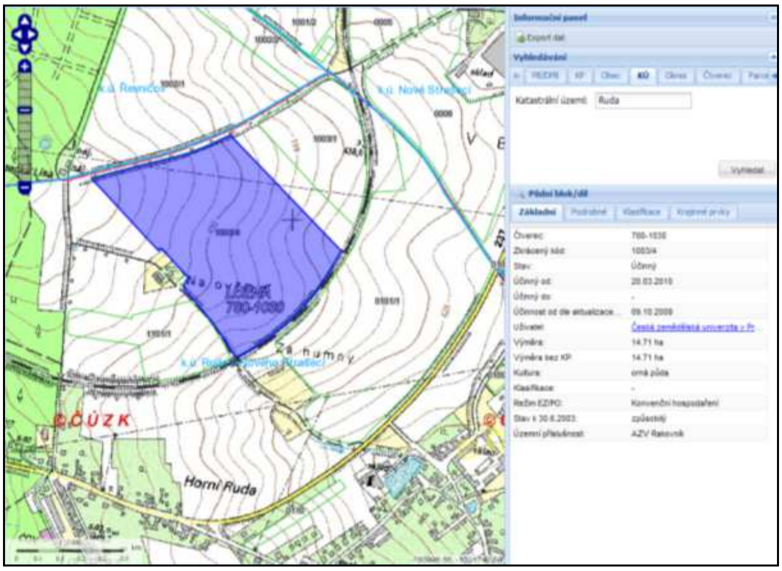



**Figure 10: Current information about the land in the LPIS system**

An important step in analysing of slope and direction of surface runoff is to create a digital terrain model (Fig.11a). The available data can be, inter alia, obtained from GPS receivers during previous work on the land.
Along with other data, especially the use of the land, it is possible to model the process of erosion processes and evaluate it by using mathematical models. Model values and the distribution of soil losses and deposition are shown in Figure 11b.

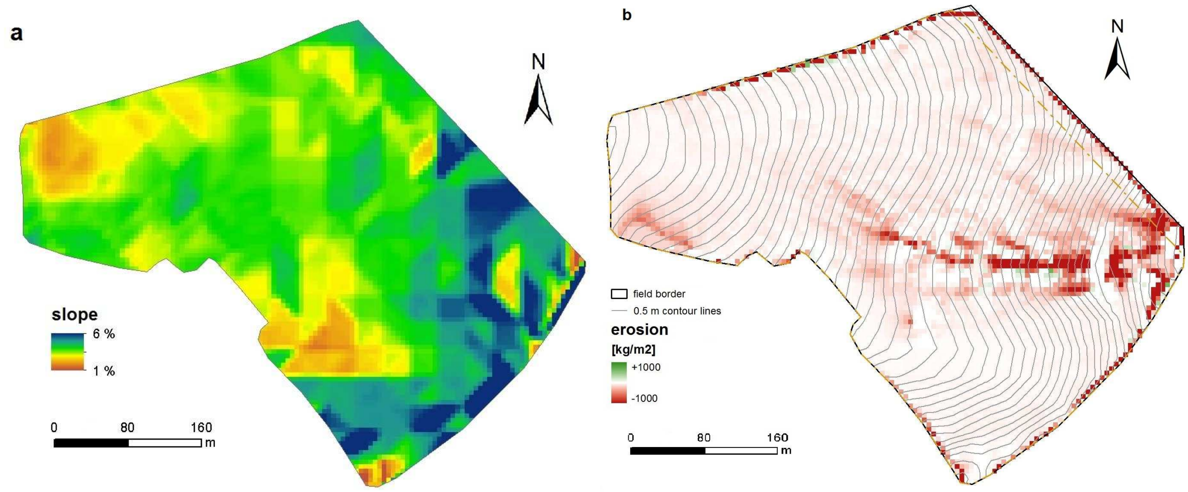



**Figure 11: The slope of the surface layer (a), balance of soil losses and deposition (b).**

Essential of these models is the identification of the areas at erosion risk phenomena and thus the identified areas describe by the file in the shape format. The farmer will be able, through aforementioned portal LPIS, to generate area for use in the navigation system for the land without charge (Fig. 12).

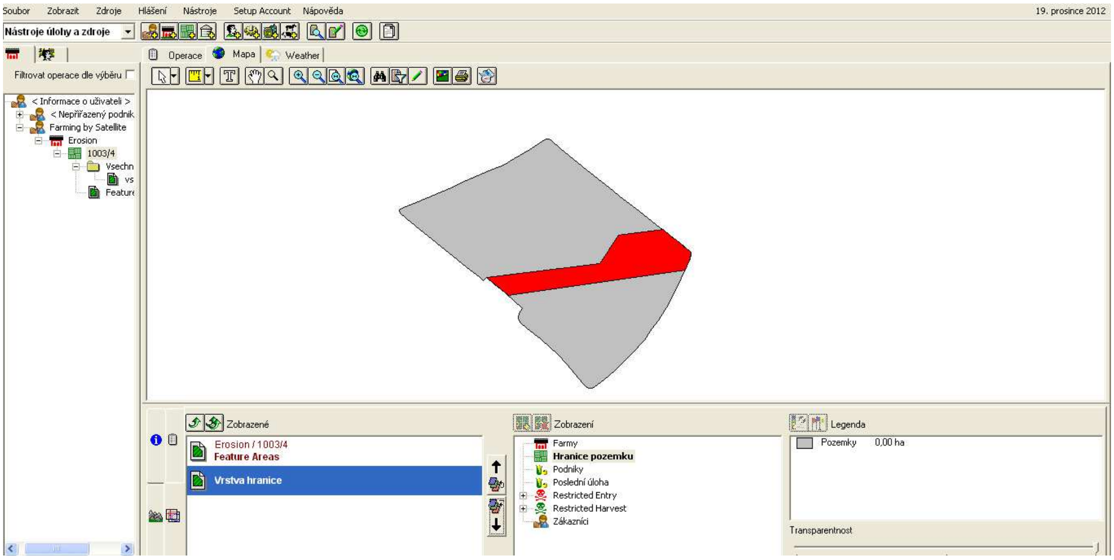



**Figure 12: Stage of the land with the requirement for anti-erosion measures**

Based on the transmitted information the navigation system will be able to manage tasks for the required anti-erosion and soil protection interventions.

Along with selecting the optimal route the navigation system could significantly promote erosion control and soil retention capacity of the land and thus also ensure agricultural activities with regards to the GAEC criteria conditions. Implementation of the proposed erosion control practices that lead to minimize the burden of the land may be a certain guarantee of compliance and meet the requirement of the erosion control measures for the control authorities.

**Logistic solution of transport trailer**

A number of field operations are dependent on the support of conveyance and requires cooperation when working with these machines. This is the replenishment of seed, fertilizer, spray liquid or, on the other hand, removal of grain from the combine harvester, chaff from forage harvesters or collection of bales. Recordings made during the work of machines showed, again, a number of reserves and deficiencies in these activities. Conveyance often moves onto a plot randomly. They reside on the land or ineffectively manoeuvring. On the other hand, was shown that the introduction of a single rail tracks could increase non-working passes on the land due to the permanent tracks. A figure 13a show that in the case of harvesting by the forage harvester the empty conveyance follows the forage harvester trailer,which cooperate with forage harvester.

On the one hand, the late furnished vehicle causes downtime, however, increases the number of repeated passes. Move of the sets onto non-production areas would limit access to the land. The question remains logistic of present trailers. The combine harvesters, where the yield is monitored, is possible to timing the fulfilment of the container (based on the current measurement) of harvester and send signal to the navigation device of transport trailer. For forage harvesters are known projects that deal with fulfilment of conveyance with regards to minimizing losses during filling. The same information could be used for optimizing the placement of vehicles. Better organization and cooperation of transport trailer with chopper would certainly help to reduce the repeated crossings.

The situation is simpler for collection of bales where the location ofbales is known (Fig. 13b). Figure 14 show the current practice. With knowledge of the position of bales is possible use the method of linear programming to design haul route with the requirement for the shortest travelled distance.

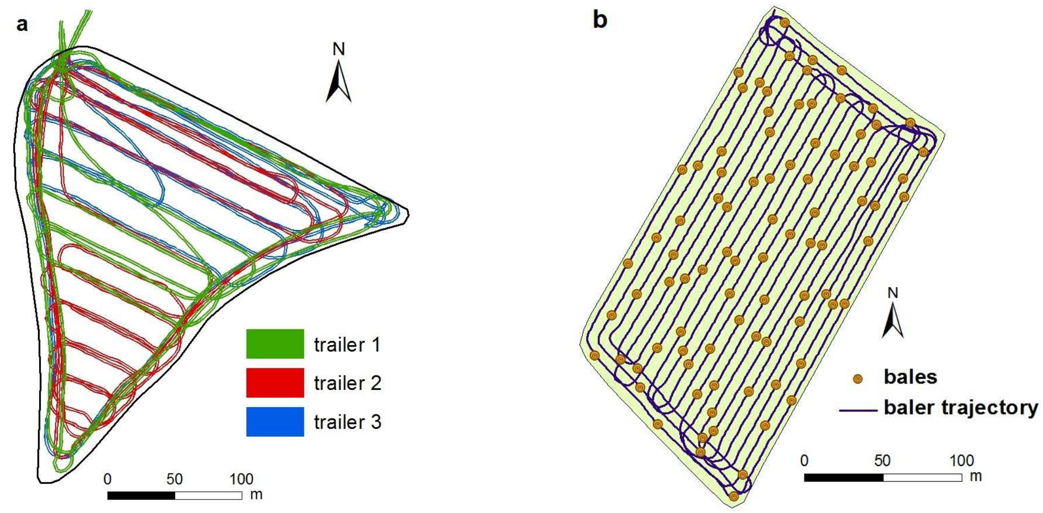



**Figure 13: Record of conveyance during forage harvest by forage cutter (a), recording of movement of round baler and position of the bales (b).**

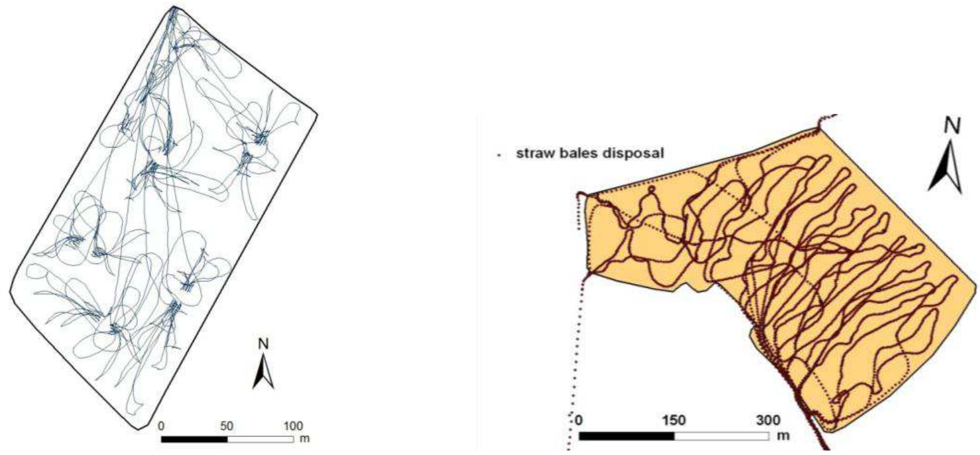



**Figure 14: Tractor trajectories from record of a machine collecting bales from the field surface.**

## Conclusion

Based on abovemeasurements is possible to say that the mere tracking of machine sets and using the DGPS receivers or navigation will reveal a number of adverse effects of intensive farming and also show the ways and possibilities where to look for reserves. Possibility of data processing by external workplace and transfer to farmers through public portals in the form of prepared data and applications;also represents easier work with minimum requirement to manage demanding tasks.

Finally are represented the main points of the proposed measure:

- Accumulation of passes, especially during periods of increased soil moisture is a major source of unwanted soil compaction. Based on knowledge of passes can be organized and specifically identified remedial measures as extremely expensive deep loosening.
- Reduction of redundant crossings by concentrating tracks to the permanent lines. In practice, we often encounter with the problem of the same wheel spacing of agricultural machinery. Nevertheless, the measure with the organization of routes is an important element for reducing the intensity of passes during random motion of machine sets.
- The shape of the land is very variable. Any curvature ration of land increases the number of passes and turns. Intensely passes area becomes less productive and the requirement for

more intensiveandexpensive land treatment. By exclusion of these areas from the production area may represent a reduction in costs associated with management of land. To offer better area for non-working passes and manipulation by conveyance and strengthening area at risk of erosion events.

- Selection of appropriate trajectories can significantly reduce non-working turns and passes. Combination of suitable trajectory and contour will contribute to time saving and to erosion measures in the form of contour farming. Route curves will be possible transmitted in a suitable format to save to the navigation through publicly accessible portals.
- Also the introduction of other erosion control measures is required to meet the requirements for erosion protection by government and a prerequisite to obtain grants. Areas with high erosion hazards are defined on the relevant web portals. If the area is provided in a format that will support the navigation, it is possible to use it with work management tools and provide the required erosion control measures. Materials can also serve to control authorities during checks compliance with the required procedures.
- Inadequate logistics solutions for transport of products are also represented by redundant passes. There is a feature for cooperation with already used systems in agriculture such as yield monitor of the combine harvesters. With the use of so-called smart phones can be solved the problem of data collection, data transmission, processing and subsequent use during application. This applies for example to organize collection of the bales.

**Acknowledgements**

Supported by the research project (Ministry of Industry and Trade of the Czech Republic) No. FR-TI3/069.

**References**

AKKER, J.J.H., CANARACHE, A., 2001. Two European concerted actions on subsoil compaction.*Landnutzung und Landentwicklung,*42, 15–22.

CHAN, K.Y., OATES, A., STAN, A.D., HAYES, R.C., DEAR, B.S., PEOPLES, M.B., 2006. Agronomicconsequences of tractor wheel compaction on a clay soil. *Soil & Tillage Research,* 89 (1), 13–21.

GYSI, M., 2001. Compaction of a EutricCambisol under heavy wheel traffic in Switzerland: field data and a critical state soil mechanics model approach. *Soil & Tillage Research,* 61 (3–4), 133–142.

REICHARDT M., JÜRGENS C., KLÖBLE U., HÜTER J., MOSER K., 2009. Dissemination of precision farming in Germany: acceptance, adoption, obstacles, knowledge transfer and training activities. *Precision Agriculture*, 10, p. 525–545.

**Contact address:**

Doc. Ing. Milan Kroulík, Ph.D.
Department of Agricultural Machines, Faculty of Engineering, CULS Prague.
Kamýcká 129, 165 21 Prague 6 Suchdol
Czech Republic
e-mail: kroulik@tf.czu.cz

# SUSTAINABILITY ASSESSMENT OF DIFFERENT CROPPING SYSTEMS

**J. Křen, S. Dušková**

Department of Agrosystems and Bioclimatology, Faculty of Agronomy, Mendel University in Brno, Czech Republic

## Abstract
The aim of the paper is to show main problems of different cropping systems from the sustainability viewpoint. On the example of three farms, using complex methodology based on experience from Western Europe, it is shown which parts of the farming practice could be potentially problematic. Especially for intensive cash crops systems the importance of long term care of the agrosystem and mainly soil fertility should be emphasised. Performance of the assessment is the first step to describe the state and identify issues to be improved. Optimisation proposals should follow as the next step, including economic calculation and a reasonable motivation for farmers to change their objectives and activities.

**Keywords:** cropping systems, sustainability, agrosystem, indicators

## Introduction
Farm agroecosystem is composed of many parts and interactions between them, from soil and grown plants to the management approach of the farmer and the applied cropping system. Soil and its fertility should be one of the main concerns of the farmer as it is the basic internal part of an agrosystem and resource for field production. On the other hand, each farm interacts also with the environment outside the farm. Therefore a comprehensive assessment of the farm husbandry, covering internal as well as external effects, is needed for a complex optimization. The basic agronomic indicators (nutrients, organic matter, energy balance) including ecological indicators (diversity, erosion etc.) should be extended by economic (gross margin, profit, profitability) and social parameters (wages, holidays, education, safety at work, role of employees in the firm development, social engagement). The above mentioned three dimensions are interconnected and the farming systems existing currently in the Czech Republic are the result of the conditions given by legislation and economic factors.
In our earlier work, we analysed the state and the main problems of the Czech agriculture. Because the Czech agriculture is very diverse as regards the conditions, structure and production focus of the farms, a more detailed view is necessary when we intend to work systematically towards its sustainability. There were some common problems identified at the country level (Hlaváček et al., 2012, Křen and Dušková, 2013), but each type of farming has different results regarding its sustainability and each has its typical strengths and weaknesses. In this paper, we would like to present the typical farm structures and results of their sustainability assessment mainly from the agronomic and ecological perspective.

## Material and methods
Three farms of different structure in different conditions were chosen as examples of the different cropping systems (Tab. 1). The selection of the agronomic indicators basically from the methods used in the Western Europe and also at the Department of Agrosystems and Bioclimatology FA MENDELU (Křen et al., 2011) was used to perform the assessment of the farms. Each indicator is translated to the scale 1 (desirable state) to 0 (alarming state) to

enable a comprehensive overview of the results and a quick identification of the week points in farm husbandry.

**Tab. 1 Basic characteristics of the farms in the study**

| | F1 | F2 | F3 |
|---|---|---|---|
| Production region | sugar beet | potatoes | mountain |
| Altitude (m) | 262–336 | 550–700 | 305–605 |
| Average temperature (°C) | 8,2 | 8,2 | 7,6 |
| Precipitation (mm) | 520 | 580 | 760 |
| Soil type | haplic luvisol | cambisol | cambisol |
| Acreage (ha) | 492 | 2 200 | 1817 |
| - arable land (ha) | 492 | 600 | 432 |
| - grassland (ha) | – | 1 600 | 1385 |
| Cereals (% AL) | 51-86 | 20-29 | 43-54 |
| Oil seeds (% AL) | 0-18 | 0-23 | 0 |
| Row crops (% AL) | 14-27 | 0 | 0-0.6 |
| Fodder crops (% AL) | 0 | 49-62 | 23-27 |
| Number of cattle: | | | |
| - with milk production | – | 340 | 200 |
| - without milk production | – | 130 | 235 |
| LU/ha | 0 | 0,35 | 0,34 |

AL – arable land; LU – livestock unit

**Results and discussions**

Earlier analyses of the Czech agriculture have shown the following essential problems (Hlaváček et al., 2012, Křen and Dušková, 2013):
low inputs in soil and crop management for a long time (since 1990),
the decrease in livestock population, particularly in cattle after 1990, followed by lack of farmyard manures,
a large part of the managed soil is rented, which destabilizes agricultural enterprises, and often leads to poor soil care,
a larger size of agricultural enterprises and farms, which leads to farming "from distance",
omitting fixed crop rotations, decrease in areas of good preceding crops (sugar beet, potatoes, legumes and perennial forage crops), a considerable enlargement of areas planted with oil crops (rapeseed and poppy),
higher variation in yield and production of the major crops in recent years, which is likely to be caused by climatic changes that are pronounced by the mentioned problems (Křen et al., 2014).
In general, it is possible to say that, from the viewpoint of sustainability of soil management, economic problems are still solved at expense of agronomic and social problems. At the country level, this causes:
increase of area with low content of nutrients (P, K, Ca and Mg) in soil and acid pH (Klement et al., 2012),
decrease of the employment rate in agriculture and rural areas (Hlaváček et al., 2012),
unbalanced production of the agricultural commodities, which leads to decrease in food self-sufficiency and negative balance of the agrarian trade (Hlaváček et al., 2012).

This situation can be seen on individual farms to a different extent. But this situation can be improved at the farm level. It is possible to identify some common farm types with typical cropping systems and typical problems from the sustainability viewpoint.
As the consequence of the current situation given mainly by agricultural subsidies but also other influences, it is possible to define two main farm types aiming to profit from current conditions. Large cereal and rape seed farms on arable land without animal production and large “range” farms on the grassland. For this paper we have chosen one farm of the first type and two mixed farms in different conditions (Tab. 2 and Fig. 1).

**Tab. 2 Overview of the results of the farms in study. Given values represent average of the 3-year period (2004-2006)**

| | | F1 | | F2 | | F3 | |
|---|---|---|---|---|---|---|---|
| | Optimum | calc. | eval. | calc. | eval. | calc. | eval. |
| N balance (kg/ha) | 0–50 | 46.54 | 1 | 43.42 | 1 | 39.17 | 1 |
| P balance (kg/ha) | -5–5 | 5.79 | 0.99 | -0.69 | 1 | 9.00 | 0,95 |
| K balance (kg/ha) | -20–20 | -9.39 | 1 | 2.86 | 1 | -1.66 | 1 |
| OM balance (%) | -90–110 | 45.08 | 0.45 | 317.95 | 0 | 130.57 | 0,73 |
| Crop diversity | 1,5 | 0.85 | 0.57 | 1.63 | 1 | 2.29 | 1 |
| Soil cover index | >0,6 | 0.35 | 0.58 | 0.63 | 1 | 0.80 | 1 |
| System productivity (GU/ha) | | 76.30 | 1 | 27.70 | 0.73 | 29.20 | 0.80 |
| Energy intensity (MJ/GU) | <200 | 123.73 | 1 | - | - | 285.47 | 0.66 |

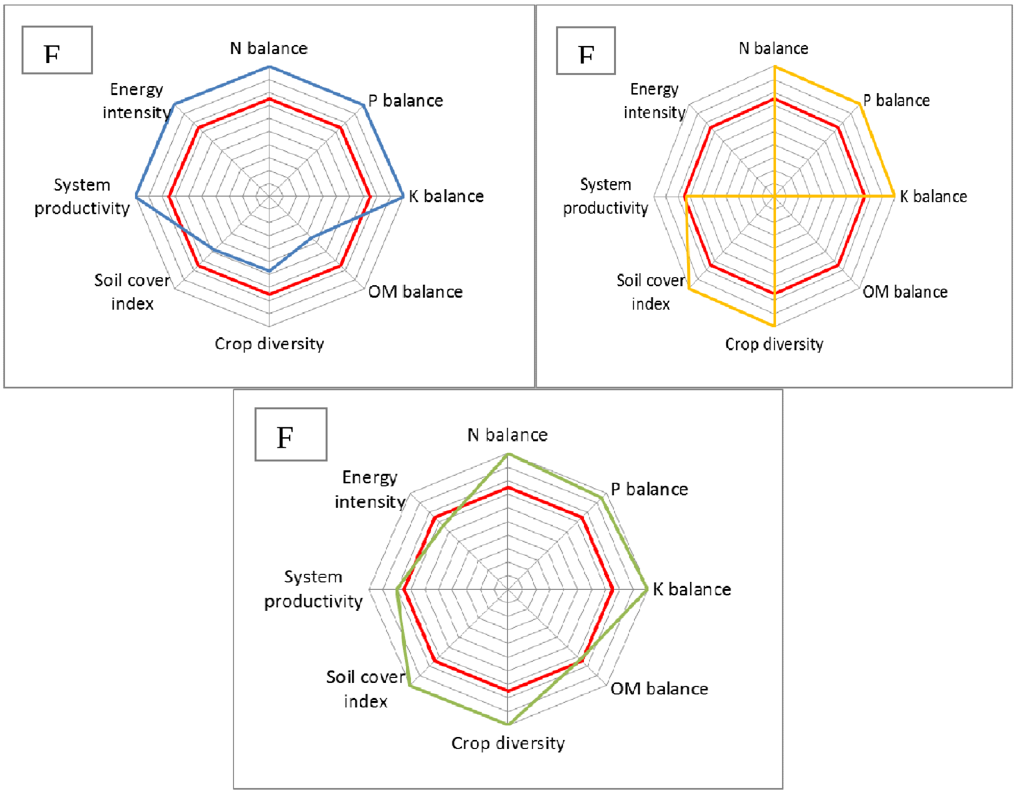



**Fig. 1 Overview of the results of the farms in study. The red line represents the sustainability threshold of the value of 0.75**

Farm 1 is a very intensive arable farm in very good conditions for agricultural production with very narrow crop structure with the purpose to grow only the most profitable cash crops. The results show a very productive and efficient system with the optimum nutrition of crops, good productivity and energy efficiency. On the other hand, indicators referring to other stabilising parts of the agrosystem and care of future state of system are under “red line”. This type of farming is common in productive regions of the CR. Because 78 % of the agricultural land is not owned by farmers who manage it, it is exploited without a proper care in many cases, and farming of this first type can have negative effects on soil fertility as well as on employment rate in rural areas.

Farm 2 represents a mixed farm with diverse crop structure in medium production conditions. The only problem which appears from the assessment is too high surplus of organic matter in the soil caused mainly by high proportion of perennial fodder crops in the rotation and their incorporation into soil. On the border of the sustainable values lies the system productivity. Unfortunately, there are no data for the energy intensity indicator. The focus on production of this farm enables agrosystem simplification with low intensity of the animal production (0.35 LU/ha) and a low number of employees who are able to manage a relatively large area (2200 ha). The number of the cash products is relatively narrow (milk, beef, oilseed rape) and their production per hectare is low as well. The positive economic result is reached by receiving subsidies (direct payments) while employing a few workers and paying low rent for land.

Farm 3 represents a mixed farm in a hilly country with diverse crop structure. As organically managed, this farm uses no mineral fertilisers, however, nutrient balance in nearly in optimal values. Some under-optimal value was calculated for the energy use indicator, which refers about too high consumption of energy per unit of production caused by lower yields. Slightly below the sustainability threshold is the indicator of organic matter balance. This farm is a good example of a farm in hills with lower intensity of production due to geographic conditions in the area. However, current situation enables to combine subsidies for organic agriculture and grassland and therefore significant part of income comes from this source. Lot of farms in the CR are of similar type but specialised strictly to beef cattle on grassland. This even improves economic situation of such farms which have minimum costs and significant income from multiple subsidies. This results in the current situation when the CR has one of the highest proportions of the organic land (ca 12 %) but only very limited organic production on arable land. This again points to the simplified agrosystems which does not fulfil the declared benefits of organic farming (higher system heterogeneity, higher employment rate).

In all demonstrated systems, there was found significant heterogeneity in the results among single fields. Usually this is in relation to the distance of the field to the farmyard in combination with omitting fixed crop rotation and an irregular scheme of fertilising the fields. Therefore it is necessary to analyse the results of assessment also at a single field level.

Farm structures and their typical management presented at the above farms is the result the farmer’s behaviour under conditions given by the rules for subsidies and by farming, especially on rented land. The presented analysis is the first step to work with the farms. Results of the assessment are the basis for the optimisation process where the identified week points should be improved by changes in farm management. But it is important to find such modifications of the management which are economically sound for the farmer and find motivation to improve the agrosystem not only in economic but also in agronomic, ecological and social indicators.

A chance for change in the above described negative trends is in more sound rules for subsidies in the period 2014–2020, the announcement of which is eagerly awaited.

**Conclusions**

It appears that in previous period (after CR joining the EU in 2004), farm management of the large farms was strongly simplified (specialised). It enables good economic provision for a relatively small group of people, mainly managers of the large farms, but it has a negative effect on other parts of the national economics:

decrease of soil fertility,

decrease of the employment rate,
decreased self-sufficiency in the food production.

The methodology used for the comprehensive analyses of the farming showed how the narrow specialisation of production of the big farms can contribute to these negative trends.

From the presented example of different farm types it is possible to conclude that highly specified, cash crop focused farms are more likely to neglect long-term acting measures important for maintaining soil fertility such as restoring organic matter in soil and prevention of the soil harms. On the other hand, for the mixed farms with fodder crops in rotation the efficiency of production (yield and energy intensity) and eventually proper management of the organic matter surplus in the soil may be a problem.

The reasonable rules for subsidies in the period 2014–2020 are one of the few possibilities for change in the negative trends in development of the Czech agriculture.

**Acknowledgements**

This study was supported by the Ministry of Agriculture of the Czech Republic, projects No. QI111A133.

**References**

HLAVÁČEK M. et al., 2012: Strategie pro růst - české zemědělství a potravinářství v rámci společné zemědělské politiky EU po roce 2013 (Strategy for growth – Czech agriculture and food industry within the framework of the Common Agricultural Policy of the EU after 2013), MZe Praha 12. 12. 2012, 72 p. http://eagri.cz/public/web/mze/ministerstvo-zemedelstvi/ koncepce-a-strategie/strategie-pro-rust.html

KLEMENT V., SMATANOVÁ M., TRÁVNÍK K., 2012: Padesát let agrochemického zkoušení zemědělských půd v České republice, Čtyřicet let dlouhodobých výživářských pokusů v ÚKZÚZ (Fifty years of Agrochemical Testing of Agricultural soils in the Czech Republic, Forty years of Long-Term Field Experiments in ÚKZÚZ). 96 p. ISBN: 978-80-7401-062-0

KŘEN J., DUŠKOVÁ S., 2013: The Czech agriculture and its issues. In: Dušková et al. *Current Trends in Agronomy for Sustainable Agriculture* – Proceedings of the International Ph.D Students Summer School. P. 7-17. ISBN 978-80-7375-835-6.

KŘEN J. et al., 2011: Metodika hodnocení trvalé udržitelnosti system rostlinné produkce pro podmínky ČR (Methodology of evaluation of crop production systems sustainability for condition of the Czech Republic). 50 p. ISBN 978-80-7375-588-1

KŘEN J. et al., 2014: Impact of climate change on cereal growth and its yield potential. *64. Tagung der Vereinigung der Pflanzenzüchter und Saatgutkaufleute Österreichs*. P. 35-41. ISBN: 978-3-902849-00-7


**Contact address:**

prof. Ing. Jan Křen, CSc.
Mendel University in Brno
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: kren@mendelu.cz
tel.: +420 545133106

# EFFECT OF SOIL TILLAGE ON THE WEEDS

**É. Lehoczky[1], A. Kismányoky[2], T. Németh[1]**

[1]Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research, Hungarian Academy of Sciences in Budapest, Hungary
[2]KWS Magyarország Kft. in Győr, Hungary

**Abstract**
The study was carried out in the long-term soil tillage experiment in 2006-2008. The study included different cultivation methods: no-till drill, disk tillage, conventional tillage (plowing) and five N fertilizer rates. The weed survey was made on the first days of June. Aerial parts of plants – weed species and maize - were collected and the fresh and dry matter weights were measured. The sample area was $1m^2$. The highest weed cover was found in the no-till treatment (35.5%). The weed species present in every treatment were the following: *Amaranthus retroflexus* L., *Chenopodium album* L., *Cirsium arvense* (L.) Scop., *Ambrosia artemisiifolia* L., *Convolvulus arvensis* L., *Echnochloa crus-galli* (L.) P. B.. During the spring weed collections the dry matter weight of weeds were significantly higher in the disc (31.1 $g \cdot m^{-2}$) and no-till treatments (27.8 $g \cdot m^{-2}$), than in the plowed treatment (14.1 $g \cdot m^{-2}$). The dry matter weight of maize was reduced with less tillage.

**Keywords: soil tillage, nutrient supply, maize, weeds, competition**

## Introduction
Cultivation systems, nutrient supply and their interaction are important in plant production research. Soil cultivation influences the productivity of agriculture and the economics of crop production. (Kismányoky et al. 1997). Conventional farming system, in which the weed control was fully based on application of chemicals, led to the development of a specific and hardly controllable weed flora. Improper tillage, lack of mechanical plant protection and cereal production without crop rotation also contributed to the excessive accumulation of some weed species (Birkás et al. 1997, 1999; Birkás 2001). Weeds damage plant production both directly and indirectly. Maize is highly susceptible to competition from weeds during it's early growth period, with yield losses greater than 25 % commonly reported (Lehoczky et al. 2007, 2008, Lehoczky and Márton 2011). There are essential differences in the cover of weeds and in the number of the weed species depending on the fertilization system employed (Lehoczky et al. 2014). Nitrogen fertilization often cannot increase the competitive ability of crops to weeds; it may even reduce it depending on the weed species (Alkämper 1976). The objective of this study aimed to determine the effect of different cultivation methods on weed flora in maize and their biomass production.

## Materials and methods
The study was carried out in 2006-2008 in Keszthely, on the soil tillage portion of a long-term experiment that was set up on a Raman-type brown forest soil (*Eutric cambisol*). In this experiment, a number of cultivation methods - no-till drill, disk tillage, conventional tillage (ploughed) – were assessed in combination with five N rates ($N_0$:0, $N_1$:120, $N_2$:180, $N_3$:240 and $N_4$:300 kg N $ha^{-1}$, all plots received a blanket application of 100 kg $P_2O_5$ $ha^{-1}$ and 100 kg $K_2O$ $ha^{-1}$. Lehoczky et al. 2009 describes detailed the experiment. The weed survey was made with the Balázs-Ujvárosi coenological method (Ujvárosi, 1973). The weed survey and sampling were carried out the first days of June. No weeds were removed prior to the

sampling date. All aboveground plant parts of every weed species from each plot were collected from a 1 $m^2$ area and the fresh and dry matter weights were determined. Furthermore, five maize plants were sampled per plot. Statistical data processing was performed with two factor variance analysis by SPSS 9.0 for Windows.

**Results and discussion**

On average, the weed cover found in the plow cultivation was lowest at 11.80% (Tab. 1).

**Table 1 The cover and dominance of weed species in the experiment, 2006-2008.**

| No. | Weed species | Weed cover (%) | | |
|---|---|---|---|---|
| | | **Plowing** | **Disc tillage** | **No-till drill** |
| 1. | *Chenopodium album* L. | 2.57 | 2.95 | 4.17 |
| 2. | *Amaranthus retroflexus* L. | 2.42 | 4.87 | 2.15 |
| 3. | *Elymus repens* (L.) Gould | 0.06 | 0.05 | 2.80 |
| 4. | *Setaria pumila* (L.) P.B. | 0.25 | 0.94 | 2.38 |
| 5. | *Cirsium arvense* (L.) Scop. | 2.12 | 8.88 | 4.90 |
| 6. | *Convolvulus arvensis* L. | 0.82 | 0.83 | 2.49 |
| 7. | *Ambrosia artemisiifolia* L. | 0.75 | 1.47 | 6.22 |
| 8. | *Lathyrus tuberosus* L. | 0.03 | 0.30 | 0.19 |
| 9. | *Cynodon dachtylon* (L.) Pers. | 0.11 | 0.82 | 0.33 |
| 10. | *Digitaria sanguinalis* (L.) Scop. | 1.75 | 0.45 | 1.91 |
| 11. | *Bilderdykia convolvulus* L. | 0.12 | 0.25 | 1.63 |
| 12. | *Echinochloa crus-galli* (L.) P.B. | 0.34 | 1.39 | 1.30 |
| | **Total weed cover** | **11.80** | **25.60** | **35.50** |
| | | | | $LSD_{5\%}$ *5.13* |

The most dominant weeds were *C. album, A. retroflexus* and *C. arvense* with 60% of the total weed cover. Seven of the 12 dominant weed species belongs to annual weeds. The cover of perennial weeds was nearly 27%.

The total weed cover of the disc tillage treatment was 25.6%, about two fold higher than in the plow plots. Here the cover of *C. album, A. retroflexus* and *C. arvense* were the highest proportion of total weed cover (65%). *C. arvense* had the highest weed cover at 8.88%, four times higher than the plow treatment. The cover of perennial weeds was 42.5% of the total weed cover.

The highest weed cover was found in the no-till treatment (35.5%). In these plots *A. artemisiifolia* was dominant (6.22%), with lesser cover by *C. arvense* (4.90%) and *C. album* (4.17%). The total weed cover was three fold higher in the no-till treatment than in the plow plots. The cover of most important perennial weeds was 30% of the total weed cover.

**Table 2 The dry matter weight ($g \cdot m^{-2}$) of weeds, 5 weeks after sowing of maize**

| **Soil cultivation** | $N_0$ | $N_1$ | $N_2$ | $N_3$ | $N_4$ | **Average** |
|---|---|---|---|---|---|---|
| Plowing | 7.63 | 14.3 | 27.4 | 9.13 | 12.30 | 14.15 |
| Disc tillage | 25.91 | 30.04 | 36.59 | 35.37 | 27.89 | 31.16 |
| No-till drill | 27.38 | 33.15 | 22.61 | 28.64 | 23.52 | 27.06 |
| **Average** | **20.30** | **25.83** | **28.86** | **24.38** | **21.23** | $LSD_{5\%}$ *16.54* |

Overall, reduced tillage depth increased the proportion of weed cover and weed species significantly. At the spring weed survey, the dry weight of weeds in the disc and no-till treatments were significantly higher than in the plow plots.
We also found from spring weed sampling that the different doses of N did not change the dry matter weight of weeds (Tab. 2). However, as noted above, soil cultivation factors did affect the weight of weeds. In the same period the dry matter weight of maize showed a similar tendency.

**Table 3 The dry matter weight ($g\cdot m^{-2}$) of maize, 5 weeks after sowing**

| Soil cultivation | $N_0$ | $N_1$ | $N_2$ | $N_3$ | $N_4$ | Average |
|---|---|---|---|---|---|---|
| Plowing | 3.91 | 4.93 | 4.47 | 4.81 | 5.39 | 4.70 |
| Disc tillage | 2.47 | 4.69 | 4.01 | 4.25 | 4.38 | 3.96 |
| No-till drill | 2.92 | 3.28 | 3.54 | 3.34 | 3.45 | 3.30 |
| **Average** | **3.10** | **4.30** | **4.00** | **4.13** | **4.40** | *$LSD_{5\%}$ 0.54* |

N fertilizer increased significantly the dry matter weight of maize until $N_1$ (Tab. 3). The higher application rates of N caused no changes.

## Conclusions

Cultivation method had a major impact on weeds. Weediness may also be affected by sowing rotation and manuring systems. The results of this weed research indicated that turning the soil by plowing resulted in fewer weeds; without tillage the most weeds.
The lowest weed cover was found on the plowed plots, the highest in the no-till treatment. The highest numbers of weed species were annual weeds. Perennial weeds were present in significant numbers also.
The weed species present in every treatment were the following: *Amaranthus retroflexus* L., *Chenopodium album* L., *Cirsium arvense* (L.) Scop., *Ambrosia artemisiifolia* L., *Convolvulus arvensis* L., *Echnochloa crus-galli* (L.) P. B.
According to our experimental results we can conclude that the minimum tillage has a favor effect on weeds appear. In long period  the accumulation of perennials is significant. The best weed control effect had effected the plowing cultivation method where the perennial and annual weeds were attenuate.
Nitrogen fertilizer increased significantly the weed cover. This proves that optimal nutrient supply increases the competition ability of weeds with maize.
During the spring weed collections the dry matter weight of weeds were significantly higher in the disc (31.1 $g\cdot m^{-2}$) and no-till treatments (27.8 $g\cdot m^{-2}$), than in the plowed treatment (14.1 $g\cdot m^{-2}$). The dry matter weight of maize was reduced with less tillage.
In this sample period the different N doses had no effect to the dry matter weight of weeds. The N fertilizer increased the dry matter weight of maize compared to no N fertilizer treatment.

## Acknowledgement

This publication was supported by the Hungarian Scientific Research Fund (OTKA), Grant No. K105789.

## References

ALKÄMPER, J. 1976: Einfluss der Verunkrautung auf die Wirkung der Düngung. *Planzenschutz-Nachrichten. Bayer*, 29: 191-235.

BIRKÁS, M., SZALAI, T., NYÁRAI, F., FENYVES, T., PERCZE, A. 1997: Kukorica direktvetéses tartamkísérletek eredményei barna erdőtalajon. *Növénytermelés*, 46: 413-430.

BIRKÁS, M., GYURICZA, CS., GECSE, M. AND PERCZE, A. 1999. Az ismételt tárcsás sekélyművelés hatása egyes növénytermesztési tényezőkre barna erdőtalajon. *Növénytermelés*, 48: 387-402.

BIRKÁS, M.: 2001: Talajművelés a fenntartható gazdálkodásban. Akaprint Kiadó, Budapest.

KISMÁNYOKY, T., HOFFMAN, S. AND TÓTH, Z. 1997: Long term effect of different soil tillage systems on crop yield and nitrate content of soil. *Bibliotheca Fragmenta Agronomica*, 2B:359-362.

LEHOCZKY, É., KISMÁNYOKY, A., NÉMETH, T. 2007: Effect of the soil tillage and N-fertilization on the weedeness of maize. *Cereal Research Communications,* 35 (2): 725-728.

LEHOCZKY, É., KISMÁNYOKY, A., NAGY, P., NÉMETH T. 2008: Nutrient absorbtion of weeds in maize. *Communications in Agricultural and Applied Biological Sciences,* 73 (4): 951-957.

LEHOCZKY, É., KISMANYOKY, A., NEMETH, T. 2009: Weediness and nutrient uptake by weeds in relation to the soil tillage. *Communication in Soil Science and Plant Analysis,* 40 (1-6): 871-879.

LEHOCZKY, É., KAMUTI, M., MAZSU, N., RADIMSZKY, L., SÁNDOR, R. 2014: Composition, density and dominance of weeds in maize at different nutrient supply levels. *Crop Production* 63(1): 287-290.

LEHOCZKY, É., MÁRTON, L. 2012: Water content and biomass production of weeds in maize. Crop Production, 61(1): 125-128.

UJVÁROSI, M. 1973. *Gyomirtás.* Mezőgazdasági Kiadó, Budapest.

**Contact address:**

Éva Lehoczky, PhD, DSc.
Institute for Soil Sciences and Agricultural Chemistry
Centre for Agricultural Research, Hungarian Academy of Sciences
Herman O. str. 15.
1022 Budapest
Hungary
Telephone: +36-1-212-2265
e-mail: lehoczky.eva@agrar.mta.hu

# ADDRESSING THE WITHIN-FIELD SPATIAL VARIABILITY IN CROP MANAGEMENT

**V. Lukas, L. Neudert, T. Dryšlová, J. Novák, J. Křen**

Department of Agrosystems and Bioclimatology, Mendel University in Brno, Czech Republic

**Abstract**
A traditional soil survey for mapping the spatial variability of soil is not too useful for purposes of precision agriculture because of the cost and labour consumption. At two experimental fields (52.5 and 37.8 ha) in South Moravia region (Czech Republic) the efficiency of the indirect methods to assess the spatial variability of soil agrochemical properties, measurement of soil electrical conductivity and aerial imaging, was verified. An optimization of soil sampling was tested based on the results of sensor mapping using ESAP-RSSD software and compared with the regular sampling grids. Finally, a modification of the interpretation of nutrient content in soil was examined to obtain the most reliable prescription maps for variable rate application of fertilizers.

**Keywords:** soil sampling, spatial heterogeneity, variable rate application, site specific management, sensors

**Introduction**
More than 54 % of agriculture land in the Czech Republic is managed by farms with a size of over 1000 ha (Ministry of Agriculture, 2010) and based on a statistical evaluation of the Land Parcel Information System (LPIS) over 40 % of arable land lies in fields with an area larger than 20 ha. Large areas of fields with a combination of a higher variability of topographical and geological factors result in visible heterogeneity of soil condition and crop yield. Site specific management, known as precision agriculture, takes into consideration the spatial variability within fields and optimizes production inputs, thus fulfilling the objectives of sustainable agriculture (Corwin and Plant, 2005).
Precision agriculture is based on application of technologies and principles to manage spatial and temporal variability (Pierce and Nowak, 1999). The higher is the spatial variability of a soil conditions (or crop properties), the higher is the potential for precision management and the greater its potential value. The degree of difficulty, however, increases with higher dynamics of temporal component. To understand the causes and the extent of variability, there is a requirement for an effective method of accurately mapping soil and crop parameters (Wood et al., 2003).

**Mapping of the soil variability**
The conventional techniques of soil variability mapping are slowly replaced by indirect methods such as the on-the-go systems (see overview by Adamchuk et al., 2004) or remote sensing. These methods have more intense spatial coverage but are less accurate compared to laboratory procedures (Christy, 2008). Soil electrical conductivity (EC) has become one of the most frequently used measurements to characterize field variability for application to precision agriculture (Corwin and Lesch, 2003). The soil electrical conductivity is influenced by combination of physico-chemical properties including soluble salts, clay content and mineralogy, soil water content, bulk density, organic matter, and soil temperature (Corwin and Lesch, 2005). A number of factors complicate the direct application of EC in site specific

management, because the interpretation of EC maps requires the determination of the dominant soil factor.

Other category of sensor mapping is remote sensing. These techniques use the spectral characteristics of soil surface to determine the soil heterogeneity. Baumgardner et al. (1986) present an overview of spectral properties of soil. Like the EC methods, remote sensing cannot be used to determine specific soil properties without additional soil survey.

An example of soil mapping results in form of maps can be seen in Figure 1. This survey has been carried out since 2004 at two different localities in South Moravia region (Czech Republic): Field Pachty (52.5 ha; 48°59’N, 16°37’E; chernozem soil type and sandy clay loam texture) and Field Haj (37.8 ha; 49°15'N, 17°06'E; haplic luvisol and silt loam texture). The results of comparison between agrochemical properties of soil (obtained by soil sampling and laboratory analysis) and sensor mapping, on-the-go measurement of soil electrical conductivity and remote sensing, are mentioned in Tab. 1. Maps of observed soil parameters are shown in Fig. 1.

**Tab. 1 Correlation coefficients between soil parameters and indirect methods**

| | | pH | P (mg.kg$^{-1}$) | K | Humus (%) | Clay (%) |
|---|---|---|---|---|---|---|
| Field Pachty (52.5 ha) | VIS_c1 | -0.371$^{**}$ | 0.560$^{**}$ | 0.501$^{**}$ | -0.428$^{**}$ | -0.506$^{**}$ |
| | MS_c1 | -0.410$^{**}$ | 0.653$^{*}$ | 0.593$^{**}$ | -0.547$^{**}$ | -0.540$^{**}$ |
| | EC (mS.m$^{-1}$) | 0.565$^{**}$ | -0.575$^{**}$ | -0.500$^{**}$ | 0.469$^{**}$ | 0.433$^{**}$ |
| | Temp. (°C) | 0.424$^{**}$ | -0.534$^{**}$ | -0.569$^{**}$ | 0.276$^{**}$ | 0.644$^{**}$ |
| Field Haj (37.8 ha) | VIS_c1 | -0.391$^{**}$ | -0.082 | -0.169$^{*}$ | -0.470$^{**}$ | -0.051 |
| | MS_c1 | -0.348$^{**}$ | -0.093 | -0.229$^{**}$ | -0.439$^{**}$ | -0.068 |
| | EC (mS.m$^{-1}$) | -0.057 | -0.258$^{**}$ | 0.174$^{*}$ | 0.061 | 0.373$^{**}$ |
| | Temp. (°C) | 0.044 | -0.159 | 0.136 | 0.194$^{*}$ | 0.261$^{*}$ |

significance level *$\alpha$ = 0.05; ** $\alpha$ = 0.01; VIS – visible spectrum; MS – multispectral; EC – electrical conductivity of soil, Temp. – surface temperature based on the thermal image; _c1 –first component of PCA

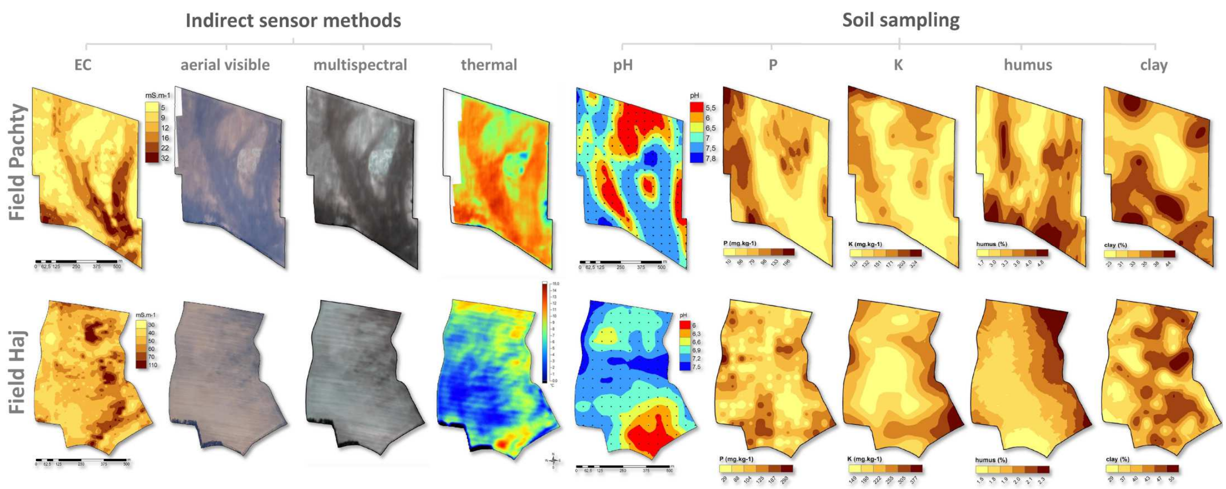



**Fig. 1 Results of soil survey by measurement of soil electrical conductivity, remote sensing of bare soil and soil sampling.**

Measurement of soil parameters by sensor mapping may be used as an ancillary method which measures variability of a secondary soil parameter to help to explain the variability of the soil parameter(s) of interest (Tarr et al., 2005). Lesch (2005) proposed for the optimization of soil samples distribution using ancillary data the *spatial response surface* (SRS) algorithm, which is built into software package *ESAP-RSSD*. The principle of this method is the selection of samples that covers a range of ancillary values, and physically separated far apart as possible (Minasny et al., 2007). A relationship between soil parameter(s) and sensor data is supposed for successful optimization of soil sampling using ancillary data.

Tab. 2 shows the prediction error of spatial interpolation for soil pH value from the sampling design with different density of sampling points. The initial variant was regular 50m sampling grid, other regular and irregular sampling variants were composed by selecting the points from this initial grid. In the case of ESAP_1 variant, the results of EC measurements were used for optimization, whilst in the case of ESAP_2, a combination of digital elevation model (DEM) and aerial image in visible spectrum as the first principle component were used. The OPT variant was used only in the Field Pachty by subjective selection of 40 samples from the original 50m-grid based on a EC map. Output of ESAP-RSSD is the position of sampling points to which pH value of the nearest points of the initial 50m-grid was assigned.

Continuous maps were generated from points of both regular and irregular grids using the ordinary kriging (OK) and cokriging (CoK) method. As a covariate data for CoK, an EC maps (regular grids, OPT, ESAP_1) and combination of aerial imaging and DEM data (ESAP_2) were used. The root means square error ($RMSE_{50}$), calculated from differences between continuous maps and initial points of 50m grid, was chosen as criterion of prediction accuracy for comparison of sampling variants.

**Tab. 2 Results of comparison between regular and irregular grids in both fields**

| | | 50m | 100m | 150m | OPT | ESAP_1 | ESAP_2 |
|---|---|---|---|---|---|---|---|
| Field Pachty | Samples count | 214 | 53 | 27 | 40 | 20 | 20 |
| | Sampling density (per ha) | 4.08 | 1.01 | 0.51 | 0.76 | 0.38 | 0.38 |
| | pH $RMSE_{50}$ OK | **0.215** | **0.724** | **0.987** | **0.758** | **0.925** | **0.693** |
| | pH $RMSE_{50}$ CoK | **0.112** | **0.586** | **0.838** | **0.625** | **0.894** | **0.691** |
| Field Haj | Samples count | 152 | 41 | 18 | - | 20 | 20 |
| | Sampling density (per ha) | 4.02 | 1.08 | 0.48 | - | 0.53 | 0.53 |
| | pH $RMSE_{50}$ OK | **0.248** | **0.387** | **0.579** | **-** | **0.448** | **0.469** |
| | pH $RMSE_{50}$ CoK | **0.185** | **0.400** | **0.585** | **-** | **0.488** | **0.464** |

50m, 100m, 150m - square sampling grids with sampling intervals of 50 m, 100 m and 150 m
OPT - subjectively selected 40 points based on EC map. Verified only in the Field Pachty
ESAP_1 - Selection of 20 points using ESAP-RSSD software based on EC map
ESAP_2 - Selection of 20 points using ESAP-RSSD software based on combination (first component) of aerial imaging and DEM data
OK, CoK – ordinary kriging, cokriging
Lower $RMSE_{50}$ = higher prediction accuracy

The comparison of variants of the sampling grids with the interpolation method OK showed a decreasing reliability of pH prediction in regular grids with lower density. Irregular grids obtained approximately the same prediction accuracy as the 100m regular grid, but with a lower number of samples (25% reduction of samples in the OPT variant, and 38% or 48% reduction in optimization using the ESAP-RSSD). The variant ESAP_1 in the Field Pachty is the only exception when the $RMSE_{50}$ value was at the same level as the 150m variant. The cokriging interpolation brought improves of accuracy only in case of regular grids with higher density of sampling. In case of irregular grids was the increase only slight (Field Pachty) or the accuracy was similar (Field Haj) to OK interpolation.

**Interpretation of soil maps for variable rate application of fertilizers**

Traditionally, estimation of application rates is based on nutrient uptake by crop product as constant for a whole field and corrected by evaluation of nutrient supply in soil from soil sampling. Soil samples are analyzed according to Mehlich 3 methodology, which was found as suitable for determination of P, K, Mg and Ca in Czech agricultural soils (Zbiral and Nemec, 2000). Czech methodology classifies the nutrition content in soil into five classes (low, low satisfactory, good, high and very high); content of K, Mg and Ca is evaluated separately according to the soil texture (light, medium and heavy soil). For each category, the correction of normative is established to increase or decrease application rates (Klement et al., 2012). Klir et al. (2008) described the smoothing of original 5-class interpretation system of Mehlich 3 methodology using linear fitting function. The result is so called balance coefficient which estimates the correction of normative dose at each value of nutrient content. However, this concept has not been used yet for variable rate application.

Following the concept of balance coefficient (Klír et al., 2008), the original 5-classes interpretation of nutrient content in soil was smoothed using multi-linear functions. Additionally, within field variability of crop yield in recent years was taken into account. The historical yield maps of various crops were separately normalized as the percentage of the whole field yield. Later all normalized raster layers were averaged to get final yield productivity map, which represents permanent higher or lower yield zones within the field. Both interpretations were implemented into ESRI ArcGIS as the reclassification table.

**Tab. 3 List of the compared variants of soil map interpretation**

| Variant Code | Application | Interpretation | Planned Yield as |
|---|---|---|---|
| UNI-M3 | uniform | Mehlich 3 | constant |
| UNI-BC | uniform | Bal.coef. | constant |
| VRA-M3 | variable rate application | Mehlich 3 | constant |
| VRA-BC | variable rate application | Bal.coef. | constant |
| VRY-M3 | variable rate application | Mehlich 3 | zones |
| VRY-BC | variable rate application | Bal.coef. | zones |

Bal.coef. – balance coefficient

To show the effect of suggested approaches on the application maps, six variants of interpretation of soil maps were verified at both experimental fields for P, K and Mg content in soil (Tab. 3). For both fields, the winter wheat was simulated as the main crop with the yield level 5 $t.ha^{-1}$ and nutrient uptake of 5 kg P, 20 kg K and 2.4 kg Mg per one tone of final yield.

CONTENT

**Tab. 4 Estimated average nutrient dose and percentage to VRA-M3 variant (%, italic) at experimental fields**

| Field | Nutrient | UNI-M3 | | UNI-BC | | VRA-M3 | | VRA-BC | | VRY-M3 | | VRY-BC | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | kg | % | kg | % | kg | % | kg | % | kg | % | kg | % |
| Pachty | P | 38 | **119** | 35 | **109** | 32 | **100** | 29 | **91** | 33 | **103** | 30 | **96** |
| Pachty | K | 125 | **103** | 119 | **98** | 121 | **100** | 120 | **99** | 122 | **101** | 122 | **101** |
| Pachty | Mg | 12 | **121** | 10 | **104** | 10 | **100** | 9 | **86** | 10 | **97** | 8 | **84** |
| Háj | P | 0 | **0** | 0 | **0** | 24 | **100** | 17 | **71** | 24 | **100** | 17 | **73** |
| Háj | K | 0 | **0** | 0 | **0** | 104 | **100** | 79 | **76** | 104 | **100** | 80 | **77** |
| Háj | Mg | 0 | **0** | 0 | **0** | 7 | **100** | 3 | **44** | 7 | **101** | 3 | **49** |

Tab. 4 shows the results of comparison among examined variants of soil map interpretation, represented by average nutrient dose (kg.ha$^{-1}$) and percentage of the doses compared to the VRA-M3 variant (as 100%). Implementation of balance coefficient led to decrease of average nutrient dose compared to the interpretation using Mehlich 3 almost at all variants - mainly at the Field Haj where the differences in nutrient content were lower than at the Field Pachty.

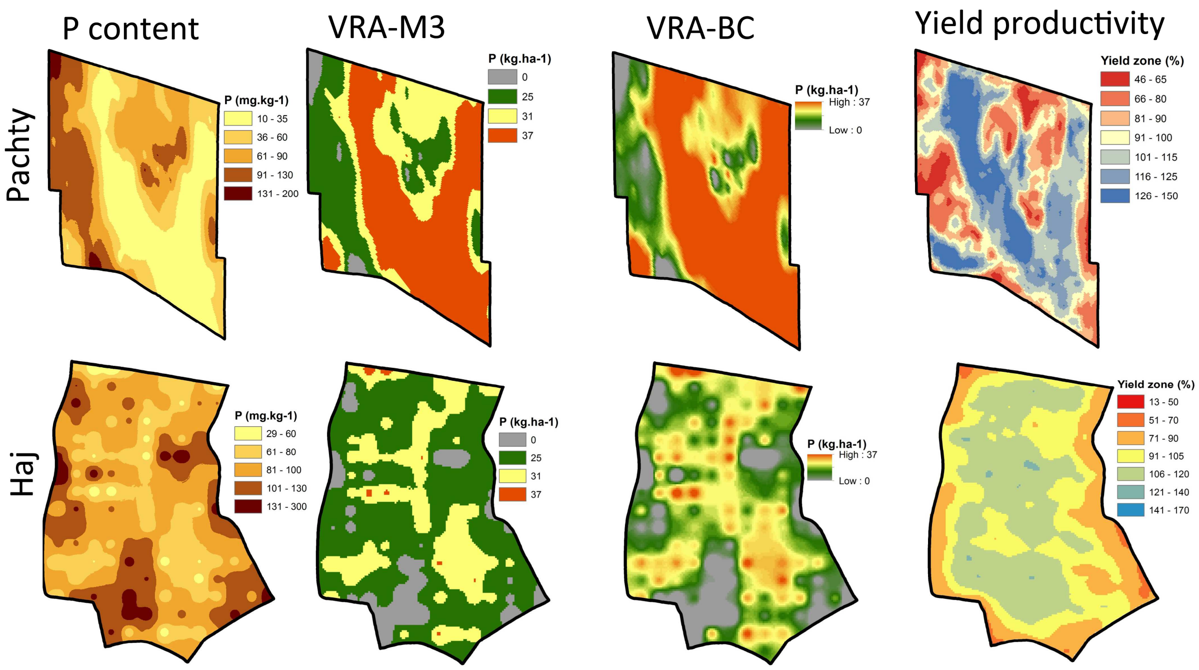



**Fig. 2 Examples of maps for both fields: P content in soil, VRA application maps interpreted by Mehlich 3 methodology (VRA-M3) or balance coefficient (VRA-BC) and map of yield productivity**

The differences between uniform (UNI) and variable rate application (VRA) had to be evaluated separately for both locations. At the Field Pachty uniform application had the same or higher average dose compared to the variable application. On the other hand the omission of fertilization was recommended at the Field Haj for uniform application, because of considering the soil texture differences within the field and masking the local extremes by average nutrient content for whole field. The integration of the yield productivity map (VRY) had in most cases similar or higher doses than VRA with constant yield per field. Only small differences (up to 5 % of doses) shows that changes of the rates are spread over the whole field area.

CONTENT

**Conclusions**

The verification of sensor methods (measurement of soil electrical conductivity, aerial multispectral and thermal imaging of bare soil) showed potential for identification of spatial variability in soil conditions, but the complexity of factors limits a detailed estimation of relevant soil parameters. Nevertheless sensor mapping could be used to get a comprehensive view of the spatial heterogeneity for optimization of traditional surveys such as soil or plant sampling.

For variable rate application of fertilizers, a modification of traditional Mehlich 3 approach into site specific crop management for variable application of P, K and Mg fertilizers was verified. As the first step, an optimization of soil sampling was done based on the sensor mapping to reduce the number of samples. The second step was the implementation of balance coefficient for more precise classification of soil nutrient maps. The last innovation included an estimation of within field productivity based on the historical yield maps to improve the calculation of nutrient uptake by crops. A model calculation of prescription maps showed the effect of suggested modifications on the decrease of the average application rate compared to the uniform treatment. However, quantification of the benefits needs further verification on different soil and farm conditions.

**Acknowledgements**

This study was supported by the National Agency of Agricultural Research as research project No. QI111A133 "Improvement of cereal variety potential realization using temporal and spatial analysis of stand spectral characteristic" and project No. QJ1210008 "Innovation of cropping systems of cereals in different agroecological conditions in Czech Republic".

**References**

ADAMCHUK, V.I., HUMMEL, J.W. MORGAN, M.T. UPADHYAYA, S.K. 2004. On-the-go soil sensors for precision agriculture. *Computers and Electronics in Agriculture*. 44(1): 71-91.

BAUMGARDNER M. F., SILVA L. F., BIEHL L. L., STONER E. R., BRADY N. C. 1986. Reflectance Properties of Soils. *Advances in Agronomy*. Academic Press, 1-44

CHRISTY, C.D.. 2008. Real-time measurement of soil attributes using on-the-go near infrared reflectance spectroscopy. *Computers and Electronics in Agriculture*, 61(1): 10-19.

CORWIN, D.L. & PLANT, R.E. 2005. Applications of apparent soil electrical conductivity in precision agriculture. *Computers and Electronics in Agriculture.* 46: 1-10.

CORWIN, D.L., LESCH, S.M. 2003. Application of soil electrical conductivity to precision agriculture: Theory, principles, and guidelines. *Agronomy Journal*. 95: 455-471.

KLEMENT, V. - SMATANOVÁ, M. - TRÁVNÍK, K.: 2012. Fifty years of Agrochemical Testing of Agricultural soils in the Czech Republic (In Czech: Padesát let agrochemického zkoušení zemědělských půd v České republice). Central Institute for Supervising and Testing in Agriculture (UKZUZ), Brno.

KLÍR, J., KUNZOVÁ, E., ČERMÁK, P. 2008. Frame methodics of plant nutrition and fertilization (In Czech: Rámcová metodika výživy rostlin a hnojení), 2. ed. Crop Research Institute., Prague.

LESCH, S. M. 2005. Sensor-directed response surface sampling designs for characterizing spatial variation in soil properties. *Computers and Electronics in Agriculture*. 46(1-3): 153-179.

MINASNY, B., MCBRATNEY, A. B. AND WALVOORT, D. J. J. 2007. The variance quadtree algorithm: Use for spatial sampling design. *Computers and Geosciences*. 33(3): 383-392.

MINISTRY OF AGRICULTURE. 2010. Agriculture status report 2009 (Zpráva o stavu zemědělství ČR za rok 2009). Ministerstvo zemědělství, Praha.

PIERCE, F.J., NOWAK, P. 1999. Aspects of Precision Agriculture. *Advances in Agronomy*, 67: 1-85.

TARR, A. B., MOORE, K. J., BURRAS, C. L., BULLOCK, D. G. AND DIXON, P. M. 2005. Improving map accuracy of soil variables using soil electrical conductivity as a covariate. *Precision Agriculture*. 6(3): 255-270.

WOOD, G.A.,TAYLOR, J.C., GODWIN, R.J. 2003. Calibration methodology for mapping within-field crop variability using remote sensing. *Biosystems Engineering*, 84: 409-423

ZBIRAL, J., NEMEC, P.: 2000. Integrating of Mehlich 3 extractant into the Czech soil testing scheme. *Communications in Soil Science and Plant Analysis*, 31: 11-14.

**Contact address:**

Ing. Vojtěch Lukas, Ph.D.
Mendel University in Brno
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: vojtech.lukas@mendelu.cz
tel.: +420 545 133 081

Photo Smutný: *Phacelia tanacetifolia stand* after strip tillage


Photo Smutný: FALCON drilling machine (FARMET)

# CROPPING PRACTICES AND FUSARIUM HEAD BLIGHT IN CEREALS

**P. Matušinsky[1], M. Váňová[1], I. Polišenská[1], M. Janeček[2], V. Smutný[3]**

[1]Agrotest fyto, Ltd., Havlickova 2787/121, 767 01 Kromeriz, Czech Republic
[2] Crop Research Institute, Prague 6 – Ruzyne, Czech Republic
[3]Mendel University in Brno, Zemedelska 1, Brno, Czech Republic

**Abstract**
Fusarium head blight caused by a complex of *Fusarium* species is widespread all over the world and ranks among most serious diseases in cereals. Soil tillage practices, crop rotation and crop residue management influence the level of weed infestation and intensity of the diseases. A high proportion of cereals in crop rotation, the management practices without incorporation of crop residues and risk crop like maize increase the likelihood of ear diseases such as head blight in both wheat and barley. In soil-conservation practices, when the soil surface is covered with crop residues, is necessary to observe the principles of good crop rotation. The integrated protection systems should contain monitoring perithecia maturity and determining the release of ascospores with subsequent refinement of estimating the term of spike infection by the pathogen.

**Keywords:** Farming practices, reduced tillage systems, plant diseases.

**Introduction**
Fusarium head blight (FHB) caused by a complex of *Fusarium* species is widespread all over the world and ranks among most serious diseases in cereals. FHB in wheat and barley is characteristic of early dying of ears or their whitening. The disease is important especially in more humid regions. Once the ears are infected, significant losses of yields caused by spikelet sterility and insufficiently developed caryopses as well as grain contamination with mycotoxins can be expected (Champeil et al., 2004). There are a large number of species of the genus *Fusarium* involved in the development of FHB but most frequent and most significant are *F. graminearum*, *F. culmorum*, *F. avenaceum* and *F. poae* (Bai and Shaner, 1994; Landschoot et al., 2012). The species *F. graminearum* and *F. culmorum* predominate in the area of the Czech Republic (Váňová et al., 2004). The last study indicates a raising proportion of *F. poae*. The harmfulness of FHB consists in yield reduction but especially in the ability of its numerous pathogens to produce mycotoxins. *Fusarium* mycotoxins can induce serious health troubles in both people and farm animals. Consequently, chronic or acute mycotoxicoses appear (indigestion, fertility defects, etc.). The most dangerous *Fusarium* mycotoxins are trichothecenes, particularly deoxynivalenol and nivalenol, and zearalenones. These harmful mycotoxins in grain are produced especially when infected by *F. graminearum* and *F. culmorum*. There is, however, a series of other toxins caused by other *Fusarium* species, for instance, T2 and HT2 toxins produced by *F. langsethiae* and *F. sporotrichioides* (Matušinsky et al., 2013).
A large number of fungicides against FHB in cereals are registered in the Czech Republic. Besides, preparations for biological protection are also registered. Plant protection against FHB, like in the other diseases, is not based only on pesticide application, but includes a complex of preventive and agronomic treatments that can prevent to a large extent from strong disease infection. The purpose of integrated protection is a consideration of all available methods that suppress the development of harmful organisms. Many of indirect

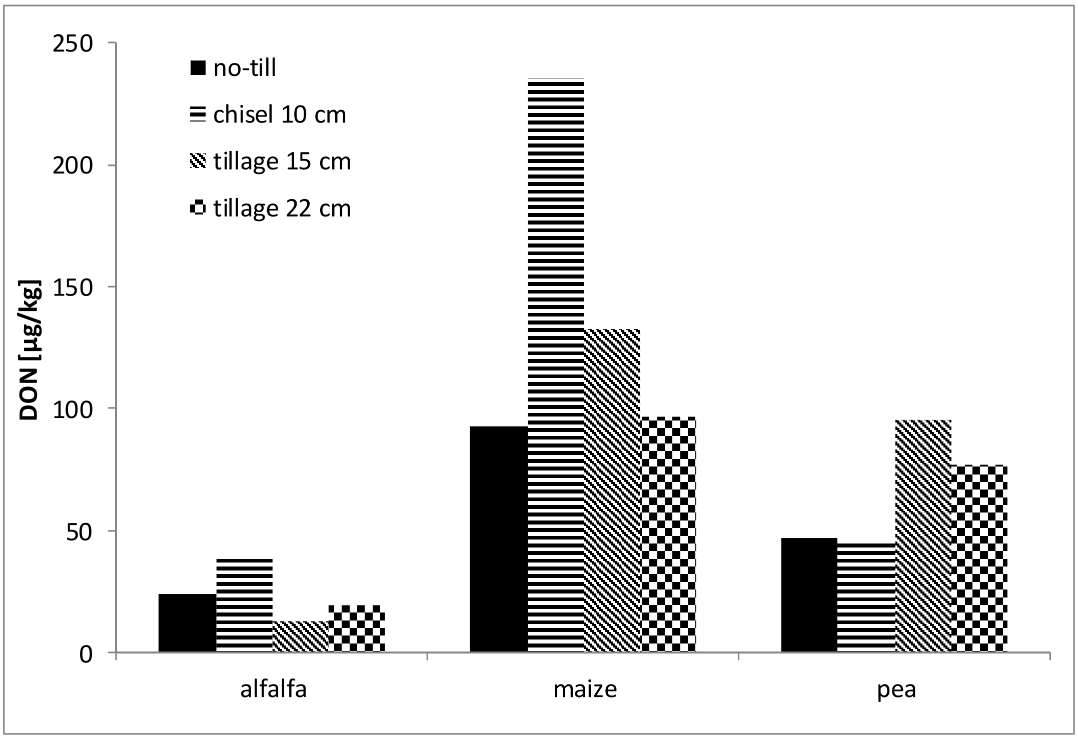
protection methods may ultimately be more effective and even cheaper than pesticide application. This statement is valid especially for diseases in which the efficacy of pesticide treatment is not usually stable and fully effective. This group includes FHB when some of *Fusarium* species occur without apparent symptoms and in spite of that grain is contaminated with mycotoxins. There have been documented cases when pesticide application increased the mycotoxin content because the fungus, being under a toxic pesticide stress, produces more of these substances. The efficacy of spraying in FHB depends on many other factors, such as application timing when it is necessary to harmonize the spray with the infection of flowering ears, or the presence of a certain species of the *Fusarium* genus that caused the disease. An accurate diagnosis of pathogens and monitoring the spores causing infection should also be part of integrated protection.

**Materials and methods**

Grain samples of winter wheat from a field experiment conducted in Ivanovice na Hané in 2011/2012 were used to assess the effect of soil tillage practices and preceding crops on the incidence of FHB. The level of infection was determined visually and using deoxynivalenol (DON) analysis. Four different soil tillage systems were used: tillage (22cm), shallow tillage (15cm), disk chisel (10cm) and no-till. All the systems were applied after three preceding crops: peas, alfalfa and maize.

**Results and discussion**

Limiting factors in the year 2012 were unfavourable winter when many winter crops did not survive or were considerably damaged, and a longer dry period in March and late May, which also adversely affected the development of cereals. Extremely cold weather was recorded during winter months, especially in the first half of February 2012 when the average daily temperature ranged below -10 °C. Also, maximum daily temperatures attacked a threshold of -10 °C, i.e. there were several arctic days in February. Minimum temperatures fell in this period to -18 °C (-18.6 °C, 13 February) and ground minimum temperatures ranged even below -20 °C. The absence of snow cover caused considerable injury to winter crops. It was hardly possible to perform objective visual assessment of the occurrence of FHB in 2012 due to extensive damage of ears by drought. A total content of DON mycotoxin in wheat in our experiment in 2012 was 76.490 $\mu g.kg^{-1}$. Significantly higher concentration of DON was found after maize than after the two other preceding crops. The factor soil tillage practice did not exhibit as strong effect on the mycotoxin content as the preceding crop (Graph 1).




**Graph 1 Deoxynivalenol content in wheat grain after different preceding crops and soil tillage practices (2012)**

Soil tillage practices including various depths, intensity and different way of soil loosening and plant residue management have recently undergone significant changes due to development and expansion of new machinery. Both conventional (disking, tillage) and minimum tillage practices are used in cereal growing. Expected benefits of minimum practices is the increase in economic effectiveness of growing and under certain conditions also maintaining and enhancing soil fertility and soil erosion protection. Minimum tillage practices may involve differently relevant risks depending on growing conditions (Dill-Macky and Jones, 2000). In cereals it is especially the occurrence of diseases. It is desirable to choose among varieties those possessing a certain level of the resistance to diseases and being recommended for individual growing regions. Wheat resistance to FHB is of a polygenic character and has various components. It can be the resistance to pathogen invasion (referred to as resistance type I), resistance to spreading the fungus in ear (type II) and resistance to mycotoxin accumulation in grain (type III). Though there are differences in FHB infection among varieties, none with satisfactory resistance are available so far (Mesterházy et al., 2005).

A significant factor in FHB infection is preceding crop (Edwards, 2004). Cereals are not considered good preceding crops because they aggravate soil properties and increase a risk of weed infestation and incidence of fungal diseases and pests for which postharvest residues provide a good substrate. The inappropriate preceding crop for both wheat and barley is maize that increases a risk of FHB infection, which was also confirmed in our experiments. One of main sources of inoculum for fungi of the genus *Fusarium*, causing FHB, are postharvest residues of host plants (Vogelgsang et al., 2011). An important role in ear infection is played by both asexually formed macroconidia and ascospores released from perithecia. Inoculum production is highly dependent on climatic factors, especially on rainfall frequency and temperature. There are two significant periods that are crucial for the development of FHB. The first period from early spring until just before anthesis of cereals is important for the production and expansion of asexual macroconidia. The second, much shorter period is during plant anthesis. This period is important for ear infection by ascospores released from perithecia. Sufficient humidity and higher temperatures are significant favouring factors in the two mentioned periods.

The time necessary for the development and maturation of perithecia depends on weather conditions. Mature ascospores release mostly after rain. Part of integrated protection should be also monitoring the occurrence of diseases and pests, and in this case it is easy to observe the level of maturity of perithecia and ascospores on postharvest residues. Under our conditions, this monitoring begins usually in the second half of May. Perithecia visible to the naked eye are taken from postharvest residues, for instance, of maize. The perithecia are dark violet and look like black. These are then placed under a microscope and squashed with a cover slip. The mature ascospores release perithecia and can cause infection of the ears.

## Conclusions

In conclusion, our one-year experiments showed that the tested soil tillage practices were rather a complementary factor considering their impact on FHB incidence. A stronger effect was observed in the preceding crop when maize significantly increased DON content. As we know from long-term observations, the most important role in FHB infection is played by the year. Seasonal variability in FHB occurrence is determined mostly by the course of climatic factors, especially in the period of anthesis, but also during the formation of perithecia on postharvest residues. In each case, the intensity of FHB infection in cereals is a result of interplay of a series of factors. Though we are not able to influence some of them, there are preventive measures that can considerably reduce a risk of infection and contamination of harvested grain with mycotoxins. The principal measures, as described above, are a choice of variety, crop rotation and postharvest residue management.

## Acknowledgement

This work was supported by project MZe NAZV no. QJ1210008 and using the institutional support of long-term conceptual development of research organization, project no. RO0211.

## References

BAI, G.H., SHANER, G.E., 1994: Wheat scab: perspective and control. *Plant Disease*. 78 (8): 760-766.

DILL-MACKY, R., JONES, R.K., 2000: The effect of previous crop residues and tillage on Fusarium Head Blight of wheat. *Plant Disease*, 84 (1): 71–76.

EDWARDS, S.G., 2004: Influence of agricultural practices on *Fusarium* infection of cereals and subsequent contamination of grain by trichothecene mycotoxins. *Toxicology Letters*. 153 (1): 29–35.

CHAMPEIL, A., DORE, T., FOURBET, J.F., 2004: Fusarium head blight: epidemiological origin of the effects of cultural practices on head blight attack and the production of mycotoxins by *Fusarium* in wheat grains. *Plant Science*. 166 (6):1389-1415.

LANDSCHOOT, S., WAEGEMAN, W., AUDENAERT, K., VANDEPITTE, J., BAETENS, J., DE BAETS, B., HAESAERT, G., 2012: An empirical analysis of explanatory variables affecting Fusarium head blight infection and deoxynivalenol content in wheat. *Journal of Plant Pathology*. 94 (1): 135-147.

MATUŠINSKY, P., POLIŠENSKÁ, I., KADLÍKOVÁ, M., TVARŮŽEK, L., SPITZEROVÁ, D., SPITZER, T., 2013: Dynamics of T-2 toxin synthesis on barley ears. *Journal of Food, Agriculture & Environment*. 11 (3-4): 1114-1122.

MESTERHÁZY, Á., BARTÓK, T., KÁSZONYI, G., VARGA, M., TÓTH, B., VARGA, J., 2005: Common resistance to different *Fusarium* spp. causing Fusarium head blight in wheat. *European Journal of Plant Pathology*. 112 (3): 267–281.

VÁŇOVÁ, M., KLEM, K., MÍŠA, P., MATUŠINSKY, P., HAJŠLOVÁ, J., LANCOVÁ, K., 2008: The content of Fusarium mycotoxins, grain yield and quality of winter wheat cultivars under organic and conventional cropping systems. *Plant Soil Environment.* 54 (9): 395–402.

VOGELGSANG, S., HECKER, A., MUSA, T., DORN, B., FORRER, H.R., 2011: On-farm experiments over 5 years in a grain maize/winter wheat rotation: effect of maize residue reatments on *Fusarium graminearum* infection and deoxynivalenol contamination in wheat. *Mycotoxin Research*. 27 (2): 81-96.

**Contact address:**

Mgr. Pavel Matušinsky, Ph.D.
Agrotest fyto, ltd.
Havlickova 2787
767 01 Kromeriz
Czech Republic
e-mail: matusinsky@vukrom.cz
tel.: +420 573 317 113

Photo Matušinsky: Fusarium head blight on barley

Photo Matušinsky: Fusarium head blight on wheat

# THE EVALUATION OF SOIL COMPACTION PARAMETERS IN THE FIELD TRIAL WITH DIFFERENT SOIL TILLAGE

**L. Neudert, V. Smutný, V. Lukas**

Mendel University in Brno, Czech Republic

**Abstract**

Soil compaction is a serious cause of many sites of significant deterioration of the fertility and productive capacity of soils. The paper summarizes the results of measurement of resistance to penetration of the soil in the field trial AGRO 2 in Žabčice in the spring 2012. It was evaluated the course resistance to penetration in the soil profile. It was determined Cone index (CI). The graphical evaluation was determined 1PCI - (Peak Code Index)- the first maximum value resistance to penetration is higher than 2 MPa and 2PCI (second maximum value resistance to penetration is higher than 2 MPa). It was determined soil depth, in which penetrometer resistance for the first time exceeded 2 MPa. The first maximum value resistance to penetration of the soil (1PCI) can be considered an attribute of soil compaction. The technology of the soil tillage without ploughing showed worse characteristics of soil compaction.

**Keywords:** soil compaction, crop rotation, Cone index

## Introduction

Soil compaction is a process that occurs during intensive farming. In many places, the compaction of soils serious cause significant deterioration of soil fertility and soil production capabilities, limits the full genetic potential of varieties and reduce the effectiveness of inputs in the production process of crops. Penetrometer resistance indicates the degree of soil compaction. It is the soil resistance against the penetration of the cone penetrometer into the soil. High compaction adversely affects plant growth and is so a criterion when selecting the method of soil tillage.

## Material and methods

The evaluation of agro-technical measures on the soil compaction parameters was compared in the field trial AGRO 2 in the maize production region on the School Farm of Mendel University Brno (Žabčice). The experiment AGRO 2 is established since 2003. The experiment site was on gleyic fluvisol (FMG). In terms grain size composition of the soil is heavy to very heavy.

The study is focused on comparison of soil compaction parameters in the different soil tillage systems to different plant. The experiment AGRO 2 can be characterized as a crop rotation for the management system with animal husbandry (all straw is harvested, to silage maize and sugar beat is fertilized with manure) with the following variants:

- Soil tillage – I. Ploughing, II. Loosening; III. Direct sowing
- Crop rotation – 1. alfalfa 1$^{st}$ year, 2. alfalfa 2$^{nd}$ year, 3. winter wheat, 4. silage maize, 5. winter wheat, 6. sugar beet, 7. spring barley.

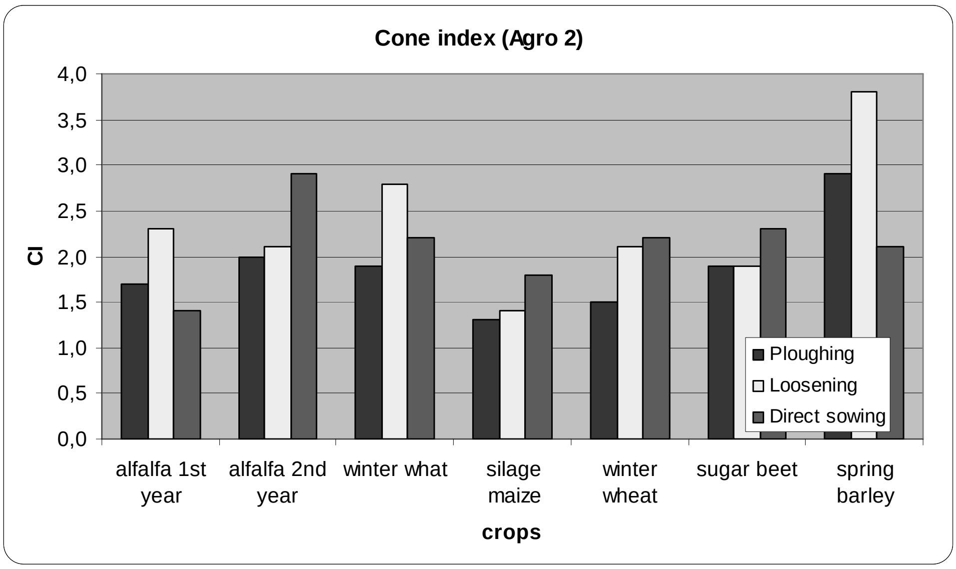
Measurements were made in spring 2012. It was used hand cone penetrometer with digital recorder Penetrologger from the firm Eijkelkamp. The equipment conforms to the ASAE (American Society of Agricultural Engineers) S313.3 (1999a). For the actual measurement was chosen diameter of 1 $cm^2$, 60 °. Speed of penetration into the soil was set to 3 $cm.s^{-1}$. In

each variant the field experiment was performed 5 measurements of penetration. During the measurements were recorded using a soil moisture probe, which is a part of Penetrologger.
The evaluation of the measured data corresponds to the standard ASAE EP 542 (1999b). For evaluation software was used PenetroViewer ver. 8.5. It was evaluated the course resistance to penetration in the soil profile. Was determined Cone Index (CI). This is the average value of the measured data with a depth of 0.01 m, 0.15 m, 0.45 m, 0.30 m. The graphical evaluation was determined 1PCI - (Peak Code Index)- is the first maximum value resistance to penetration is higher than 2 MPa and 2PCI second maximum value resistance to penetration is higher than 2 MPa. It was determined soil depth, in which penetrometer resistance for the first time exceeded 2 MPa.

**Results and discussions**

Measurements of penetrometer resistance recorded by hand penetrometer for each variant showed a different course of soil penetrometer resistance in different methods of stand establishment of individual crops in the crop rotation in experiment AGRO2. Penetrometer resistance increases with increasing depth. The value of soil penetrometer resistance that restricts root growth, according to ASAE EP542 (1999b) determined the level of 2 MPa. Lhotsky (2000) determined a limit value for heavy soil compaction in the interval from 3.3 to 3.7 MPa. For compacted layer of soil is usually considered when the value of penetrometer resistance rises sharply and then falls again. The first maximum value penetrometer soil resistivity (1PCI) can be considered as an attribute of soil compaction. The second maximum compaction (2PCI) usually arises in a natural way the pressure of the overlying soil layers or technology as a remnant of deeper soil tillage. From the measured values is not clearly seen that for some crops occurred above described effect rises sharp and falls penetrometer resistance of soil. The course penetrometer resistance exhibits a rather slow increase with depth, however, the differences between the variants soil tillage. For most crops, it is seen that the minimum soil tillage technology and technology without tillage showed higher soil penetrometer resistance against variants with ploughing, this conclusion is confirmed by the values Cone index (CI) shown in Table 1 and Graph 1.

**Graph 1 Cone index in field experiment AGRO 2**



**Tab. 1 Characteristics of soil penetration resistance in field experiment AGRO 2**

| crop | alfalfa 1st year | | | alfalfa 2nd year | | | winter wheat | | | silage maize | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| preceding crop | spring barley | | | alfalfa 1st year | | | alfalfa 2nd year | | | winter wheat | | |
| soil tillage | Ploughing | Loosening | Direct sowing | Ploughing | Loosening | Direct sowing | Ploughing | Loosening | Direct sowing | Ploughing | Loosening | Direct sowing |
| soil moisture (%) | 17,40 | 19,00 | 27,80 | 24,50 | 24,60 | 23,80 | 20,20 | 18,00 | 20,00 | 18,30 | 19,40 | 20,10 |
| Cone index (CI) | 1,7 | 2,3 | 1,4 | 2,0 | 2,1 | 2,9 | 1,9 | 2,8 | 2,2 | 1,3 | 1,4 | 1,8 |
| 1 PCI (m) | 0,24 | 0,25 | 0,11 | 0,07 | 0,05 | 0,03 | 0,13 | 0,24 | 0,10 | 0,05 | 0,11 | 0,06 |
| 2 PCI (m) | 0,29 | 0,42 | 0,22 | 0,16 | 0,14 | 0,31 | 0,34 | 0,49 | 0,18 | 0,29 | 0,25 | 0,10 |
| soil depth over 2 MPa (m) | 0,28 | 0,19 | - | 0,04 | 0,04 | 0,01 | 0,28 | 0,14 | 0,08 | 0,28 | 0,68 | 0,28 |

| crop | winter wheat | | | sugar beet | | | spring barley | | |
|---|---|---|---|---|---|---|---|---|---|
| preceding crop | silage maize | | | pšenice ozimá | | | sugar beet | | |
| soil tillage | Ploughing | Loosening | Direct sowing | Ploughing | Loosening | Direct sowing | Ploughing | Loosening | Direct sowing |
| soil moisture (%) | 17,00 | 20,20 | 22,00 | 17,70 | 23,00 | 20,20 | 23,00 | 22,00 | 27,00 |
| Cone index (CI) | 1,5 | 2,1 | 2,2 | 1,9 | 1,9 | 2,3 | 2,9 | 3,8 | 2,1 |
| 1 PCI (m) | 0,22 | 0,20 | 0,09 | 0,12 | 0,19 | 0,15 | 0,12 | 0,24 | 0,11 |
| 2 PCI (m) | 0,30 | 0,33 | 0,28 | 0,33 | 0,34 | 0,27 | 0,40 | 0,30 | 0,19 |
| soil depth over 2 MPa (m) | 0,34 | 0,27 | 0,18 | 0,26 | 0,22 | 0,15 | 0,06 | 0,03 | 0,05 |

The measurement of penetrometer resistance of the variant tillage in spring barley after sugar beet has the characteristics of compacted soil. The negative effects of this bad state were exacerbated by adverse weather in 2012. The cause of this unfavourable situation can be seen in the negative impacts use of improper harvesting machines (1 row harvester), when the soil is more burdened crossings relatively heavy machinery and date of entry harvesting machines for harvesting sugar beets to the field.
Comparison of different attributes of soil compaction at different tillage for each crop of crop rotation AGRO 2 shows in Table 1. The data in the table shows that the minimum soil tillage without ploughing had lower soil compaction characteristics (see Table 1) evaluated by using the CI. The table also shows that minimum soil tillage technology showed higher values of moisture of the soil. This confirms the advantage of minimum soil tillage technology in the form of better water management.

**Conclusions**

Presented results showed differences among particular variants of soil tillage systems and among crops, as well. Soil compaction is the result of unsuitable soil tillage and usage of inappropriate machines and tools. Improper choice of fore-crop harvest (especially when soil is wet) plays also important role in this relation. Nowadays, there are efficient possibilities how to eliminate soil compaction. Deeper loosening without soil inverting could be a solution for it.

**Acknowledgements**

The study was supported by Research project No. QJ1210008, financed by the Ministry of Agriculture of the Czech Republic and Research project No. TA02010669, financed by the Technology Agency of the Czech Republic. The participation in international conference was supported by project No. CZ.1.07/2.2.00/28.0302.

**References**

ASAE Standards. ASAE Standard S313.3, Soil cone penetrometer, ASAE, 1999a.

ASAE Standards. ASAE Engineering Practice EP542, Procedures for using and reporting data obtained with the soil cone penetrometer, ASAE, 1999b.

NĚMEČEK et al. Taxonomický klasifikační systém půd České republiky. Vyd. 1. Praha: Česká zemědělská univerzita, 2001, 79 s. ISBN 80-238-8061-6.

LHOTSKÝ, J. Zhutňování půd a opatření proti němu: (studijní zpráva). Praha: Ústav zemědělských a potravinářských informací, 2000, 61 s. ISBN 80-7271-067-2.

**Contact address:**

Ing. Lubomír Neudert, Ph.D.
Mendel University in Brno
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: neudert@mendelu.cz
tel.: +420 545133109

# ASSESSMENT OF SOIL VARIABILITY BASED ON THE SATELLITE IMAGERY

**J. Novák, V. Lukas, J. Křen**

Mendel University in Brno, Czech Republic

---

**Abstract**

The aim of this paper is to compare two sets of remote sensing data, acquired between 2012 and 2013, for assessing the variability of arable land. Data are capturing the South Moravien Region with a total area of 1100 km$^2$ by RapidEye (2012) and Landsat 8 (2013) satellites. As the other input data, field boundaries from government database iLPIS were used to identify the blocks of arable land. The first step was a selection of arable land through polygons from the iLPIS and identification of bare soil by calculation of normalized differential vegetation index (NDVI) from spectral data. An image classification was performed on these grounds in order to create class of information describing the spectrum of surfaces forming the bare soils. Comparison of both satellite datasets proved difference between the images. Landsat 8 data showed higher error, probably due to the lower spatial resolution of data (30 m per pixel). In this case Rapid Eye imagery offers higher spatial resolution (5 m per pixel), which seems to be more suitable for identification of soil heterogeneity, especially in smaller fields.

**Keywords:** remote sensing, RapidEye, Landsat 8, NDVI, soil heterogeneity, coefficient of variation

## Introduction

The level of heterogenity of site conditions determined by direct or indirect methods of mapping is crucial information for implementation of precision farming technologies into the farm enterprise. Methods of indirect mapping can ,presented in this case by remote sensing (RS), be subject to the appropriate data basic and cheaper indicator of this variability.

In the field of precision agriculture, remote sensing (RS) is special, very powerful way to mapping soil variability performed by air or Satellite carriers of sensors. The spectral behavior of soil is described by Lillesand et al. (2008). They indicates the soil properties that affect reflectivity, such as organic matter content, soil moisture , grit and soil structure or presence of iron oxides.

According to Ben- Dor et al. (2009), a remote sensing is an important part of soil survey and aerial photography is one of the basic tools that are used in soil mapping. Brooke et al. (2010) concluded that satellite images, in this case RapidEye imagery, can be a good data for estimation of soil heterogeneity. Assessment of variability can be performed by the statistical measure of variability. These include variance, variation range, standard deviation and coefficient of variation. The rate of soil variability is expressed in this paper by the coefficient of variation ($C_v$). It is mentioned by Borůvka (2001), who discloses the use of $C_v$ in the study of hydraulic conductivity, porosity and pH. Another example can be found in paper by Wollenhaupt et al. (1997), which shows $C_v$ for available P, available K, organic matter and other factors ensuring higher yield.

The aim of this paper is to compare two sets of remote sensing data, acquired between 2012 and 2013, for assessing the variability of bare arable land.

**Material and methods**

The first entry were 4 frames from March, April and September 2012 acquired by RapidEye Satellite. Second part of imagery was completed by Landsat 8 images immediately after Landsat mission launching in April and September 2013. Both sets of data captured approximately the same area (1100 km2) of the South Moravian region (Czech Republic). More than 90% of agricultural land in the region, where agricultural subsidies are provided an arable land, is not in time of the above mentioned periods covered by vegetation. At this time there was an assumption of the largest area of bare soil before the start of the growing season (March and April) and after harvest (September).Rapid Eye images have a spatial resolution of 6.5 m radiometric and geometric corrections to the fundamental bands of the VIS, NIR and Red Edge. Data were purchased as the Level 1B product, which needs to be geometrically processed. The orthorectification was processed by digital elevation model from ASTER satellite and subsequently new bitmap mosaics were created in the Arc GIS 10.1.Landsat 8 data were downloaded from the U.S. Geological Survey website as the free product geometric and radiometric corrected. It consists of eleven bands with a resolution of 15-100 m / pixel. For each dataset the normalized difference vegetation index (NDVI) index (Rouse et al., 1974) was calculated using a Raster calculator and set a limit for arable land based on the grand observation in combination with polygon layer from iLPIS it allowed to identify fields with arable land and bare soil at the same time. The LPIS is a geographic information system for the registration of usage of agricultural land in the Czech Republic, for which are given European and national subsidies to farmers. It does not, therefore, include all arable land area. This approach of data selection (combination of intervals of arable land and polygons with arable land) considerably reduced the area which truly represents the arable land. Therefore, the blocks of bare arable land with the number of pixels greater than or equal to 50 % of the original number of bare soil´ pixels selected by data from the system iLPIS were added to classification. Areas of pixels that met the specified conditions, were subsequently converted into polygons and if their area was greater than 300 $m^2$, they entered as a training area into the process of supervised classification of all the scenes in ERDAS IMAGINE 2013.To determine the coefficient of variation and descriptive statistics a tool called Zonal statistic was used. Areas of bare soil were divided into three groups according to the variation coefficient (se Tab. 1).

**Tab 1:The clue for the classification of land according to the coefficient of variation**

| **The value of** Cv | **Soil variability** | **Variability in Statistic** |
|---|---|---|
| 0 - 49 % | slightly variable soil | Slightly sparse data set |
| 50 - 100 % | variable soil | Strongly scattered data set |
| More then 100% | highly variable soil | extremely sparse data set |

**Results and discussions**

The coefficient of variation obtained from Landsat data has left positively skewed distribution with an excess of small values (Fig. 1). This is confirmed by a higher average than the median and is also positively skewed. Higher value of maximum is probably the result of errors and hangs lower resolution data. Also, a higher standard deviation indicates higher variability data from LANDSAT 8 exact opposite is then the RapidEye data. Here is the skewness negative and the median value is higher than average. This data set is therefore right hand negatively skewed and distributed with excess higher values. Dispersion of the data is lower than the data Landsat 8. Negative kurtosis values and histogram captured in the picture also show a

CONTENT

flatter distribution of data. From the perspective of the proposed classification seems to more variable soil sensed by satellite RapidEye and it happens probably because of the higher resolution that better captures changes in the monitored block.

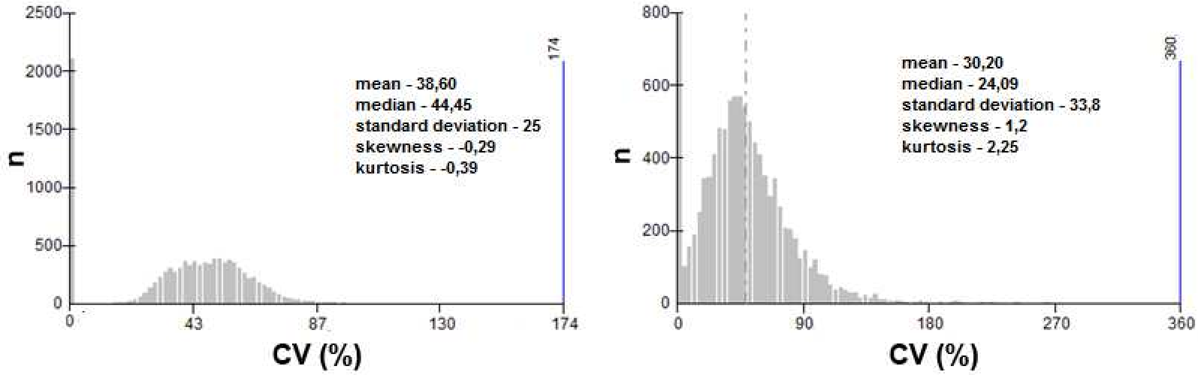



**Fig. 1: Histograms of $C_v$ created from data-driven classification of RapidEye (left) and Landsat 8 (right)**

Fig. 2 shows a map with the resulting output variability derived from Rapid Eye data. Most of notably, it seems at first glance the western side of the region overlapping the Highlands, in which is concentrated the largest percentage of variable soil. Rather then, it is a land with a smaller than average specific occupation of the area. Similar interpretation is valid for eastern part of the country and in adjacent areas of the Zlín region too. The central part of the region is an area of slightly variable soil with occasional occurrence of variable land. The occurrence of variable soil is lower than in the western part.

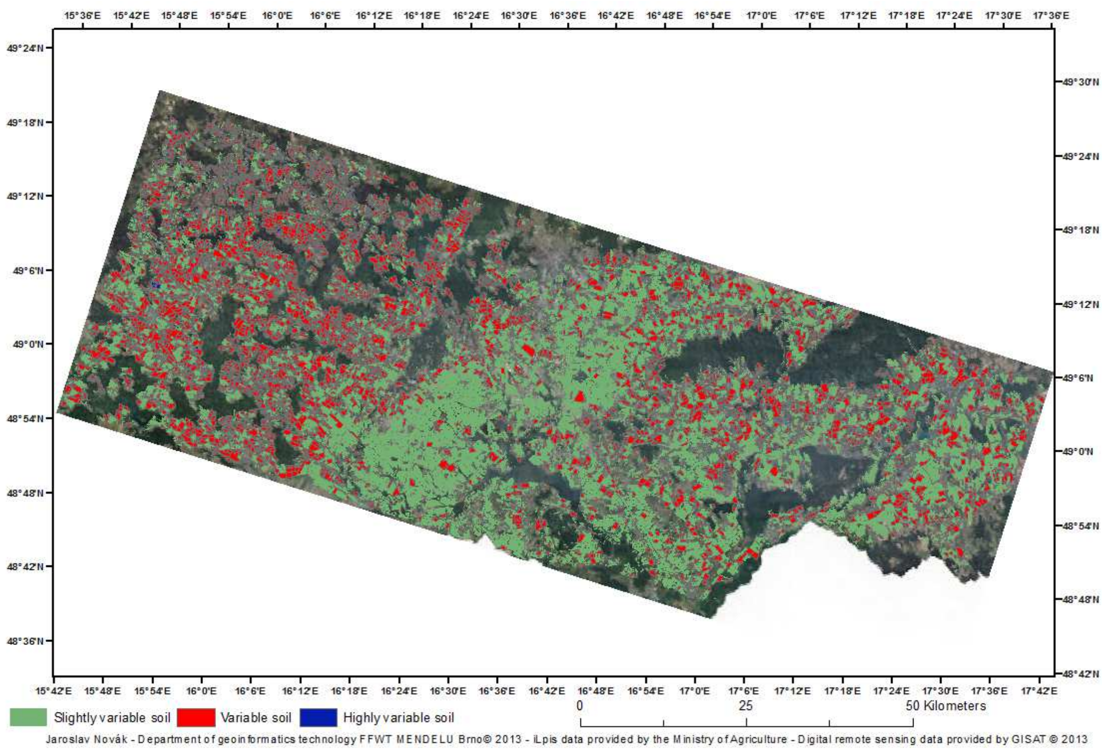



**Fig. 1 - Levels of variability for south moravien region in 2012**

**Conclusions**

Both data sets can certainly be used as a preview to the variability of soil; however, data Rapid eye seem to be more suitable due to their higher spatial resolution. Their main disadvantage is the cost and the necessity to pre-processing of data sets at this level of quality. Data of Landsat 8 data are free available, but their low resolution can distort the possible variability, especially on land with an area less than 10 ha. Selected process of variability evaluation and classification into three grades are only the first steps in creating of a relevant information source. For more detailed description of spatial variability of soil parameters and their effects on the crop management, more specific soil survey is needed.

**Acknowledgements**

This paper was supported by the project IGA FFWT MENDELU No. 59/2013, entitled "Evaluation of soil variability of the selected area with remote sensing data " and by research project of National Agency of Agricultural Research No. QI111A133 “Improvement of cereal variety potential realization using temporal and spatial analysis of stand spectral characteristic”. Data from the system iLPIS, in the form of spatial and descriptive representation of blocks of arable land as SHP format, was provided by the Ministry of Agriculture.

**References**

BEN-DOR, E., CHABRILLANT, S., DELMATT, J. A.M., TAYLOR, G.R., HILL, J., WHITING, M. L., SOMMER, S.. 2009: Using Imaging Spectroscopy to study soil properties.In: *Remote Sensing of Environment*. vol. 113.

BORŮVKA, L. *Variabilita půdních vlastností a jejich hodnocení*. Habilitační práce, Katedra pedologie a geologie, Česká zemědělská univerzita v Praze, Praha, 2001.

BROOKE , T., MILENOV, P., TASDEMIR, K., 2010: Analysis of RapidEye imagery for annual landcover mapping as an aid to European union comon agricultural polic. In: Wagner W., Székely, B. (eds.): *ISPRS TC VII Symposium – 100 Years ISPRS.* Vienna, Austria, July 5–7, 2010, IAPRS, Vol. XXXVIII, Part 7B. ISSN 1682-1777.

ROUSE, J.W., H., HAAS R., A., SCHELL J. 1974. Monitoring the vernal advancement and retrogradation (greenwave effect) of natural vegetation. Texas A and M University, College Station.

LILLESAND, T. M., KIEFER, R. W., CHIPMAN, J. W., 2008: *Remote sensing and image interpretation*. Hoboken, NJ: John Wiley & Sons, ISBN 9780470052457.

WOLLENHAUPT, N. C., MULLA, D. J., GOTWAY CRAWFORD, C. A., 1997: Soil sampling and interpolation techniques for mapping spatial variability of soil properties, pp. 19-53. In: *The State of Site Specific Management for Agriculture*.

**Contact address:**

Ing. Jaroslav Novák
Mendel University in Brno
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: jaroslavxnovak@gmail.cz
tel.: +420 545133119

# ELEMENTS CONTENT AND ITS RELATIONSHIP TO DIFFERENT CARBON FORMS IN SOIL

**Pospíšilová, L.[1], Hábová, M.[1], Drápelová, I.[2], Formánek, P.[2]**

[1]Mendel University in Brno, Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition, Zemědělská 1, Brno, Czech Republic

[2] Mendel University in Brno, Faculty of Forestry and Wood Technology, Department of Geology and Pedology, Zemědělská 3, Brno, Czech Republic

---

**Abstract**

Elements content in relationship to labile and stable carbon forms was studied during the period 2008 – 2012. Object of our study was *Haplic Chernozem* and *Haplic Cambisol*. Humic and fulvic acids were considered to be stable (=recalcitrant) forms of soil carbon. Labile carbon forms were represented by water extractable carbon and microbial carbon. Basic soil properties and humic acids isolation were determined using standard methods. Macro elements bound to humic acids were determined using energy-dispersive X-ray spectroscopy. Water extractable carbon was determined by analyser Shimadzu TOC-VCSH with $CO_2$ detection in infrared spectral region. Microbial carbon was measured using fumigation-extraction method. Results showed that humic acids are able to bind various elements depending on their speciation and concentration in soil.

**Key words**: *macro elements, stable (recalcitrant) and labile carbon forms*

## Introduction

Soil organic carbon may occur in soluble form (fast cycling carbon pool) and insoluble form (slow cycling carbon pool). The identification and characterization of both of them is largely based on stability of carbon pools in the environment. However, it is not well understood yet to which extend the biodegradability effects the stability of ecosystems. Labile carbon forms are represented by water extractable carbon and microbial carbon. Stable carbon form are mainly humic substances (humic acids, fulvic acids and humins). Humic acids, an important component of humic substances, possess a highly complex and refractory character. They have capacity for diverse chemical and physical interactions in the environment and directly influence transport of pollutants and nutrient bioavailability (Hayes & Malcolm, 2002, Madronová et. al., 2011). Humic acids mainly consist of hydroxyphenols, hydroxybenzoic acids, and others aromatic structures with linked peptides, amino compounds, and fatty acids (Grandy & Neff, 2008). Association among dissolved humic acids, heavy metals and hydrophobic organic compounds is studied by means of new approaches such as infrared spectroscopy and X-ray spectroscopy. Energy dispersive X–ray spectroscopy (EDXS) is capable to identify elements *in situ* that are actually present under electron probe (Milori et al., 2002).

The aim of our work was to determine nutrient content, total carbon content, water extractable carbon and microbial carbon, humic substances carbon content. Non-destructive energy-dispersive X–ray spectroscopy was used for humic acid samples determination.

## Material and methods

Nutrient content in mineral soil samples was determined using Mehlich III. Energy-dispersive X-ray spectroscopy was used to determine elements content in isolated humic acids samples. Energy-dispersive X-ray spectrofluorimeter XEPOS was used. Humic acids were isolated from *Haplic Chernozem* (locality Hrušovany nad Jevišovkou) and *Haplic Cambisol* (locality

Vatín). Standard IHSS extraction method was applied (Pospíšilová et al. 2008; Pospíšilová and Tesařová, 2009). Humic acids samples were purified, dialysed and lyophilised at -50°C. Elemental analysis of HA was performed with PE2400 CHNS/O. Total carbon and nitrogen content in soil samples was determined using LECO Truspec. Water extractable carbon content was determined by analyser Shimadzu TOC-VCSH with $CO_2$ detection in infrared spectral region. Carbon of soil microbial biomass was determined by fumigation-extraction method according to Vance et al. (1987).

**Results and discussion**

Studied soils varied widely in pH, CEC (cation exchange capacity), nutrient content, total organic carbon and nitrogen content, HS content, water extractable content and microbial carbon content. Correlation between carbon forms, macro elements content, and CEC was studied. Obtained results showed that with increasing total organic carbon content the content all carbon forms in soils increased – see Tab. 1. Concentration of basic macro element correlated with total organic carbon content and with cation exchange capacity. Humic acids isolated from studied soils varied in elemental composition. Humic acids isolated from *Haplic Chernozem* contained more carbon (38.6 %) and nitrogen (3.5 %) and less hydrogen (37.9 %). HA isolated from *Haplic Cambisol* contained less carbon (36 %) and nitrogen (2.4 %) and more hydrogen (41.7 %) in their molecule. Similar results for carbon, nitrogen, hydrogen, and oxygen content in HA isolated from *Cambisols* and HA isolated from *Chernozems* were published by Fujitake et al. (1999) and Barančíková et al. (2002). EDX-ray spectroscopy of HA samples indicated the presence of *Fe, Cu, Zn, Ti, Ca, K, S, P, Si, Cl and Br* in HA molecule – see Fig. 1 and 2. Energy-dispersive X-ray spectra had similar character and elements content in HA molecule was comparable in both studied humic acids samples.

**Conclusion**

Humic acids elemental composition showed wide variety of elements occurred in HA molecule. We would like to give the evidence that humic acids play an important role not only in soil fertility but they also affect agricultural ecosystems. Binding of trace elements is important for plants and microorganisms and documents the diverse chemical interaction between HA and mineral soil components.

**Acknowledgement**

This work was supported by NAZV projects No: QJ1210263.

**Reference**

1. Barančíková, G., 2002: Changes of humic acids structure on selected key monitoring localities of arable soils. *Soil, Plant and Environ*. 48, 40-42.
2. Fujitake, N., Kawahogashi, M., 1999: $^{13}$C NMR spectra and elemental composition of fractions with different particle sizes from Andosol Acids. *Soil Sci Plant Nutr*. Vol. 45, No 2, 359-366.
3. Grandy, A. S., Neff, J. C. 2008: Molecular c dynamic downstream: the biochemical decomposition sequence and its impact on soil organic matter structure and function. *Science of the Total Environment* 406, 297-307.
4. Hayes, M. H. B., Malcolm, R. M., 2001: Consideration of composition and aspects of structures of humic substances. In: Clapp C. E. (Eds.), Humic substances and chemical contaminants. *Soil Sci. of America*, Madison, WI, 3-39.

CONTENT


5. Madronova, L., et al. 2011: Humic acids from raw materials of the Czech Republic. Nova Science Publishers, Inc. N. Y. 133p.
6. Milori, D. M . B. P., Martin-Neto, L., Bayer, C., Mielniczuk, J., Bagnato, V. S. , 2002: Humification degree of soil humic acid determined by fluorescence spectroscopy. *Soil Sci.* 167, 11: 739-749.
7. Pospíšilová, L., Fasurová, N., Barančíková, G., Liptaj, T., 2008: Spectral characteristics of humic acids isolated from south Moravian lignite and soils. Petroleum & Coal 50, 2: 30-36.
8. Pospíšilová, L., Tesařová, M., 2009: Organický uhlík obhospodařovaných půd. In: Folia II, Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, Brno: 4-41.
9. Vance, E. D., Brookes, P. C., Jenkinson, D. S. 1987: An extraction method for measuring soil microbial biomass C. Soil Biology and Biochemistry. 19: 703–707.


**Tab. 1. Correlation between carbon forms, cation exchange capacity and nutrient content**

| | *Corg (%)* | *CHS (%)* | *Cwe (%)* | *Cmic mg/g* | *K (mg/kg)* | *Mg (mg/kg)* | *P (mg/kg)* | *Ca (mg/kg)* | *CEC cmol/kg* |
|---|---|---|---|---|---|---|---|---|---|
| Corg (%) | 1 | | | | | | | | |
| CHS (%) | ***0,46908*** | 1 | | | | | | | |
| Cwe (%) | ***0,70097*** | -0,0191 | 1 | | | | | | |
| Cmic mg/g | ***0,2992*** | ***0,34638*** | ***0,23736*** | 1 | | | | | |
| K (mg/kg) | ***0,2638*** | -0,0707 | ***-0,2289*** | -0,1677 | 1 | | | | |
| Mg (mg/kg) | ***0,2448*** | -0,0897 | -0,0915 | ***-0,2772*** | ***0,2877*** | 1 | | | |
| P (mg/kg) | ***0,1997*** | -0,0417 | -0,0179 | ***-0,1986*** | ***0,3452*** | ***0,98517*** | 1 | | |
| Ca (mg/kg) | ***0,2161*** | -0,047 | -0,1862 | -0,1123 | ***0,3862*** | ***0,86173*** | ***0,80608*** | 1 | |
| CEC cmol/kg | ***0,23169*** | ***0,54966*** | 0,00532 | ***0,32726*** | ***0,2380*** | ***0,3033*** | ***0,2441*** | ***0,303*** | 1 |

(n = 112, α = 0.05, $r_{krit}$ = 0.195, Corg = Organic carbon, CHL = Carbon of humic substances, Cwe = Water extractable carbon, Cmic = Microbial carbon, CEC = Cation Exchange Capacity)

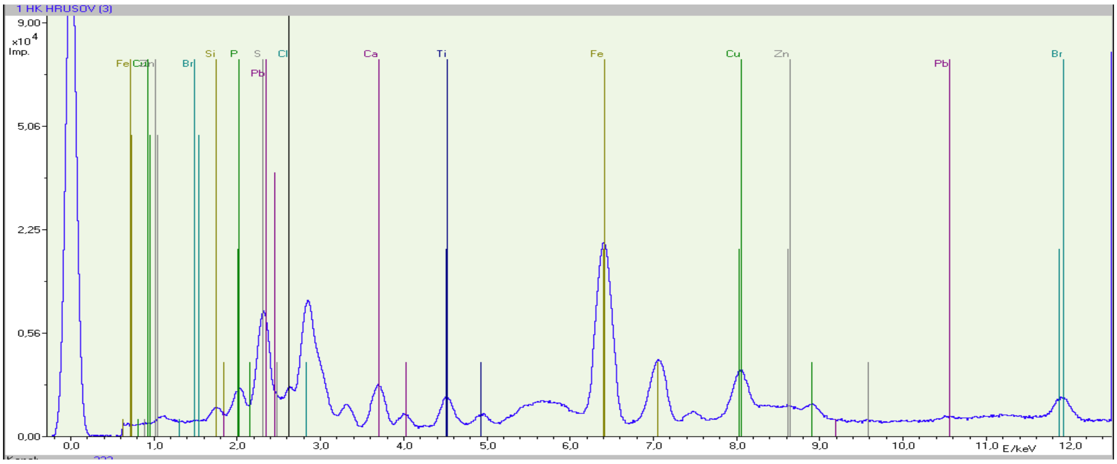



**Fig. 1. EDXS spectra of humic acids isolated from Haplic Chernozem**

CONTENT

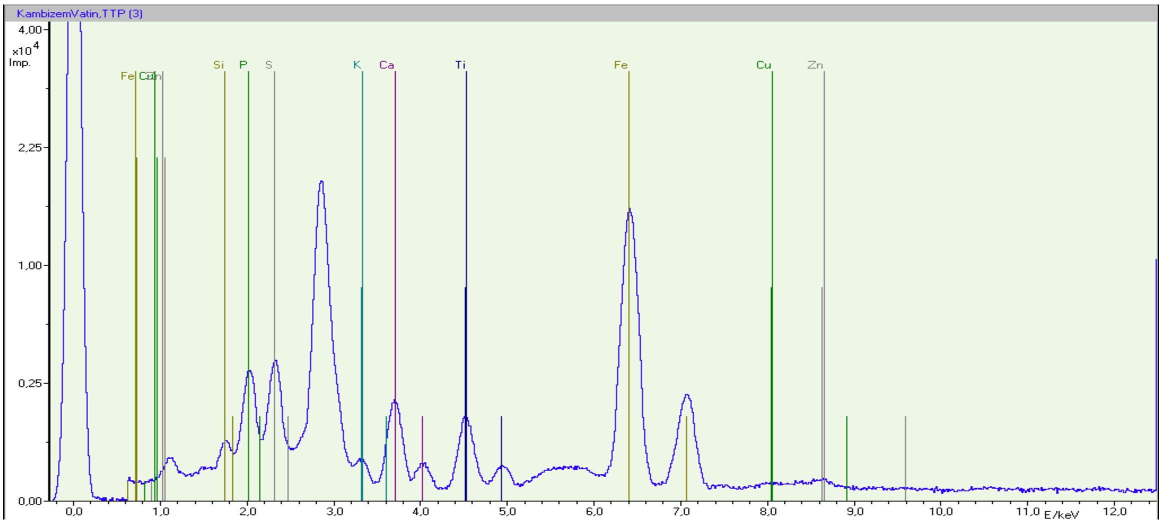



**Fig. 2. EDXS spectra of humic acids isolated from Haplic Cambisol**

## Contact address:

Doc. RNDr. Ľubica Pospíšilová, CSc.,
Ústav agrochemie, půdoznalství, mikrobiologie a výživy rostlin,
Mendelova univerzita v Brně,
Zemědělská 1, 613 00 Brno,
Czech Republic
e-mail: lposp@mendelu.cz

# DISTRIBUTION OF VERTICAL STRESS AT THE SOIL-TYRE INTERFACE

**R. Pražan[1], K. Kubín[1], I. Gerndtová[1], O. Syrový[1], V. Podpěra[2]**

[1]Research Institute of Agricultural Engineering, p. r. i., Czech Republic
[2]Czech University of Life Sciences Prague, Czech Republic

**Abstract**
The stress at the tyre-soil interface is the upper boundary condition in soil stress prediction models. Hence, there is a need to find relationships between vehicle parameters and contact stress and to study the effect of contact stress distribution on stress propagation. The aim of the measurements was to determine the effect of size of the tyre contact area and the effect of the number of passes on soil compaction during grain harvest and transport. The effect of the use of road and flotation tyres was evaluated based on the measured parameters, which were penetration, resistance, porosity and measurement of soil compaction of the upper layer profile under specific soil conditions. The same track was crossed repeatedly to determine the effect of multiple passes on soil compaction.

**Keywords:** inflation pressure, soil-tyre interface, tyre, soil compaction,

## Introduction

During recent decades, tyres used in agriculture have continuously increased in size. There is a general expectation that tyres with larger contact patches will reduce the stress applied to soil compared to smaller tyres. However, it is striking that quantitative data is very scarce. We know that the distribution of vertical stresses at the soil–tyre interface may be highly non-uniform [1]. It is also well documented that stresses in the tyre-soil contact area generally increase with inflation pressure [2]. However, to our knowledge no systematic comparisons between tyres of different type, diameter and width have been performed with respect to stresses at the soil–tyre interface. Furthermore, the few studies on stress distribution in the contact area have reported their results in a very empirical way, which makes it difficult to draw general conclusions on the effects of wheel load, inflation pressure, tyre characteristics and soil conditions. Grečenko and Prikner carried out tests using several tyres to see how the size of the contact area related to compaction and determined the "CC factor", or compaction capacity, representing the amount of soil compaction caused by the tyre. An important aspect of the CC factor is that it is a precise laboratory non-contact measurement of pressure in the soil under the tyre [3]. The goal of their research was to establish a relationship between soil compaction created by a laboratory pressure plate and by a real wheel. The CC factor was thus developed to quantify the risks associated with soil compaction, which is useful when making decisions about the maximum tyre dimensions for off-road vehicles. CC is based on the relationship between the efficiency of soil compaction by a tyre and by a pressure plate. Keller [4] suggested mathematical equations that could describe the stress distribution across the contact area. In a previous study, we modified and combined these expressions to obtain a mathematical model (named FRIDA). The model fitted well to measured data for the soil–tyre contact area as well as for the measured stress distribution for two tyres tested at different inflation pressures [5]. The model yields quantitative information on the stress distribution in the driving direction as well as in the direction perpendicular to the driving direction (across the wheel). In this study, we measured stresses near the soil–tyre interface for five different tyres typically used on towed agricultural trailers. We performed the tests at two wheel loads and used the rated inflation pressures.

**Material and methods**

For measurement we chose a tractor with trailer, specifically a John Deere 7720 tractor with a Mega 20 trailer (made by ZDT Nové Veselí). The trailer had tandem axles and was filled with rapeseed for the entire duration of the measurement. Before the actual measurements, the tractor trailer set (John Deere 7720 with Mega 20 trailer) was weighed on a HAENNI wheel load scale. The total weight of the tractor and trailer was 32.6 tons (weight of the load was 15.6 tons). The tractor had the same tyres for the entire duration of the measurement (on the front axle - MITAS RD-02 Radial Drive, 480/70 R 30, with an inflation pressure of 190 kPa, on the back axle FIRESTONE MAXI TRACTION 620/70 R42 with an inflation pressure of 150 kPa). Then, the footprints of both tyres were taken (Fig. 1). From the measured weight per wheel and the tyre tread print, the average static surface pressure on a soft surface was calculated according to ČSN 30 0523.

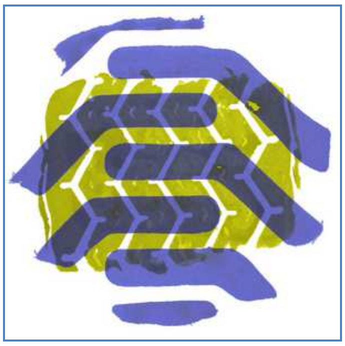


**Fig. 1 Comparison of the tread print of MITAS TRACTION TR-08, 550/60 – 22.5 flotation tyres (blue colour) and BARUM BT 41 ROAD TRAILER, 445/65 R 22-5 road tyres (yellow colour) under the same load on a hard surface at an inflation pressure of 120 kPa for the tractor trailer set (John Deere 7720 tractor with Mega 20 trailer)**

The actual measurement of soil compaction took place on a stubble field following the harvest of winter rapeseed and for the duration of the measurements the trailer was filled with rapeseed. The MEGA 20 trailer was fitted with flotation tyres (MITAS TRACTION TR-08, 550/60 – 22.5) at the manufacturer recommended inflation pressure for the given load (350 kPa). Before the actual measurement, soil samples were collected to determine porosity of the designated parcel (3 samples at three depths for each measurement variant), as well as soil samples to determine soil moisture. Penetration resistance was measured and a wire profiler was used to determine the transverse profile of soil at three places before the pass. The tractor and trailer then passed over the measured section. At designated places, samples were once again collected, soil resistance measured by a penetrometer, and the soil profile measured after the first pass over the section. The tractor trailer set passed over the section a total of three times. After each pass, the aforementioned parameters were measured. Then the flotation tyres on the trailer were removed and replaced with road tyres (BARUM BT 41 ROAD TRAILER, 445/65 R 22-5, with an inflation pressure of 750 kPa). The measurements were carried out again on measurement section II in the same order as with the flotation tyres. For the entire duration of measurement, the tractor had the same tyres with the same inflation pressure. The road and flotation tyres on the trailer were inflated to the manufacturer recommended pressure for the given load.

**Results and discussions**

The mean static surface pressure of tyres on a soft surface was low for the tractor tyres and was 1.27 kg/cm$^2$ for the front wheels and 1.38 kg/cm$^2$ for the rear wheels. For the loaded MEGA 20 trailer fitted with road tyres, the average mean static surface pressure was 7.2 kg/cm$^2$. When flotation tyres were used, this pressure dropped on average by 41 %. This fact was confirmed by assessment of measured data, i.e. soil penetrometer resistance, soil samples to determine porosity collected at three depths, and changes in the profile of upper soil levels. The beneficial effect of flotation tyres was also seen during repeated passes, as evident in Fig. 2. The porosity of the soil before the first pass was similar in both variants and was 45 % at the first depth. The first pass of the tractor and trailer with flotation tyres reduced porosity to 43 %, after the second pass porosity dropped to 36 %, while after the next pass it dropped to 34 %. For the road tyre variant, the drop in porosity was already marked after the first pass, when it dropped to 33 %.

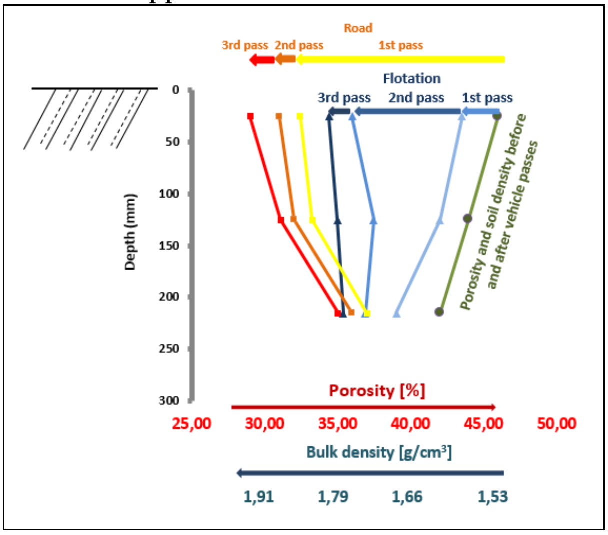



**Fig. 2 Effect of number of passes on change in porosity and density of soil at individual depths for a John Deere 7720 tractor and Mega 20 trailer using road and flotation tyres**

The advantageous effect of flotation tyres on compaction was also clear from the penetrometer resistance of the soil. The average penetrometer resistance of the soil was higher for road tyres than for flotation tyres. The soil resistance before any passes at a depth of 40 mm was 0.4 MPa, which increased after individual passes. For road tyres the soil resistance after three passes of the equipment increased to 2.4 MPa while for flotation tyres the value was roughly 25 % less.

Assessment of data from the wire profiler in Fig. 3 showed the greatest compaction of the topsoil after the first pass, both for flotation and road tyres. For road tyres this compaction was an average of 4.1 cm, during the second pass of the vehicles compaction increased to 5.2 cm, while after the last pass it increased to 5.9 cm. For flotation tyres the compaction was less severe compared to road tyres.

Additionally, the collected soil samples were used to analyze granularity according to ČSN 46 5302. This analysis showed the soil in question to be moderately heavy sandy loam soil. Soil moisture was also monitored during the measurement of individual sections. This is given by the momentary water content in the soil. The upper layer of soil at a depth of 0 - 50 mm was dry to moist with a water content ranging from 11.69 % to 18.22 % hm. At a depth of 100 - 150 mm the soil was dry with a water content of 11.62 % to 14.54 % hm., at a depth of 200 - 250 mm it was also dry with a water content of 10.98 to 12.93 % hm.

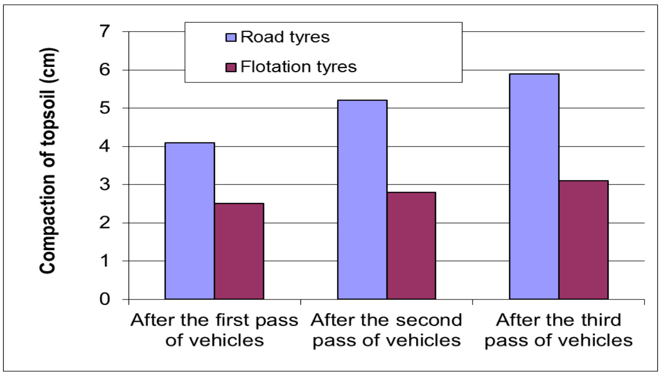



**Fig. 3 Influence of the number of passes of a John Deere 7720 tractor and Mega 20 trailer using road and flotation tyres on the average compaction of topsoil measured by a wire profiler**

## Conclusions

All three measured parameters demonstrated the more favourable effects of using flotation tyres instead of road tyres. In practice, it is quite common that flotation tyres are replaced with cheaper road tyres with a more durable construction. Measurement has shown the magnitude of the difference between the two when driving in the field. A wire profiler has verified that when flotation tyres are correctly inflated for the given load, stress distribution is constant across the contact area.

## Acknowledgements

The research has been supported by the grant project VG20102014020 - Stanovení minimální potřeby energie pro zajištění základních funkcí zemědělství v krizových situacích a analýza možností jejího zajištění z vlastních energetických zdrojů resortu.

## References

[1] SCHJØNNING P, LAMANDE´ M, TØGERSEN FA, ARVIDSSON J, KELLER T. Modelling effects of tyre inflation pressure on the stress distribution near the soil–tyre interface. Biosystems Eng. 2008;99:119–33.
[2] ARVIDSSON J, RISTIC S. Soil stress and compaction effects for four tractor tyres. J. Terramechan 1996;33:223–32.
[3] GREČENKO, A.; PRIKNER, P. Progress in tire rating based on soil compaction potential. Journal of Terramechanics [online]. 2009, 211-216.
[4] KELLER T. A model for the prediction of the contact area and the distribution of vertical stress below agricultural tyres from readily available tyre parameters. Biosystems Eng. 2005;92:85–96.
[5] RAPER RL, BAILEY AC, BURT EC, WAY TR, LIBERATI P. The effects of reduced inflation pressure on soil–tire interface stresses and soil strength. Journal of Terramechan 1995;32:43–51.

**Contact address:**

Ing. Radek Pražan, Ph.D.
Research Institute of Agricultural Engineering, p. r. i.
Drnovská 507
161 00 Praha
Czech Republic
e-mail: prazan@vuzt.cz,
tel.: +420 233 022 111

# STUBBLE CATCH CROPS IN STRUCTURE OF PLANT PRODUCTION

**B. Procházková[1], M. Handlířová[1], T. Filipský[1], J. Procházka[2]**

[1] Mendel University in Brno, Czech Republic
[2] Research Institute of fodder crops, Ltd., Czech Republic

## Abstract
Production capabilities of stubble catch crops and their effect on yields of subsequent spring barley were monitored. Field experiment was conducted on clay loamy flovisol in the years 2006 - 2013 in maize growing region. The experiment included 10 kinds of catch crops. The catch crops stands were established in two periods (immediately after harvest of winter wheat as forecrop and in mid-September). After catch crops spring barley was grown with fertilizer and without nitrogen fertilizers. The best production capabilities showed cruciferous species of catch crops and tancy phacelia. The early sowing plays an important role. The negative relationship was showed between the yield of catch crops and the yield of spring barley by missing nitrogen fertilizing. Negative effect of higher yield of catch crops biomass was eliminated by nitrogen fertilization.

**Keywords:** stubble catch crops, spring barely, yield

## Introduction
Growing of catch crops is an important part of farming systems. The widest represented are stubble catch crops. Their expansion is influenced mainly by the favorable soil environment, relatively low cost of cultivation, subsides support under agri-environmental measures, their application in soil conservation tillage technologies and stand establishment on soils vulnerable to erosion (Procházková et al., 2001, Haberle , 2006, Haberle et al., 2009, Hermuth and Vach, 2008, Hůla, Procházková, et al., 2008, Vach et al., 2009).
The aim of the research was to evaluate the production capability of selected species of stubble catch crops grown in corn production area and their effect on the yield of after growing spring barley.

## Material and methods
Field experiment was conducted in the years 2006 - 2013 in corn production area on clay-loam gleyic fluvisol. In the experiment there were used ten stubble catch crops. Catch crops stands were established after the harvest of winter wheat in two terms. In the first term (immediately after forecrop harvest) were sown all catch crops. In the second term (mid-September) were sown six selected species. Catch crops were left on the field till spring. After forecrops spring barley was grown without nitrogen fertilization and since 2010 in combination with N fertilization (60 kg $N.ha^{-1}$) and without N fertilization. Spring barley was sown directly into catch crops residues. Stand of catach crop *Secale cereale* var. *multicaule* was desiccated by non-selective herbicide in the spring.

**Results and discussions**

The results of monitoring are in the following tables. From the point of yield certainty under the given conditions was shown as the most suitable growing of cruciferous species of catch crops and tancy phacelia. The success of other studied species was more dependent on weather conditions. Important is early sowing. In case of late sowing catch crops emerge slowly and before winter they do not create enough biomass. Success of catch crops generally depends on their quick and regular emerge, quick initial growth and creation of sufficient biomass.

Also was observed decreasing of spring barley yields grown after catch crops with higher amount of biomass (cruciferous species of catch crops and tancy phacelia in I. term of sowing) without nitrogen fertilizing.
In case of nitrogen application increased yields of spring barley grown after both catch crops sowing terms (strongly after I. term). Nitrogen fertilization recovered negative influence of higher amount of catch crops biomass on following spring barley.

**Tab. 1 Fresh matter and dry matter yields of catch crops (t ha$^{-1}$) in I. and II. term of sowing average for the period 2006 – 2013**

| Catch crops | fresh mass | dry mass |
|---|---|---|
| ***I. term of sowing*** | | |
| ***Sinapis alba* – Veronika (varieties)** | 11.63 | 1.96 |
| ***Sinapis alba* - Severka** | 11.35 | 1.82 |
| ***Sinapis alba* - Ascot** | 11.37 | 1.98 |
| ***Raphanus sativus v. oleifera* - Ikarus** | 16.23 | 2.10 |
| ***Phacelia tanacetifolia* - Větrovská** | 13.61 | 1.79 |
| ***Phacelia tanacetifolia* - Angelia** | 15.43 | 2.19 |
| ***Fagopyrum esculentum* - Pyra** | 3.61 | 1.23 |
| ***Secale cereale v. multicaule* - Lesan** | 3.18 | 0.71 |
| ***Panicum miliaceum* - Hanácké mana** | 2.20 | 0.53 |
| ***Crambe abyssinica* - Borowska** | 13.61 | 1.84 |
| ***Malva verticillata* - Dolina** | 6.46 | 0.91 |
| ***Phalaris canariensis* - Judita** | 2.56 | 0.39 |
| ***Carthamus tinctorius* - Sabina** | 6.17 | 0.91 |
| ***II. term of sowing*** | | |
| ***Sinapis alba* - Severka** | 5.46 | 0.61 |
| ***Raphanus sativus v. oleifera* - Ikarus** | 5.86 | 0.57 |
| ***Phacelia tanacetifolia* - Větrovská** | 4.65 | 0.48 |
| ***Secale cereale v. multicaule* - Lesan** | 1.45 | 0.23 |
| ***Malva verticillata* - Dolina** | 0.64 | 0.08 |
| ***Phalaris canariensis* - Judita** | 0.40 | 0.06 |

**Tab. 2 Spring barley yields grown after catch crops (t.ha$^{-1}$)**

| Catch crops | 2007 - 2013 | 2010 - 2013 | |
|---|---|---|---|
| | without nitrogen fertilization | without nitrogen fertilization | nitrogen fertilization |
| ***I. term of sowing*** | | | |
| ***Sinapis alba* – Veronika (variety)** | 4.35 | 3.96 | 5.93 |
| ***Sinapis alba* - Severka** | 4.26 | 3.92 | 5.91 |
| ***Sinapis alba* - Ascot** | 4.19 | 4.02 | 5.90 |
| ***Raphanus sativus v. oleifera* - Ikarus** | 4.41 | 4.25 | 6.02 |
| ***Phacelia tanacetifolia* - Větrovská** | 4.22 | 3.79 | 5.80 |
| ***Phacelia tanacetifolia* - Angelia** | 4.18 | 3.79 | 5.73 |
| ***Fagopyrum esculentum* - Pyra** | 4.85 | 4.38 | 6.04 |
| ***Secale cereale v. multicaule* - Lesan** | 4.05 | 3.66 | 5.22 |
| ***Panicum miliaceum* - Hanácké mana** | 5.24 | 5.13 | 6.26 |
| ***Crambe abyssinica* - Borowska** | 4.99 | 4.80 | 5.99 |
| ***Malva verticillata* - Dolina** | 4.63 | 4.53 | 6.06 |
| ***Phalaris canariensis* - Judita** | 5.24 | 5.09 | 6.21 |
| ***Carthamus tinctorius* - Sabina** | 5.11 | 4.97 | 6.06 |
| **Control - without catch crops** | 5.21 | 5.06 | 6.28 |
| ***II. term of sowing*** | | | |
| ***Sinapis alba* - Severka** | 5.27 | 5.24 | 5.91 |
| ***Raphanus sativus v. oleifera* - Ikarus** | 5.39 | 5.64 | 5.89 |
| ***Phacelia tanacetifolia* - Větrovská** | 5.36 | 5.44 | 6.16 |
| ***Secale cereale v. multicaule* - Lesan** | 5.48 | 5.32 | 5.58 |
| ***Malva verticillata* - Dolina** | 6.10 | 5.81 | 6.30 |
| ***Phalaris canariensis* - Judita** | 6.11 | 5.76 | 6.04 |
| **Control - without catch crops** | 6.02 | 5.57 | 6.10 |

## Conclusions

From the point of yield certainty and soil coverage was in the given conditions proved that the most suitable is growing of cruciferous species of catch crops and phacelia. The success of other observed catch crops was more dependent on weather conditions. Important is early sowing of catch crops. In case of late sowing catch crops emerge slowly and before winter they do not create enough biomass. The negative relationship between catch crops yields and spring barley yields occurred when nitrogen fertilization was leaved out. Negative influence of higher amount of catch crops biomass yield was eliminated by nitrogen fertilization.

## Acknowledgements

The research was supported by projects:
*NAZV QJ1210008 “Innovation cereal farming systems in different agro-ecological conditions of the Czech Republic "*
*TAČR - TA02010669 "Research and development of machines and technologies for differentiated tillage and fertilization"*

**References**

HABERLE, J., 2006: Agrometeorologické podmínky pro efektivní pěstování meziplodin. *Úroda*, 54 (2): 50-51.

HABERLE, J. a kol., 2009: Vliv termínu setí a průběhu počasí na biomasu strniskových meziplodin. *Úroda*, 57 (6): 16-19.

HERMUTH, J., VACH, M., 2008: Vliv počasí na růst a vývoj strniskových meziplodin. *Farmář*, (3): 26-29.

HŮLA, J., PROCHÁZKOVÁ, B. a kol., 2008: Minimalizace zpracování půdy. *Profi Press,* Praha, 246 s. ISBN 978-80-86726-28-1

PROCHÁZKOVÁ, B. a kol., 2001: Organické hnojení při hospodaření bez živočišné výroby. *Ústav zemědělských a potravinářských informací,* Praha, 29 s. ISBN 80-7271-083-4.

VACH, M. a kol., 2009: Pěstování strniskových meziplodin: *Metodika pro praxi, Výzkumný ústav rostlinné výroby,* Praha, 34 s. ISBN 978-80-7427-009-3.

**Contact address:**

Ing. Blanka Procházková, CSc.
Mendel University in Brno
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: proch@mendelu.cz
tel.: +420 545133117

# EFFECT OF INCUBATION OF SOIL CONDITIONER WITH SOIL AND SOIL SOLUTIONS ON pH SOLUBLE K, Ca, Mg AND Si IN SOIL SOLUTION

**W. Rattanapichai[1,2], P. Duangpatra[2], P. Kanghae[2], J. Křen[1]**

[1]Department of Agrosystems and Bioclimatology, Mendel University, Czech Republic
[2]Department of Soil Science, Kasetsart University, Bangkok, Thailand

## Abstract
Two experiments were conducted by using of 2 kg of 2 types of agricultural soils; Korat series (Kt) and Ongkharak series (Ok). The first experiment was conducted to investigate the effects of various soil conditioners, MK doses (0 and 6 g/kg soil) and incubation time (5, 10 and 20 days) on pH and the release of K, Ca, Mg and Si into soil solution. The second experiment was conducted to determine the effect of solubility of MK and nutrient release of soil solutions during various incubation times (0, 5, 10 and 20 days). The results showed that soil incubations with MK decreased acidity in both soil series. Moreover, they resulted in available K, Ca, Mg and Si in soil solution of the Kt series by 5.11, 207.95, 4.65 mg/kg respectively, and soil solution of Ok series by 0.18, 214.58 and 20.59 mg/kg respectively. A 5-day soil incubation was sufficient for improvement of soil chemical properties of Kt soil series and Ok soil series by MK which was dissolved in soil solution by 26-28%.

**Keywords:** Soil conditioner, Silicon, Acid sulfate soil, Acid soil.

## Introduction
Acid soil and acid sulfate soils reduce farm productivity. The acid in the soils make several soil nutrients less available to plants. The acid dissolves iron and aluminium from the soil so that they become available to plants in toxic quantities in soil solution. Such conditions reduce plant growth. Many traditional and modern practices exist which can improve soil chemical properties. One of them is the application of liming material.

"MK" as soil conditioner is a by-product from concrete manufacturing. The components of MK are calcium compounds and hydrosilicate compounds. About 60-70% forms other components such as silicon, aluminium and anhydrous silica. Its electrical conductivity is 2.1 dS/m, the cation exchange capacity is 25.0 cmol/kg, pH is very high (pH 10.2), available P is 0.50 mg/kg, and exchangeable K Ca Mg are 1.348, 1.726 and 78 mg/kg, respectively. Moreover, they have 20.3% of total Si and 3,294 mg$SiO_2$/kg of extractable Si. Based on their properties, MK can be used as soil conditioners which improve soil chemical properties, especially in acid soil and acid sulphate soil, including soil physical properties as infiltration and surface crust. Moreover, silicon (Si) application can reduce aluminium toxicity to plants including rice (Hara et al., 1999). Silicon enhances the photosynthesis of rice and increases rice resistance to several diseases and insects (Ma and Takahashi, 2002)

However, MK grains sized 1-3 mm are slowly soluble (9.2% in water pH 5.5 during 72 hours). Solubility rate of MK in water and soil solution affects nutrient release into soil as K, Ca, Mg and Si. Therefore, it is important to know how MK affects soil properties and how long it releases available nutrition into the soil for an appropriate management. Major goal of this paper was to study the effects of soil incubation with MK on pH and release of K, Ca, Mg and Si into soil solution, and the effect of solubility of MK and nutrient release of soil solutions.

## Material and methods

Two experiments were carried out in 2010 at the Kasetsart University, Bangkok, Thailand. Two agricultural soils were selected for this study. Surface soil samples (0–15 cm) from a Korat series (Kt) and Ongkharak series (Ok) were taken for analysis. Soil samples were air dried at room temperature for four days and sieved through a 2 mm mesh sieve. The samples were characterized for soil pH which was determined using 1:1 ratio of soil to deionised water. Organic matter content was determined by wet oxidation and titration using the Walkley and Black method (Nelson et al. 1982). The available phosphorus was extracted with BrayII and was determined by flame emission. The exchangeable K, Ca and Mg in the $NH_4OAc$ solution were determined by atomic absorption spectrophotometry (AAS). Extractable Si was extracted by $CH_3COOH$ and Si in the solution was determined by AAS. Soil chemical properties are shown in Table 1.

Tab 1. The chemical properties of soil in the experiment.

| Soil series | pH | OM | Avai.P | Exch.K | Exch.Ca | Exch.Mg | Exch.Si |
|---|---|---|---|---|---|---|---|
| | | (%) | (mg/kg) | | | | (mg $SiO_2$/kg) |
| Kt | 4.4 | 1.18 | 4.6 | 31.3 | 3,031.0 | 9.0 | 42.8 |
| Ok | 3.9 | 3.36 | 6.5 | 110.5 | 6,450.5 | 258.7 | 53.5 |

The first experiment studied the effects of soil incubation with MK on pH and release of K, Ca, Mg and Si into the soil solution. This experiment was conducted with 2 replications. Two factors were studied in 2 soil series (Kt and Ok). The first factor consisted of 3 variants of incubation times during 5, 10 and 20 days. The second factor represented 2 rates of MK; 0 and 6 g/kg soil. In this experiment we used 2 kg soil. The Korat soil series was incubated with and without MK at the field capacity. The Ongkharak soil series was incubated with and without MK at the saturation capacity. After incubation, the samples and sucked soil solution by suction pump were taken for chemical analyses.

The second experiment focused on the effect of solubility of MK and nutrient release of soil solutions. The experiment was conduct with 2 replications at 4 different incubation times; 0, 5, 10 and 20 days. The solvents of this experiment were taken from soil solutions of Korat soil series which was incubated at the field capacity and the Ongkharak soil series was incubated at the saturation capacity for 72 hours then sucked soil solution by suction pump set. Further, 10 g of MK (50 mesh grain size) was mixed with 100 ml of the solvents and incubated during 0, 5, 10 and 20 days. After incubation, the rest of MK from solutions was filtered for calculating the percentage of solubility and the samples of solvents were taken for chemical analyses.

## Results and discussions

**Korat Series:** Longer time of soil incubations with and without MK caused more increased soil pH. Soil incubations with MK increased 0.33 pH unit when compared to the treatment without MK (Table 2). It was shown that MK could be used as soil conditioner for improving soil pH of acid soil (pH 4.4). Moreover, individual effects of MK showed the increase of K, Ca and Mg released into soil solution by 5.11, 207.95, 4.65 mg/kg respectively. Although longer time of soil incubations had a slight effect on nutrients release, soluble cations (K, Ca and Mg) were sufficient for plants. Therefore, short time incubations (only 5-10 days) were sufficient for improvement of soil chemical properties. Soil incubation with MK also increased soluble Si in soil solution (24.78 mg $SiO_2$/kg), and individual effect of MK increased soluble Si by 11.1 mg $SiO_2$/kg. Soil incubations for a longer time with MK caused more decreased soluble Si in soil solution. Soil incubation during 5 days resulted in the highest soluble Si (27.8 mg $SiO_2$/kg) because some of the soluble forms became insoluble as soluble Si in soil solution was sensitive to reformation (Knight and Kinrade, 2001). Table 3 indicates that soil solution from Kt series dissolved MK by 27.8%. The incubation of MK in soil solution increased 2.9 pH units; moreover, it increased the solubility of K, Ca and Si as well. However, it had no effect on Mg solubility. Longer time of soil solution incubations with MK caused more increased solubility of K, Mg and Si which was beneficial to nutrient uptake by plants.

**Tab 2. Chemical analysis of soil solution which was taken from soil incubation for 5, 10 and 20 day**

| Treatment | Incubation (days) | pH | Soluble K (mg/kg) | Soluble Ca (mg/kg) | Soluble Mg (mg/kg) | Soluble Si (mg $SiO_2$/kg) |
|---|---|---|---|---|---|---|
| **Korat Series : Kt** [1/] | | | | | | |
| 1. Soil+$H_2O$ | 5 | 6.10 | 7.78 | 1.69 | 0.97 | 13.9 |
| | 10 | 6.50 | 8.53 | 2.99 | 1.39 | 13.9 |
| | 20 | 7.00 | 9.42 | 3.25 | 1.52 | 13.4 |
| 2. Average | | **6.53** | **8.58** | **2.64** | **1.29** | **13.73** |
| 3. Soil+$H_2O$+MK | 5 | 6.30 | 13.1 | 207 | 5.08 | 27.8 |
| | 10 | 7.00 | 13.5 | 212 | 5.62 | 25.1 |
| | 20 | 7.30 | 14.5 | 212 | 7.14 | 21.4 |
| 4. Average | | **6.87** | **13.69** | **210.60** | **5.95** | **24.78** |
| 5. Individual effect of MK (④-③) | | **0.33** | **5.11** | **207.95** | **4.65** | **11.05** |
| **Ongkharak Series: Ok** [2/] | | | | | | |
| 1. Soil+$H_2O$ | 5 | 4.30 | 9.43 | 152 | 86.8 | 22.5 |
| | 10 | 4.40 | 8.84 | 154 | 109 | 22.5 |
| | 20 | 4.30 | 8.84 | 165 | 118 | 21.9 |
| 2. Average | | **4.33** | **9.04** | **156.92** | **104.68** | **22.28** |
| 3. Soil+$H_2O$+MK | 5 | 4.40 | 10.0 | 348 | 125 | 34.8 |
| | 10 | 4.50 | 9.38 | 369 | 125 | 34.8 |
| | 20 | 4.40 | 8.24 | 397 | 126 | 52.4 |
| 4. Average | | **4.43** | **9.20** | **371.50** | **125.27** | **40.64** |
| 5. Individual effect of MK (④-③) | | **0.10** | **0.17** | **214.58** | **20.59** | **18.36** |

[1/] Incubation at the field capacity
[2/] Incubation at the saturated capacity

**Ongkharak Series:** Soil incubations with MK for a longer time had no effect on soil pH and caused slightly increased soil pH when compared to the treatment without MK (0.10 pH unit) because the rate of MK (6g/kg soil) was not enough to neutralize acidity in the soil. Moreover, Ok Series had a clay soil with high potential acidity (potential acidity refers to the hydrogen and aluminium cations that are held by soil exchange sites.) or high buffering capacities (a resistance to change in pH). Therefore, MK as a lime material was neutralized completely in a short time without increased soil pH. Soil incubations with MK resulted in K, Ca and Mg release 0.177, 214.58 and 20.59 mg/kg, respectively, when compared to the treatment without MK. Longer time of soil incubations with and without MK caused slightly increased Ca and Mg released into soil solution but soil incubations during 10-20 days didn’t have effect on K release. The average Si release during soil incubations with MK increased from 22.28 to 40.64 mg $SiO_2$/kg, and 20 days of incubation time increased soluble Si 34.8 to 52.4 mg $SiO_2$/kg. It can indicate that application of MK increased available Si in the saturated soil but should be incubated for more than 10 days. Table 3 indicates that soil solution from Ok series dissolved MK by 25.8%. The dissolution of MK increased soil solution pH to 4.0 because it had no effect on potential acidity and soil buffering capacity. The incubation of MK in soil solution effected the solubility of K, Ca, Mg and Si by 70.7, 383, 35.9 mg/kg and 6.42 mg $SiO_2$/kg, respectively. The soil solution incubations with MK during 5 days increased the solubility of K, Ca, Mg and Si (66.7, 546, 50.6 mg/kg and 13.8 $SiO_2$/kg) and after 5 days it increased only slightly. It indicates that 5 days were enough for incubation of MK. However, there may be a continuous release of Si after 20 days. Saigusa et,al.(1999) found that Tobermorite was a porous hydrated calcium silicate mineral which was a by-product in the form of autoclaved lightweight concrete which could continually release available Si during the growing season of rice. The highest rate was found at 53 days after planting.

**Tab 3. Solubility of MK in soil solution when incubated during 5, 10 and 20 days**

| Treatment | Incubation | pH | Soluble K | Soluble Ca | Soluble Mg | Soluble Si | Solubility |
|---|---|---|---|---|---|---|---|
| | (days) | | (mg/kg) | | | (mg$SiO_2$/kg) | (%) |
| **Korat series: Kt** [1/] | | | | | | | |
| 1. Soil solution | 0 | 4.5 | 8.96 | 5.43 | 1.79 | 13.8 | - |
| 2. Soil solution + MK | 5 | 7.4 | 74.1 | 527 | 1.09 | 18.5 | 29.5 |
| | 10 | 7.4 | 76.3 | 527 | 1.41 | 28.5 | 26.5 |
| | 20 | 7.5 | 81.0 | 527 | 1.58 | 35.0 | 27.3 |
| 3.Average of incubation | - | **7.4** | **77.1** | **527** | **1.36** | **27.3** | **27.8** |
| 4. Individual effect of MK (③-①) | - | **2.9** | **68.2** | **522** | **-0.43** | **13.5** | **-** |
| **Ongkharak Series: Ok** [2/] | | | | | | | |
| 1. Soil solution | 0 | 3.5 | 7.08 | 170 | 10.6 | 10.0 | - |
| 2. Soil solution + MK | 5 | 7.5 | 66.7 | 546 | 50.6 | 13.8 | 25.8 |
| | 10 | 7.3 | 78.3 | 554 | 47.0 | 17.5 | 25.8 |
| | 20 | 7.5 | 88.2 | 560 | 41.9 | 18.0 | 26.0 |
| 3.Average of incubation | **-** | **7.4** | **77.7** | **553** | **46.5** | **16.4** | **25.8** |
| 4. Individual effect of MK (③-①) | **-** | **4.0** | **70.7** | **383** | **35.9** | **6.42** | **-** |

[1/] Incubation at the field capacity
[2/] Incubation at the saturated capacity

## Conclusions

Soil incubations with MK (12g/kg soil) could decrease soil acidity of Korat soil series, but in the Ongkharak soil series the decrease was only a slight. In addition, they increased available K, Ca, Mg and Si in soil solution. MK could dissolve in soil solution by 26-28% and increase the solubility of K, Ca, Mg and Si, moreover, it increased pH of soil solution. Five days of incubation were enough for the improvement of soil chemical properties of submerged soil or saturated soil (Kt series) and unsaturated soil (Ok series).

**Acknowledgements**

This work was supported by a grant from the Construction Products Public Co.,Ltd. and Department of Soil Science, Faculty of Agriculture, Kasetsart University, Thailand. Furthermore, I would like to thank Prof. Jan Kren for his kind assistance and guidance in the writing process.

**References**

HARA,T., GU, M.H. AND KOZAMA, H., 1999: Amelioration effect of silicon on aluminium injury in the rice plant. *Soil Science & Plant Nutrition*. 45 (4), 929-936.

HEINAI, H., SAIGUSA, M., YOSHIDA, K. and OKAZAKI, H., 2005: Effect of Application of Acidified Porous Hydrate Calcium Silicate and Porous Hydrated Calcium Silicate on the Growth of Rice Plants (*Oryza sativa* L.). *Soil Science & Plant Nutrition.* 51: 961–966.

KAWAGUCHI, K. and KYUMA, K., 1969: Lowland rice soils in Thailand. The center for Southeast Asia Studies, Kyoto University, Kyoto

KNIGHT, C.T.G. and KINRADE, S.D., 2001: A primer on the aquous chemistry of silicon. In Silicon in Agriculture, Elsevier Sci. B.V., The Netherlands. p.57-84.

MA,J.F. AND E. TAKAHASHI, 2002: Soil fertilizer and plant silicon research in Japan. Elsevier Science, The Netherland. 281 pp.

NELSON DW, SOMMERS LE., 1982: Total carbon, organic carbon and organic matter. In: Page AL, Miller RH, Keeney DR (eds) Methods of Soil Chemical Analysis, Part2: Chemical and Microbiological Properties. 2$^{nd}$ edn. ASA and SSSA. Madison, Wisconsin. 570-572.

SAIGUSA, U., Yamamoto, K. and Shibuya, K. 1999: Effcets of parous hydrated calcium silicate on silicon mutrition of paddy rice. *Silicon in Agriculture*. Progrou Agenda and Abstracts. Stet. 26-30, 1999, Lago Mar Resort, Fort Lauderdale, Florida ,USA, p.35.

SOIL SURVEY STAFF, 1992: Soil survey laboratory methods manual. Soil survey investigations report No. 42 (version 2.0). USDA-SCS. U.S. Gov. Print. Office, Washington, DC.

**Contact address:**

Wutthida Rattanapichai, M.Sc.
Mendel University in Brno
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: xrattana@node.mendelu.cz
tel.: +420 733221196

# PREVENTION OF SOIL EROSION, SURFACE RUNOFF, PESTICIDE AND NUTRIENT LOSS WITH MINIMUM TILLAGE AND DIRECT- SEEDING

**J. Rosner[1], W. Deix[1], A. Klik[2]**

[1]Office of the Lower Austrian Provincial Government, Tulln, Austria
[2]University of Agricultural Science Vienna, Department of Hydraulics and rural water management, Vienna, Austria

## Abstract
In Austria more than 400.000 ha arable land are seriously endangered by soil erosion. Soil loss, nutrient loss, water runoff and pesticide loss are environmental risks and also danger for settlements. The same situation we find in almost every country, depending from the topography. Minimum tillage systems can significantly reduce soil erosion and all the negative consequences. In combination with effective cover crops we can introduce the system of permanent covered arable land with a maximum protection of soil against soil erosion, surface runoff, nutrient- and pesticide loss. The technical requirement and the farmers know how are necessary for the success of this system.

**Keywords**: soil erosion, no tillage, minimum tillage, direct seeding

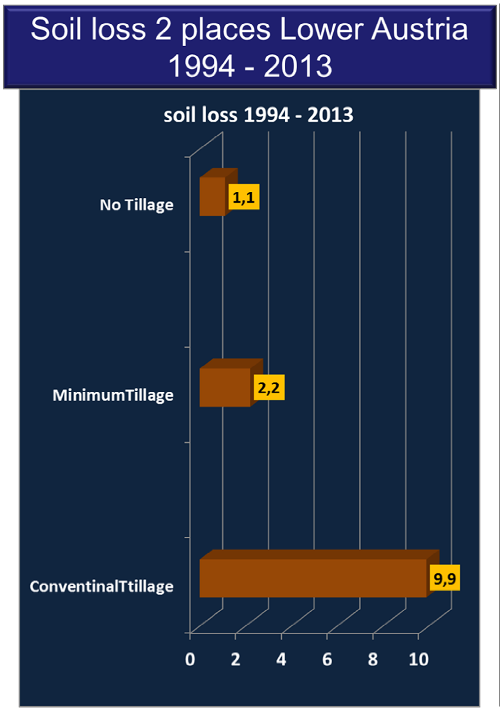
## Introduction
Not tillage and zero tillage research have been performed for more than half a century in many countries around the world because of the benefits of these systems. Less traffic on the arable land, less fuel consumption, less time for cultivation are economic advantages; ecological interests are higher microbiological activity, better C sequestration, humus constitution and prevention of soil erosion with all its consequences.
Soil erosion causes water runoff by a reduced infiltration rate. Are pesticides solute, high concentrations are found in the deposition zone with the result of infiltration into ground water.  Pesticides are found there, usually at the end of a slope as groundwater samples from wells demonstrate.

## Material and methods
On 7 locations in Lower Austria tillage trials are operated for more than 7 years; on 2 locations tillage trials and soil erosion measurements are arranged in cooperation with the Austrian University of Agricultural Science Vienna, Department of Hydraulics and rural water management for 20 years. In the tillage trials 4 different tillage methods are settled – conventional tillage with plow and cultivator; reduced tillage with cultivator and disc harrow, minimized tillage with disc harrow or light rigid – tine cultivator and no tillage. Net plot harvest allows measuring the yield.
60 m² plots for investigation of soil erosion are located in Pixendorf near Tulln on the river Danube and in Mistelbach 40 km north of Vienna. After every storm event the measurement is analysed in the laboratory of the University.

CONTENT

**Results and discussion**

The following figure 1 shows the significant reduction of soil erosion from long- time erosion trials on 2 locations in Lower Austria; figure 2 demonstrates the reduction of organic Carbon loss in different tillage systems. The crop rotation is row cultivars (corn, sunflowers, sugar beets) with a high potential risk of soil erosion and cereals.



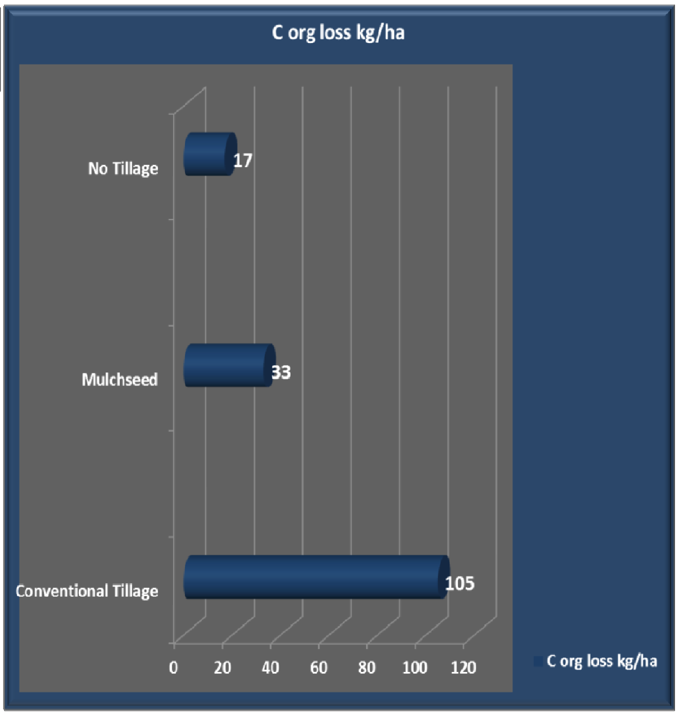
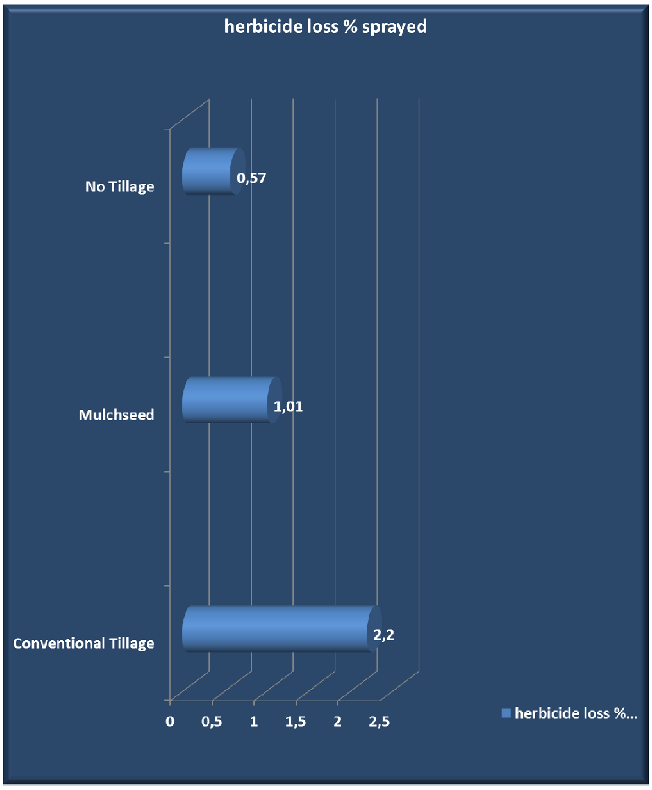




**Figure 1: soil loss** **Figure 2: organic carbon($C_{org}$)loss**




The storage of $C_{org}$ is important for the aggregate stability in soils and constitutes more than 30 % in Glomalin, a glycoprotein in the Mycorrhiza responsible for stabile aggregates.

**Figure 3:**

The herbicide loss of sprayed pesticide can be significantly reduced by mulch- and direct seed and is important for the environment. As finding pesticide residues in surface- or groundwater leads to prohibition of these with negative aspects for plant protection. It is to consider, that in the saturated zone at the end of a slope the concentration of pesticide residues is much higher and an infiltration into the groundwater threatens. The same effect shows the loss of nutrients like Nitrogen and Phosphorous.

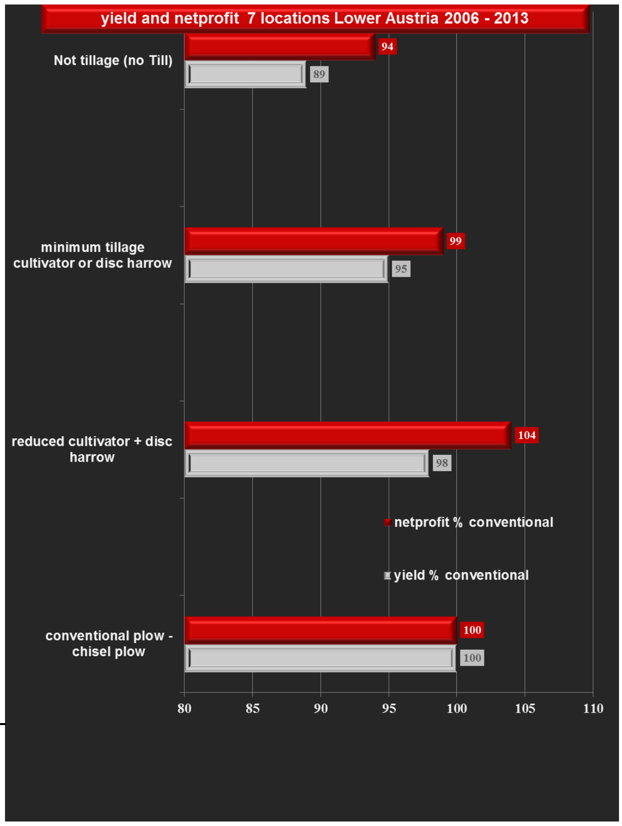
CONTENT

Important for farmers are the yields and the net profit. The next figures 4 and 5 show the tendencies in different tillage systems for 7 years.

**Yield in relative % 1994 – 2013 Mistelbach-Pyhra(St.Pölten)-Pixendorf(Tulln)**

**Rosner, Zwatz, Bartmann, Spieß**

| Tillage method/ Yield kg per ha | Mistelbach | Pyhra | Pixendorf |
|---|---|---|---|
| Conventional Cultivator – plow No cover crop | 100 | 100 | 100 |
| Cultivator – Mulchseed – Cover Crop: yellow mustard, california bluebell, buckwheat, red clover, oil radish | 96 | 102 | 102 |
| Cultivator – direct drilling/NoTill Cover crop : 7 kg/ha California Bluebell, 3 kg/ha Yellow Mustard | 93 | 106 | 106 |
| Cultivator – direct drilling/NoTill cover crop : 80 kg/ha winter rye | 89 | 93 | 93 |
| Cultivator – direct drilling/NoTill Cover crop :120 kg/ha summer barley | 97 | 112 | 112 |




## Conclusion

Minimum Tillage an no tillage are practicable and allow lower working time, lower fuel consumption, significantly reduced soil erosion and all solved nutrients and pesticides. The technical equipment is well developed but often not announced to the farmers in Europe, other continents like South America use these tillage operations for several decades successfully and could decrease the severe soil erosion to an acceptable amount. Yields are stabile in minimum tillage and decreasing in No tillage – but only on heavy soils and on sandy soils and with sugar beets in crop rotation. Often the poor work of speeders is responsible for bad field emergency and following low yields. The right equipment like coulter discs for producing loosened soil for closing the seed slot is the key of success (figure 6)

**Figure 6:** coulter discs for loosening soil for closing the slots after seeding

**Acknowledgements**
Soil erosion can be minimized by mulch- and direct seed. The environmental effect is as big as the economical. Deposition of soil in villages, on streets and in ditches is an environmental risk and intensive in costs. Lawsuits in the past consider conventional tillage on slopes and row crops as an incorrect land management and compensation for damages has to be paid by the causer – in that case the famer.

**Contact address:**

Dipl. Ing. Josef Rosner, Ph.D.
Office of the Lower Austrian Provincial Government
Department of Agricultural Education
Frauentorgasse 72
A – 3430 Tulln
Austria
Email: josef.rosner@noel.gv.at
Tel.: 0043 6644025477

# PRODUCTION OF SPRING BARLEY, CULTIVATED UNDER VARIANT SOIL MANAGEMENT AND DIFFERENT LEVEL OF NITROGEN NUTRITION

**M. Vach, M. Javůrek, Z. Strašil**

Crop Research Institute, Prague - Ruzyně, Czech Republic

**Abstract**

In long term field experiment (since 1995), in the period 2010-2013, the influence of different methods of soil tillage and three fertilization levels of nitrogen on grain yields of spring barley was studied. The stands were established by four different methods of soil tillage: by conventional technology including ploughing, by no tillage method, by minimum tillage with post harvest residue of forecrop incorporated, by no tillage with mulch of intercrop (*Phacelia tanacetifolia, Benth.*) use.

There were found significantly lower grain yields on plots with conventional technology, compared with no tillage drilling variant and sowing into the soil with shallow incorporation of organic matter from forecrop residues. Among conservation tillage variants no significant yield differences were detected.

The impact of three levels of nitrogen fertilization on grain yield of barley under different methods of soil cultivation was observed as well. There was found that grain yield of barley was affected by graduated nitrogen doses differently in the particular tillage treatments.

**Keywords:** spring barley, yields, different soil tillage, N fertilization, soil fertility

## Introduction

The range of simplified methods of soil tillage are utilized in agricultural practice, depending on soil – climatic conditions of sites, level of soil management and on possibilities of farms from point of view of technical equipment. Beneficial effect on the soil structure, better soil-water management (lower soil water losses under lower intensity of soil tillage, mitigation of undesirable evaporation from the soil surface through mulch utilization etc.), protection against wind and water soil erosion, reduction of nitrogen washing out from soil profile are the main arguments for spreading of minimization and conservation tillage technologies in plant production (Hůla - Procházková et al., 2008). It is known that the soil deeply loosened by ploughing is being predisposed to over-compaction under field traffic by tractors and other machines, especially in case of higher soil moisture. On the other hand, without ploughing it is difficult to incorporate higher doses of farmyard or green manure into the soil. Therefore, the goal of chosen system of soil tillage at a concrete site should be to achieve the stable and resistant topsoil and subsoil structure which is connected with long-term care of soil environment. After all, correct organic matter management in the system of soil tillage is a priority for sustainability of crop production (Kukal et al., 2009). Up to now methods of crop husbandry drains more of carbon from soil, than it is supplied, which resulted in decrease of soil fertility and crop production. This situation is usually corrected by increasing of fertilizer doses, more often application of expensive herbicides, alternatively by irrigation, which is leading to cost increasing with negative effect on profitability of the whole system of crop production. Conservation soil tillage methods with mulch from postharvest residues, alternatively from catch-crop biomass or with use of other forms of organic matter management have a potential to improve this negative tendencies (Franzluebbers, 2002).

**Materials and methods**

The field experiment was launched in 1995 in a temperate semiarid climate, 338 m above sea level, with an annual mean air temperature of 8.2 °C, and mean annual precipitation of 477 mm. At the field site it is a soil of clay-loam texture, Orthic Luvisol (FAO Taxonomy), with 7.7 pH (KCl), organic carbon content 1.86 – 2.09 %, total N 0.164 %, Mehlich 3 P 155 - 207 (NT-CT variants) $mg.kg^{-1}$, K 285 - 413 (NT-CT) $mg.kg^{-1}$. The experiment was established as a rotation of three crops: winter wheat, spring barley, and pea (white mustard from 2005). A split-plot method, with four replications, was used and four treatments (tillage methods) were set-up: 1) Conventional tillage (CT), i.e. mouldboard ploughing to a depth of 0.20 m, usual seed bed preparation and sowing; 2) No tillage (NT), i.e. sowing with special drill machine into no-tilled soil; 3) Shallow disking about 10 cm deep (SDS) and chopped straw with post harvest residues of fore-crop incorporating. 4) Direct drilling + mulch (DDM), i.e. direct drilling into no tilled soil covered with mulch from frost-heaving catch crop (*Phacelia tanacetifolia, Benth.),* whose stand was established in autumn by conventional method (shallow tillage, surface levelling and sowing). All crops (including CT) were sown with a John Deere 750A drill machine. Three levels (low, medium, high) of nitrogen fertilization were used for all crops; 30, 60, and 90 kg N per ha for spring barley. The P and K fertilizer doses were determined and applied according to P, K content in the soil. Standard herbicides were used, depending on the intensity of weed infestation. Grain yields were determined on a 24 $m^2$ test area, at harvest. The data reported were evaluated by ANOVA method and conclusive yield differences among cultivation parameters were assessed with help of least significant differences at the $P_{0.05}$ level.

**Results and discussion**

The table 1, it is shown that in average of years 2010 – 2013 the highest grain yield of spring barley (8.33 $t.ha^{-1}$) and simultaneously the highest yield increase (+6,4%), compared with control (conventional) tillage variant, were identified from shallowly disked plots with chopped straw and postharvest residue incorporated (SDS treatment). In the other experimental variants (NT and DDM), the average grain yields were lower than the most productive variant but comparable. The table 3 confirms no significant yield differences among three conservation tillage variants. On the contrary, from this table resulted significant difference of yields of all conservation variants in comparison with conventional tillage treatment.

Table 2 showed significant yield differences among all monitored years which indicate different influence of weather on the barley production in individual years. Strong impact of weather conditions on production of especially cereals is generally known and therefore this finding brings nothing new. But analysis of weather impact in individual years showed the positive influence of minimization and conservation tillage technologies on grain yield in dry years (2011, 2012), which was confirmed by other authors (Hůla et al., 2008 and others). We achieved the similar results in the same experiment with winter wheat (Javůrek et al., 2011).

However, the impact of nitrogen fertilization of spring barley is worth noting. In the table 4, it is possible to find the differences among the individual doses, in average of yields, especially between N1 and other two N doses. But the significant yield differences were found out only between N1 and N3 doses. As for the nitrogen effect in the individual tillage treatments (table 1), in the NT variant already N2 dose showed the most striking yield effect, which was connected with lower nutrient content in upper layer of topsoil in no-tilled lands (Sainju et al., 2002). The third dose in this variant was not effective, similarly as in the DDM variant, where is also lower tillage intensity of upper layer of topsoil. Unlike these tillage treatments, both in conventional and SDS variants there was recorded gradual increase of grain yields of barley by increasing of N fertilization level, while the higher progress in SDS variant was found out.

**Table 1: Grain yields of spring barley ($t.ha^{-1}$) in relation to soil tillage methods and nitrogen fertilization level**

| Soil tillage treatment | Doses of nitrogen fertilization | Grain yields ($t.ha^{-1}$) in years | | | | Average yields ($t.ha^{-1}$) 2010-2013 | Relative values (%) by soil tillage | Relative values (%) by nitrogen fertilization |
|---|---|---|---|---|---|---|---|---|
| | | 2010 | 2011 | 2012 | 2013 | | | |
| **CT** | $N_1$ | 8.53 | 7.25 | 6.00 | 9.04 | 7.70 | 100.0 | 100.0 |
| | $N_2$ | 8.45 | 7.63 | 6.13 | 9.29 | 7.87 | 100.0 | 102.2 |
| | $N_3$ | 8.54 | 7.75 | 6.15 | 9.30 | 7.93 | 100.0 | 103.0 |
| | average | 8.50 | 7.54 | 6.09 | 9.21 | **7.84** | **100.0** | -- |
| **NT** | $N_1$ | 8.19 | 8.44 | 6.13 | 8.80 | 7.89 | 102.5 | 100.0 |
| | $N_2$ | 8.55 | 8.63 | 7.26 | 9.41 | 8.46 | 107.5 | 107.2 |
| | $N_3$ | 8.45 | 8.70 | 7.19 | 9.66 | 8.50 | 107.2 | 107.7 |
| | average | 8.40 | 8.59 | 6.71 | 9.29 | **8.28** | **105.7** | -- |
| **SDS** | $N_1$ | 8.25 | 8.50 | 6.59 | 8.89 | 8.06 | 104.7 | 100.0 |
| | $N_2$ | 8.68 | 8.75 | 7.03 | 9.09 | 8.38 | 106.5 | 104.0 |
| | $N_3$ | 8.58 | 8.88 | 7.00 | 9.78 | 8.56 | 107.9 | 106.2 |
| | average | 8.50 | 8.71 | 6.87 | 9.25 | **8.33** | **106.4** | -- |
| **DDM** | $N_1$ | 8.68 | 8.31 | 6.43 | 8.94 | 8.09 | 105.1 | 100.0 |
| | $N_2$ | 8.95 | 8.75 | 6.54 | 9.44 | 8.42 | 107.0 | 104.1 |
| | $N_3$ | 8.80 | 8.50 | 6.76 | 9.54 | 8.40 | 105.9 | 103.8 |
| | average | 8.81 | 8.52 | 6.58 | 9.30 | **8.30** | **106.0** | **--** |

Notes: CT = conventional soil tillage; NT = no-tillage without mulch, SDS = shallow disking and chopped straw incorporating, DDM = direct drilling into no-tilled soil covered with mulch from frost-heaving catch crop. Nitrogen fertilization: $N_1 = 30$, $N_2 = 60$, $N_3 = 90$ ($kg\ N.ha^{-1}$)

When choosing the level of nitrogen fertilization for spring barley growing, it is necessary to find the correct compromise decision between grain yield level and its food quality. Regarding the stands, established by minimization or conservation, respectively no-tillage technology, it should be applied fertilization intensity with respect to different effectiveness of nitrogen applied.

**Table 2: The significant differences for grain yield, classified according to year**

| Group | Case load | Average | 2012 | 2011 | 2010 | 2013 | |
|---|---|---|---|---|---|---|---|
| **2012** | 48 | 6.5590 | | * | * | * | \| |
| **2011** | 48 | 8.3448 | * | | * | * | \| |
| **2010** | 48 | 8.5533 | * | * | | * | \| |
| **2013** | 48 | 9.2635 | * | * | * | | \| |
| *Value of the least significant difference:* **SD = 0.184** | | | | | | | |

**Table 3: The significant differences for grain yield, classified according to soil tillage method**

| Group | Case load | Average | CT | NT | SDS | DDM | |
|---|---|---|---|---|---|---|---|
| **CT** | 48 | 7.8365 | | * | * | * | \| |
| **NT** | 48 | 8.2833 | * | | | | \| |
| **DDM** | 48 | 8.3035 | * | | | | \| |
| **SDS** | 48 | 8.3273 | * | | | | \| |
| *Value of the least significant difference:* **SD = 0.431** | | | | | | | |

**Table 4: The significant differences for grain yield, classified according to nitrogen fertilization level**

| Group | Case load | Average | N1 | N2 | N3 | |
|---|---|---|---|---|---|---|
| **N1** | 64 | 7.9395 | | | * | \| |
| **N2** | 64 | 8.2844 | | | | \|\| |
| **N3** | 64 | 8.3516 | * | | | \| |
| *The value of the least significant difference:* **SD = 0.373** | | | | | | |

From many home and foreign publication (Hůla - Procházková et al. 2008; Kukal et al. 2009 and the others), it is known that effective utilization of N fertilization with minimum losses depends especially on soil properties and weather conditions during vegetation period, but soil tillage depth and intensity appears as very important attributes as well.

## Conclusions

In long-term field experiment, this study verified and confirmed higher efficiency of spring barley growing with help of conservation tillage technology compared with conventional method under above mentioned soil and weather conditions. But it is necessary to modify the system of N fertilization with regards to soil depth and intensity of soil tillage and grain food quality as well.

## Acknowledgements

This contribution was financially supported by the research project No. QJ 1210008 of the Ministry of Agriculture of the Czech Republic.

## References

FRANZLUEBBERS, A.J., 2002: Soil organic matter stratification ratio as an indicator of soil quality. *Soil and Tillage Research, 66: 95-106.*

HŮLA, J., PROCHÁZKOVÁ, B. et al., 2008: Minimalizace zpracování půdy.*Profi Press, Praha, 246 s.*

JAVŮREK, M., MIKANOVÁ, O., VACH, M., ŠIMON, T., 2010: Význam půdoochranných technologií v rostlinné výrobě pro rozvoj půdní úrodnosti. *Certified methodology applied to agricultural practice. Praha, 29 s.*

JAVŮREK, M., MIKANOVÁ, O., VACH, M., 2011: Hodnocení dlouhodobého efektu půdoochranných technologií na výnosy ozimé pšenice a vlastnosti půdy typu luvisol. *Úroda 12: 355-358.*

KUKAL, S.S., REHANA-RASOOL, BENBI, D.K., 2009: Soil organic carbon sequestration in relation to organic and inorganic fertilization in rice-wheat and maize-wheat systems. *Soil and Tillage Research, 102:1. 87-92.*

SAINJU, U.M. et al., 2002: Long-term effects of tillage, cover crops, and nitrogen fertilization on organic carbon and nitrogen concentrations in sandy loam soils in Georgia, USA. *Soil and Tillage Research 63:3- 4. 167-179.*

## Contact address:

Ing. Milan Vach, CSc.
Crop Research Institute,
Drnovská 507, 161 06 Praha 6 – Ruzyně,
Czech Republic
E -mail: vach@vurv.cz
Phone: +420 233022248

# THE EFFECT OF SOIL CONDITIONERS ONTO PHYSICAL PROPERTIES IN SOILS OF ARID REGIONS

**V. Vlček, L. Pospíšilová, V. Hybler, J. Jandák**

[1]Mendel University in Brno, Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition, Zemědělská 1, Brno, Czech Republic, e-mail: wlkodav@seznam.cz

---

**Abstract**

Within the model project „Prevention of Soil biological degradation in arid climate conditions" was studied hydro-physical parameters of Arenosols in the area Ratiskovice. Experiment was running from 2008 to 2012 like a simulation of problematic sites representing the hypothetical situation by extension of arid climate on a larger territory of the Czech Republic for the next 50 years. The pilot project in condition of South Moravia region was deal with the possibilities of using soil conditioners, autochthonous species and less known drought-resist grasses and legumes for reclamation of dry soil. We can eliminate water stress in plants by different agro technical and technical arrangement based on knowledge of the physiological reaction of plants or using soil conditioners (natural or synthetic origin, it can in appropriate batch positively effect of soil properties).

**Key words**: *Arenosols, soil conditioners*

## Introduction

Soil, the main part of ecosystem, is a very complex system of solid particles, liquids and air. Pedogenesis and soil forming factors effected the basic soil properties. Parent material and climatic factor, microorganisms, relief, time, and anthropogenic factors are the main soil forming factors. According to (Vlček et al., 2010) that is why, we can expected also in the Central Europe, decreasing of precipitation, hot and dry summer on a larger part of the Czech Republic territory. This prediction is limited by high variability of climate in the Czech Republic, because of mixture between oceanic and continental climate. There is also today in this region lack of precipitation and drought during vegetation period. Soils are there mostly represented by Arenosols, Regosols and Leptosols, which are easily mineralized and disturbed. These soils are considered as light textured soils with non-stable structure, with low cation exchange capacity and lack of humus. Within the model project „Prevention of Soil biological degradation in arid climate conditions" was studied hydro-physical parameters of Arenosols at Ratíškovice. Experiment was running from 2008 to 2012. The aim of this study was to evaluate effect of soil conditioners and autochthonic grasses for soil recultivation.

## Material and methods

Soil profiles were located at Ratíškovice (N 48°52´, E 17°07´) in 2007, before application of soil conditioners – *see* Fig. 1. Three soil profiles were classified according to Němeček et al. (2001). Long-term field experiments were established in three variants and area of each experimental site was 10 368 $m^2$. Soil sampling was made since spring 2008 till autumn 2012. Following soil conditioners were applied into the depth 0.15 m:

- Agrisorb (hydro absorbent), application doze was 20 $g/m^2$ (200 kg/ha),
- Lignite (natural material, crush), application doze was 1 $kg/m^2$ (10 t/ha),
- Zeolite, application doze was 3 $l/m^2$ (30 $m^3$/ha).

Basic physical soil parameters were determined by standard methods. For determination of water and air regimes soil sampling was done in physical cylinders. We followed density, bulk density, porosity, and aeration, water holding capacity, hydrolimits, texture, structure and micro aggregate analysis (Jandák et al., 2010; Hraško et al., 1962).

**Results and discussion**

Soil conditioners represent wide group of different substances, which could directly affect soil environment, microorganisms, and plants (Chen et al., 2004; Salaš et al., 2012). We have found out that different soil conditioners in different way affected soil physical properties.
Retention capacity (RVK) after Agrisorb application showed statistically significant higher values to compare with control – *see* Fig. 2. Also application of Zeolite and Lignite leads to increasing of RVK values but results were not statistically significant. Maximum RVK values were determined in 0.15 cm during July and minimum in October. Monthly variation was of high significance. In general, values of RVK were very low and after soil conditioners application they were low. Maximum water holding capacity (MKVK) after application of Agrisorb, Zeolite, and Lignite increased by the results were not statistically significant. Different results were published by Bušinová and Pekař (2008), who stressed high water holding capacity of lignite. We suppose that lignite in form of hydrogel act in soil in different way to compare with natural crush lignite. Maximum of KVK values were determined in 0.15 cm during July and minimum in October. Monthly variation was of high significance. Bulk density of dry soil (OHR) after Agrisorb, Zeolite and Lignite application decreased but results were not statistically significant. Average porosity after Agrisorb, Zeolite and Lignite application increased but results were not statistically significant – *see* Tab. 1. In spring were results of porosity higher and in autumn was porosity low. Monthly variation was of high significance**.** Soil moisture was not statistically significant affected by selected conditioners. Content of agronomic valuable micro aggregates (2.00-0.50 mm) was very low as well as amount of colloids. Content of macro aggregates was the highest after Zeolite application. Monthly and yearly variation was not significant.

**Conclusion**

Soil conditioners could directly affect soil physical properties. After four years of application statistically significant effect of Agrisorb on to RVK was found.

**Acknowledgement**

This work was supported by the project of MŠMT No: 2B08020.

**Reference**

1. Bušinová, P., Pekař, M., 2008: Lignite behaviour in aqueous environment. In: VII. Pracovní setkání fyzikálních chemiků a elektrochemiků v Brně, Masarykova univerzita, 21-22.ISBN 978-80-210-4525-5.
2. Hraško, J. a kol., 1962: Rozbory pôd, SVPL Bratislava. 335s.
3. Chen, S. L., Zommorodi, M., Fritz, E. et al., 2004: Hydrogel modified uptake of salt ions and calcium in *Populus euphratica* under saline conditions. *Tree structure and functions,* 2004, 18: 175-183.
4. Jandák, J., a kol., 2010: Půdoznalství. Mendelova univerzita v Brně, 143s.
5. Němeček, J., 2001: Taxonomický systém půd České republiky. ČZU. Praha. ISBN 80-238-8061-6. 79s.
6. Salaš, P. a kol., 2012: Opatření vedoucí ke zamezení biologické degradace půd a zvýšení biodiversity v suchých oblastech ČR. Certifikovaná metodika. Mendelova univerzita v Brně. Grafex Agency Brno. 104s. ISBN 978-80-7375-585-0.

7. Vlček, V., Brtnický, M., Pokorný, E., 2010: Očekávané pedoklimatické změny na území ČR. [CD-ROM]. In Problematika sucha a možnosti její nápravy- sborník příspěvků. s. 1 ISBN 978-80-7375-432-7.

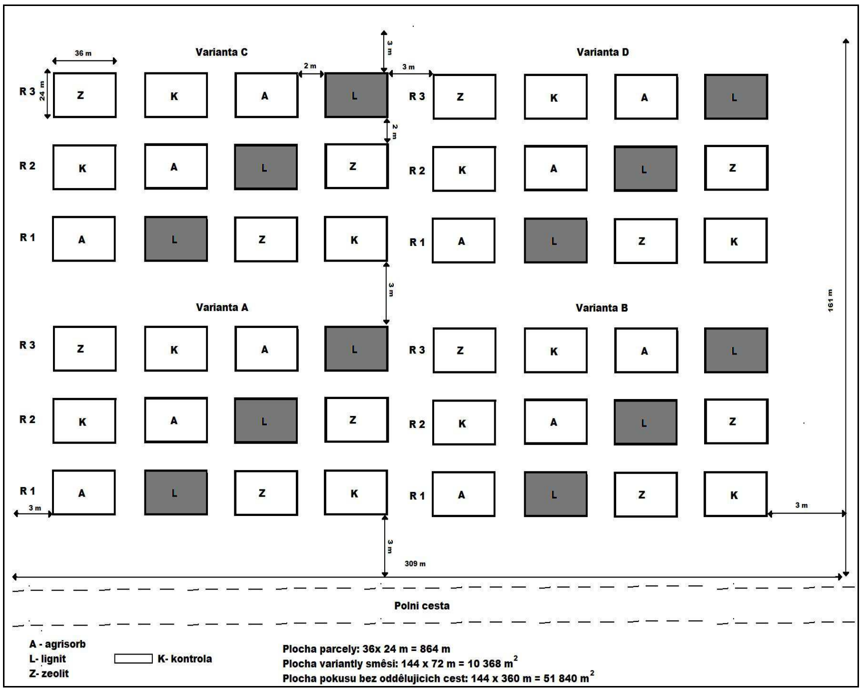



**Fig. 1: Schema of long-term field experiment at Ratíškovice**

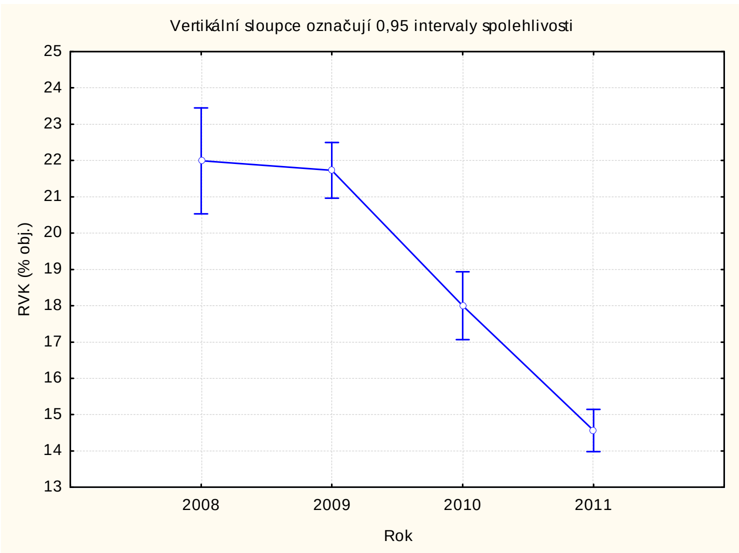



**Fig. 2: Statistically significant effect of Agrisorb on water retention capacity**

CONTENT

**Tab. 1: Average values of porosity (P, % vol.)**

(A = Agrisorb, L = Lignite, Z = Zeolite, K = control, B, C a E = experimental sites)

| Variant/depth | P (%) | Variant/depth | P (%) | Variant/depth | P (%) | Variant/depth | P (%) |
|---|---|---|---|---|---|---|---|
| B/15 cm | 37,40 | C/15 cm | 37,86 | E/15 cm | 37,36 | - | - |
| B/30 cm | 36,58 | C/30 cm | 37,29 | E/30 cm | 35,29 | - | - |
| B/45 cm | 36,78 | C/45 cm | 35,81 | E/45 cm | 35,12 | - | - |
| B | 36,92 | C | 36,99 | E | 35,93 | - | - |
| A/15 cm | 37,80 | L/15 cm | 37,59 | Z/15 cm | 37,89 | K/15 cm | 37,24 |
| A/30 cm | 37,28 | L/30 cm | 36,98 | Z/30 cm | 36,83 | K/30 cm | 36,74 |
| A/45 cm | 36,79 | L/45 cm | 35,35 | Z/45 cm | 36,42 | K/45 cm | 36,51 |
| A | 37,29 | L | 36,64 | Z | 37,05 | K | 36,83 |

**Contact address:**

Ing. Vítězslav Vlček, PhD.
Ústav agrochemie, půdoznalství, mikrobiologie a výživy rostlin
Mendelova univerzita v Brně
Zemědělská 1, 613 00 Brno
Česká republika
e-mail: wlkodav@seznam.cz

# IMPACT OF SOIL TILLAGE AT COMPACTION PHYSICAL PARAMETERS

**V. Vukadinović[1], D. Jug[1], I. Jug[1], B. Đurđević[1], S. Cvjetković[2], B. Stipešević[1], B. Brozović[1]**

[1]Faculty of Agriculture in Osijek, Croatia
[2]Agricultural Land Agency, Croatia

**Abstract**
This paper presents results of one-year trials of compaction at two sites in Croatian region Slavonia and Baranya. Trial has been set up as CRBD with five soil tillage treatments: 1-conventional (mouldboard ploughing), 2-conservation (chisell), 3-conservation (disk-harrowing), 4-conservation (paraplough), 5-direct drilling. At both sites in spring 2013 maize has been sown. Soil compaction and soil moisture has been observed twice per month, from mid-June to end-September 2013. Samples had been obtained from depths 5, 20 and 45 cm by Kopecky soil sampling cylinders ($V = 100\ cm^3$) on each soil tillage treatment. Statistical data analysis showed that at Čačinci site soil bulk density and soil moisture were in negative correlation. The strongest correlation has been obtained for disk-harrowing conservation tillage ($r = -0.501$), and weakest for conventional soil tillage ($r = -0.016$). At Magadenovac site soil bulk density and soil moisture were in positive correlation, which was unexpected. Correlation between compaction and depth had the strongest expression at Čačinci site, for conventional tillage ($r = 0.628$), and the weakest expression at Magadenovac site for paraplough ($r = 0.216$).

**Keywords:** soil compaction, bulk density and soil moisture correlation

## Introduction

Soil, as the one of the most important resources for human population food production, is undergoing different changes which are affecting its properties. Accelerated growth of human population created need for production of extra food. Result is growth of agricultural areas at global level, which is inevitably followed by wish of larger, faster and easier income from the food industry. Consequences in some regions are catastrophic, due to different kinds of soil and land degradations, on smaller or larger scale. One of the problems is higher energy consumption, where soil tillage is one of the largest energy consumers in crop production.

Pelizzi et al. in 1988 (quoted in: Filipović et al., 2005) presented that 55-65% of total energy consumption for field work is for soil tillage, due to waste energy requirement for cutting, breaking, turning, chopping and mixing of soil aggregates. According to Košutić et al. (2001) application of non-conventional soil tillage systems (conservational, reduced and no-tillage) can save significant amount of energy. Nevertheless, in Croatia, conventional soil tillage is still widely used, which results with additional soil compaction, one of the main soil physics properties degradation factor (Dilkova et al., 2002; Pagliai et al., 2003).

The resulting changes (Czyz, 2004) have deteriorating impact at crops in early development stages, due to limitation of germination, emergence and rooting into the depth, disturbance of water and nutrient uptake (McKenzie, 2010) , which significantly decrease crop yield.

The usage of heavy-duty mechanisation, large number of passes (Weisskopf et al., 2009) in conventional soil tillage compress soil aggregates into smaller volume, and at the same time deteriorate water-air ratio by decreasing volume of air and water pores. Very frequent outcome is overwetting of tilled and sub-tilled soil layers due to impaired free drainage

(Vukadinović et al., 2013), which decreases soil reaction and availability of nutrients to plant. According to research of Nikolić et al. (2003), the average crops grain yields can be reduced from 15 to 20% due to soil compaction.

The goal of the research presented in this paper is to establish how different soil tillage systems are affecting arable soils compaction through bulk density and moisture content at three different depths during the maize vegetation period.

## Materials and methods

Within the project "Conservation soil tillage as the measure of climatic changes mitigation", financed by the Ministry of agriculture of the Republic of Croatia, research has been conducted at two sites in Slavonia&Baranja region (Čačinci and Magadenovac). Trial on both sites has been set up in autumn of 2012, after CBRD design, with 5 different soil tillage treatments: 1-conventional (mouldboard ploughing), 2-conservation (chisell), 3-conservation (disk-harrowing), 4-conservation (paraplough), 5-direct drilling. In spring of 2013, mercantile maize crop has been seeded. From mid-June till end of September, twice per month, undisturbed soil samples had been taken by Kopecki cylinders (V= 100 $cm^3$) at all soil tillage treatments, from 5, 20 and 45 cm depths. Samples were used for determination of the bulk density (according to HRN ISO 11272:2004) and soil moisture content. Obtained data were statistically processed by package Statistica v.10 (StatSoft, Inc., 2011) in order to establish correlation of researched parameters for soil tillage treatments.

## Results with discussion

**Table 1. Correlation of soil tillage compaction parameters (soil depth, moisture content and bulk density) for different soil tillage systems**

| Site | Property | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c |
| Čačinci | a | 1.000 | - | - | 1.000 | - | - | 1.000 | - | - | 1.000 | - | - | 1.000 | - | - |
| | b | -0.049 | 1.000 | - | 0.114 | 1.000 | - | 0.178 | 1.000 | - | -0.145 | 1.000 | - | 0.299 | 1.000 | - |
| | c | 0.628** | -0.016 | 1.000 | 0.499* | -0.107 | 1.000 | 0.451 | -0.501* | 1.000 | 0.418 | -0.190 | 1.000 | 0.501* | -0.095 | 1.000 |
| Magadenovac | a | 1.000 | | | 1.000 | | | 1.000 | | | 1.000 | | | 1.000 | | |
| | b | 0.441 | 1.000 | | 0.369 | 1.000 | | 0.477* | 1.000 | | 0.314 | 1.000 | | 0.415 | 1.000 | |
| | c | 0.303 | 0.286 | 1.000 | 0.431 | 0.093 | 1.000 | 0.527* | 0.497* | 1.000 | 0.216 | 0.199 | 1.000 | 0.219 | 0.553* | 1.000 |

Legend: 1- conventional (mouldboard ploughing), 2-conservation (chisell), 3-conservation (disk-harrowing), 4-conservation (paraplough), 5-direct drilling.
a - soil depth, cm; b - soil moisture content, %vol.; c - bulk density, g $cm^{-3}$

In Table 1. are presented correlation coefficients for soil depth, moisture and bulk density. At Čačinci site the significant positive correlations have been found between soil depth and bulk density for conservation soil tillage by chisel ($r = 0.499^{*}$) and direct drilling system ($r = 0.501^{*}$). Very significant positive correlation ($r = 0.628^{**}$) has been recorded for conventional soil tillage, which can be connected with the higher clay content (Vukadinović et al., 2013). Bulk density and soil moisture were, as expected, negatively correlated. The lowest

correlation was obtained by conventional soil tillage (r = -0.016), and statistically significant was only for conservation soil tillage by disk-harrowing (r = -0.501*).
At another site (Magadenovac), bulk density and soil moisture were, unexpectedly, in positive correlation. In direct drilling system these two parameters were even significant (r = 0.553*). The lowest correlation of compaction and soil depth was established for soil tillage by paraplough (r = 0.216).
Conservation soil tillage by disk-harrowing resulted with significant positive correlation of the soil depth and compaction, expressed as bulk density (r = 0.527*), as with soil moisture content (r = 0.477*).

**Conslusions**
In Slavonia&Baranja region, on trial set up at two sites (Čačinci, Magadenovac), with 5 soil tillage systems (1- conventional (mouldboard ploughing), 2-conservation (chisell), 3-conservation (disk-harrowing), 4-conservation (paraplough), 5-direct drilling), based on samples of soil from three depths, following has been found:

- very significant positive correlation between soil depth and bulk density has been found under conventional soil tillage treatment at Čačinci site,
- negative correlation between bulk density and soil moisture at Čačinci site, but positive at Magadenovci site.

**References**
CZYZ, E. A., 2004: Effects of traffic on soil aeration, bulk density and growth of spring barley. Soil and tillage research. 79 (2): 153-166.
DILKOVA, R., JOKOVA, M., KERCHEV, G., KERCHEVA, M., 2002: Aggregate stability as a soil quality criterion. Options méditerranéennes, 7 International Meeting on Soils with Mediterranean Type of Climate. Série A n.50: 305-311.
FILIPOVIĆ, D., KOŠUTIĆ, S., GOSPODARIĆ, Z., 2005: Utrošak energije u konvencionalnoj obradi praškasto-glinastog tla u zapadnoj Slavoniji. Agronomski glasnik, 5: 383-392.
KOŠUTIĆ, S., FILIPOVIĆ, D., GOSPODARIĆ, Z., 2001: Maize and winter wheat production with different soil tillage systems on silty clay. Agricultural and Food Science in Finland, 10: 81-90.
MCKENZIE, R.H., 2010: Agricultural Soil Compaction: Causes and Management. Agri-Facts, Practical Information for Alberta´s Agriculture Industry. Agdex 510-1. www.agriculture.alberta.ca
NIKOLIĆ, R., FURMAN, T., GLIGORIĆ, R., POPOVIĆ, Z., SAVIN, L., 2003: Sabijanje zemljišta-uzroci, posledice, mere. Zbornik radova Naučnog instituta za ratarstvo i povrtarstvo Novi Sad. Vol.38: 37-48.
PAGLIAI, M., MARSILI, A., SERVADIO, P., VIGNOZZI, N., PELLEGRINI, S., 2003: Changes in some physical properties of clay soil in central Italy following the passage of rubber tracked and wheeled tractors of medium power. Soil and Tillage Research. 73: 119-129.
StatSoft, Inc., 2011: STATISTICA (data analysis software system), version 10. www.statsoft.com.

VUKADINOVIĆ, V., JUG, D., ĐURĐEVIĆ, B., JUG, I., VUKADINOVIĆ, V., STIPEŠEVIĆ, B., LOVIĆ, I., KRALJIČAK, Ž., 2013: Agricultural compaction of some soil types in eastern Croatia. Proceedings & Abstracts of 2nd International Scientific Conference: Soil and Crop Management: Adaptation and Mitigation of Climate Changes / Jug, I., Vukadinović, V., Đurđević, B., (ed.). CROSTRO - Croatian Soil Tillage Research Organization, Osijek, 26-28 September 2013. 38-45.

WEISSKOPF, P., OBERHOLZER, H-R., REK, J. (2009): Effect of Different Compaction Impacts and Varying Subsequent Management Practices on Soil Structure and Soil Air Regime. ISTRO 18th Triennial Conference Proceedings, June 15-19, 2009. Izmir, Turkey: T4-009, 1-7.

**Contact address:**

Izv. prof. dr. sc. Vesna Vukadinović
Poljoprivredni fakultet u Osijeku
Predstojnica Zavoda za kemiju, biologiju i fiziku tla
Kralja Petra Svačića 1d
HR-31000 Osijek
Croatia
tel.: +385 31 554 890, +385 31 554 950
e-mail: vvukadin@pfos.hr

# LIST OF PARTICIPANTS

## AUSTRIA

**Rosner** Josef
Office of the Lower Austrian Provincial Government,
Department of agricultural Education
Frauentorgasse 72
3430 Tulln
Austria
Email: josef.rosner@noel.gv.at
Phone: 0043664 4025477

**Rosner** Kathrin
Office of the Lower Austrian Provincial Government,
Department of agricultural Education
Student
Frauentorgasse 72
3430 Tulln
Austria

## CROATIA

**Brozović** Bojana
Faculty of Agriculture in Osijek
Kralja Petra Svacica 1d
31000 Osijek
Croatia
e-mail: bojana.brozovic@pfos.hr

**Durdević** Boris
Faculty of Agriculture in Osijek
Kralja Petra Svacica 1d
31000 Osijek
Croatia
e-mail: bdurdevic@pfos.hr

**Jug** Danijel
Faculty of Agriculture in Osijek
Kralja Petra Svacica 1d
31000 Osijek
Croatia
e-mail: djug@pfos.hr

**Jug** Irena
Faculty of Agriculture in Osijek
Kralja Petra Svacica 1d
31000 Osijek
Croatia
e-mail: irena.jug@pfos.hr

**Vukadinović** Vesna
Faculty of Agriculture in Osijek
Kralja Petra Svacica 1d
31000 Osijek
Croatia
e-mail: vvukadin@pfos.hr

## CZECH REPUBLIC

**Badalíková** Barbora
Agricultural Research, Ltd.
Zahradní 1
664 41 Troubsko
Czech Republic
e-mail: badalikova@vupt.cz

**Bárányiova** Irena
Mendel University in Brno
PhD. Student
Zemědělská 1
613 00 Brno
Czech Republic

**Bartlová** Jaroslava
Agricultural Research, Ltd.
Zahradní 1
664 41 Troubsko
Czech Republic
e-mail: bartlova@vupt.cz

**Dryšlová** Tamara
Mendel University in Brno
Department of Agrosystems and Bioclimatology
Faculty of Agronomy
Zemědělská 1
613 00 Brno
Czech Republic
e-mail: dryslova@mendelu.cz

**Elbl** Jakub
Mendel University in Brno
PhD. Student
Zemědělská 1
613 00 Brno
Czech Republic
e-mail: jakub.elbl@mendelu.cz

**Hamplová** Marcela
Supervisory Board
pensionable officer
667 01 Židlochovice
Czech Republic
e-mail: ondrej_ha@volny.cz
**Houšť** Martin
Mendel University in Brno
Department of Agrosystems and Bioclimatology
Zemědělská 1
613 00 Brno
Czech Republic
houst.martin@seznam.cz

**Horáček** Jan
University of South Bohemia
Faculty of Agriculture
Studentská 13
370 05 České Budějovice
Czech Republic
e-mail: horacek@zf.jcu.cz

**Hůla** Josef
[1]Czech University of Life Sciences Prague
Kamýcká 129
165021 Praha 6
[2]Research Institute of Agricultural Engineering p.r.i.
Drnovská 507
161 01 Praha 6-Ruzyně
Czech Republic
e-mail: hula@tf.czu.cz; josef.hula@vuzt.cz

**Hybler** Vítězslav
Mendel University in Brno
Departement of Agrochemistry, Soil Science,
Microbiology and Plant Nutrition
Zemědělská 1
613 00 Brno
Czech Republic
e-mail: hybler@mendelu.cz

**Chovancová** Světlana
Mendel University in Brno
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: svetlana.chovancova@mendelu.cz

**Jakabová** Lenka
Mendel University in Brno
Zemědělská 1
613 00 Brno
Czech Republic
e-mail: xjakabo1@node.mendelu.cz

**Jandák** Jiří
Mendel University in Brno, Zemědělská 1
Department of Agrochemistry, Soil Science,
Microbiology and Plant Nutrition
613 00 Brno, Czech Republic
e-mail: jandak@mendelu.cz

**Kintl** Antonín
Mendel University in Brno
Zemědělská 1
613 00 Brno
Czech Republic
e-mail: antonin.kintl@mendelu.cz

**Kovaříček** Pavel
Research Institute of Agricultural Engineering
Drnovska 507
161 01 Praha 6
Czech Republic
e-mail: pavel.kovaricek@vuzt.cz

***Kroulík** Milan*
Department of Agricultural Machines,
Faculty of Engineering, CULS Prague
Kamýcká 129,
165 21 Prague 6 - Suchdol
Czech Republic
e-mail: kroulik@tf.czu.cz

***Křen** Jan*
*Mendel University in Brno*
Faculty of Agronomy
Department of Agrosystems and Bioclimatology
Zemědělská 1
613 00 Brno
Czech Republic
e-mail: kren@mendelu.cz

**Lukas** Vojtěch
Mendel University in Brno
Faculty of Agronomy
Department of Agrosystems and Bioclimatology
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: vojtech.lukas@mendelu.cz

**Matušinsky** Pavel
Agrotest fyto, ltd.
Havlickova 2787
767 01 Kromeriz
Czech Republic
e-mail: matusinsky@vukrom.cz

**Nedělník** Jan
Research Institute for Fodder Crops, Ltd.
Zahradní 1
664 41 Troubsko
Czech Republic
e-mail: nedelnik@vupt.cz

**Neudert** Lubomír
Mendel University in Brno
Zemědělská 1
613 00 Brno
Czech Republic
e-mail: neudert@mendelu.cz

**Novák** Jaroslav
Mendel University in Brno
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: jaroslavxnovak@gmail.cz

**Pospíšilová** Lubica
Mendel University in Brno
Departement of Agrochemistry, Soil Science,
Microbiology and Plant Nutrition
Zemědělská 1
613 00 Brno
Czech Republic
e-mail: pospisi1@mendelu.cz

**Pražan** Radek
Research Institute of Agricultural Engineering
Drnovská 507
161 01 Praha 6-Ruzyně
Czech Republic
e-mail: radek.prazan@vuzt.cz

**Procházková** Blanka
Mendel University in Brno
Department of Agrosystems and Bioclimatology
Zemědělská 1
613 00 Brno
Czech Republic
e-mail: proch@mendelu.cz

**Rattanapichai** Wutthida
Mendel University in Brno
Student
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: xrattana@node.mendelu.cz

**Smutný** Vladimír
Mendel University in Brno
Department of Agrosystems and Bioclimatology
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: smutny@mendelu.cz

**Šedek** Antonín
P & L, spol. s r. o.
Biskupice 206
763 41 Biskupice u Luhačovic
e-mail: asedek@pal.cz

**Vach** Milan
Crop Research Institute
Dept. of Crop Growing Technologies
Drnovská 507
161 01 Praha 6 – Ruzyně
Czech Republic
e-mail: vach@vurv.cz

**Vlček** Vítězslav
Mendel University in Brno
Department of Agrosystems and Bioclimatology
Zemedelska 1
613 00 Brno
Czech Republic
e-mail: wlkodav@seznam.cz

**Winkler** Jan
Mendel University in Brno
Department of Agrosystems and Bioclimatology
Zemědělská 1
613 00 Brno
Czech Republic
e-mail: winkler@mendelu.cz

## HUNGARY

**Lehoczky** Éva
Institute for Soil Sciences and Agricultural Chemistry
Centre for Agricultural Research,
Hungarian Academy of Sciences
Herman O. str. 15.
1022 Budapest
Hungary
e-mail: lehoczky.eva@agrar.mta.hu

| | |
|---|---|
| ***Title of publication:*** | Soil management in sustainable farming systems |
| ***Manner of publication:*** | Proceedings from International Conference |
| ***Authors of publication:*** | Collective of Authors from Contents |
| ***Editor:*** | Barbora Badalíková |
| ***Edition:*** | 50 copies |
| ***Format:*** | CD |
| ***Printing station:*** | Vladimír Konopáč**,** Veverská Bitýška, Czech Republic |
| ***Publisher:*** | Research Institute for Fodder Crops Ltd.,<br>Troubsko, Czech Republic |

**ISBN 978-80-86908-32-8**