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International Conference
Czech Branch of ISTRO

Pruhonice August 31 – September 2, 2011

HOTEL "FLORET"

CONTENT

Section I

Section I

Degradation Processes taking Place in Soils under Conditions of Different Tillage

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Abstract

Differences in physical properties of soil and the degradation processes in different variants of tillage were followed in three localities of individual production regions with different soils. Experiments were performed within the period of 2008 – 2010 under field conditions and it was found out that although the technologies of minimum tillage increased values of soil bulk density, they also improve its water reserves in periods of lower rainfalls. The highest values of reduced bulk density were recorded in locality Lesonice with modal brown soils. In this locality also the most intensive processes of soil physical characteristics degradation were observed. Experiments involved also the monitoring of yields in all localities; the lowest ones were recorded in variants with conventional ploughing.

Keywords: soil physical properties, soil tillage, crop yields, soil degradation

Introduction

Fertility is the basic property of soil. It cannot be characterised only by its one or a few properties; soil fertility is the result of joint action of a very complex set of many factors that mutually influence each other. These properties may be very variable (e.g. temperature, soil humidity etc.) and this fact induces qualitative changes not only in individual soil characteristics but also in its fertility. Changes in soil fertility taking place under conditions of different methods of soil processing were studied also by Birkás et al. (2007) who demonstrated that physical properties of soil were the primary factor, which determined the soil fertility.

Changes caused by tillage are at most manifested and reflected in the reduced bulk density of soil, which represents its basic physical characteristic. Bulk density influences a whole complex of physical properties of soil, i.e. its porosity, air and water holding capacity, heat conductivity etc. These changes are associated with simultaneous changes in content, availability and movement of water in soil (Pokorný et al., 1998). An inappropriate method of tillage, however, may influence and change many processes that take place in soil; they can be either reversible or irreversible and this usually results in the occurrence of soil degradation and in the subsequent loss of its basic function (i.e. soil fertility). According to Birkás (2008), if operations of ploughing and/or deep soil loosening are preformed under conditions of too high soil humidity, the inevitable consequence of this is soil compaction and damage.

Material and methods

Studies on effects of tillage on the pedosphere were performed within the framework of monitoring physical soil properties in the period of 2008 – 2010. Experiments were performed in three localities situated in different growing regions, viz. in Hrusovany nad Jevisovkou (maize-growing region); Uncovice (sugar-beet-growing region) and Lesonice (potato-growing region). The physical condition of soil was studied using Kopecky stainless steel cylinders and estimated were the following parameters: reduced bulk density, total porosity, actual contents of air and water, maximum water holding capacity and minimum air holding capacity. Reduced volume density is defined as the weight of a unit volume of anhydrous soil (dried at 105 °C). This value characterises the state of soil looseness or compactness. Values of the reduced volume density range from 1.0, i.e. very loose soils to 1.6, i.e. very compact

soils, above all in the subsoil (B horizon). Values of reduced volume density are used when calculating the weight (mass) of topsoil (A horizon) and its other components. Changes in volume density result in conditions defined as looseness and/or compactness of soil.
Soil samples used for the estimation of physical properties of soil were taken in three depths (i.e. 0-0.10, 0.10-0.20 and 0.20-0.30 m). at the beginning and to the end of the growing season.
The following three variants of tillage were applied in all three localities:

Variant 1 – conventional, ploughing to the depth of 0.22 m
Variant 2 – deep soil loosening to the depth of 0.35-0.40 m
Variant 3 – shallow tillage to the depth of 0.15 m

Yields of individual crops were recorded and evaluated within the framework of monitoring effects of soil processes on yield characteristics of individual cultivated crops. The crop turnover system involved the following crops: winter wheat, maize, and spring wheat. In 2009, there was a slight difference in cultivated crops among these three localities as in Hrusovany nad Jevisovkou maize was grown for grain while in localities Uncovice and Lesonice this crop was grown for silage. Also in 2010 there was a difference between Hrusovany nad Jevisovkou on the one hand and localities Uncovice and Lesonice on the other; because of technical reasons, spring wheat had to be sown instead of winter wheat in the latter two.

Soil and climatic conditions
Hrusovany nad Jevisovkou – maize-growing region, altitude 210 m; average annual sum of precipitation 461 mm; warm and semiarid zone; medium-heavy, Modal Chernozem.
Uncovice – sugar-beet-growing region; altitude 227 m; average annual sum of precipitation 536 mm; warm and slightly humid zone; medium-heavy to heavy Luvic Chernozem.
Lesonice – potato growing region; altitude 510 m; average annual sum of precipitation 567 mm; slightly warm and slightly humid zone; medium-heavy to heavy, Stagno-gleyic Luvisol.

Results and discussion
Higher values of bulk density change the ratio between water holding and air holding capacities of soil in favour of the former reduce the total soil porosity and increase the percentage of capillary pores (Czyz, 2006). The tillage technology influences the development of and changes in soil structure, porosity and bulk density (Badalíková and Hrubý, 2008) and consequently also crop yields. Although the method of soil processing can influence its bulk density but it does not change its stability *per se*.
There are many factors that influence the soil bulk density. In general, however, this parameter is usually considered to be the most important indicator of the physical condition of soil. Increasing or decreasing values of bulk density influence the rate of mineralisation of organic matter.
It was found out in this experiment that in localities Hrusovany and Lesonice, average values of reduced bulk density gradually decreased; the most marked changes were observed in Variant 3 with minimum tillage (Figs 1 and 3). In Variant 1 (conventional ploughing), there was a significant difference between years 2008 and 2010. As compared with other localities, the lowest values of reduced bulk density were recorded in Uncovice (Fig. 2). Relatively balanced values were found out in Variant 1 and the most marked differences existed in Variant 3 with shallow tillage. Statistically significant differences existed between Variant 2 (deep loosening) and Variant 3 (shallow tillage). In the locality Lesonice, no significant differences between individual variants of soil processing were found out; the only significant difference existed between years 2008 vs. 2009 and 2008 vs. 2010. In this locality, however,

the highest degree of soil compaction was found out. Within the period of 2008 – 2010, values of reduced bulk density increased with the depth of soil in nearly all variants of soil processing. As compared with subsoil, lower values of reduced bulk density were recorded in all experimental variants (Tab. 1).
In locality Lesonice, values of reduced bulk density ranged from 1.6 (Variant 3) to 1.74 (Variant 1 – subsoil); this result indicated a damaged soil structure. Measured values overpassed the agro-ecological limit for medium-heavy soils so that this soil could be characterised as compacted. Although in subsequent years the values of reduced bulk density decreased, in Variant 3 values of reduced bulk density in the subsoil remained above the critical limit defined for this type of soil. Differences in reduced bulk density, as measured at the beginning and to the end of growing season, were dependent on the sum of precipitation in each of experimental localities. As compared with Variant 1, there was a visible decreasing trend in values of reduced bulk density in Variant 3 in the second and in the third year of study; in Variant 1, an increase in values of reduced bulk density in subsoil was observed in localities Hrušovany and Lesonice. The significance of differences existing among data measured in individual years is illustrated in Figs 1 and 3. In the locality Uncovice, all values of reduced bulk density remained at the same level and the differences between individual variants and years were not significant (Fig. 2). In this locality, the highest degree of compaction was found out in Variant 2. Also Blecharczyk et al. (2007) observed that, as compared with conventional ploughing, higher values of bulk density occurred in variants with minimum tillage, above all in the depth of 10 – 20 cm. However, increased values of reduced bulk density contributed to a better water-holding capacity of soil (Czyz and Dexter, 2009). These authors corroborated that the most stable values of soil humidity occurred in variants with reduced tillage. However, the degree of soil compaction must not exceed the critical limit because otherwise the infiltration capacity of soil is impaired and it can become either dry or water-logged and thus unsuitable for crop production.

Table 1: Reduced bulk density of soil (g.cm^{-3}) in variants with different methods of tillage

Variants	depth (m)	Hrusovany			Uncovice			Lesonice		
		2008	2009	2010	2008	2009	2010	2008	2009	2010
1	0 - 0.1	1.57	1.35	1.38	1.37	1.33	1.34	1.44	1.30	1.31
	0.1 - 0.2	1.56	1.50	1.49	1.32	1.40	1.40	1.60	1.54	1.40
	0.2 - 0.3	1.67	1.55	1.49	1.50	1.50	1.46	1.74	1.61	1.49
2	0 - 0.1	1.45	1.23	1.37	1.40	1.28	1.39	1.62	1.35	1.23
	0.1 - 0.2	1.58	1.50	1.53	1.56	1.49	1.45	1.66	1.52	1.59
	0.2 - 0.3	1.63	1.52	1.52	1.63	1.52	1.55	1.66	1.59	1.49
3	0 - 0.1	1.54	1.16	1.32	1.45	1.28	1.26	1.60	1.34	1.29
	0.1 - 0.2	1.53	1.49	1.56	1.45	1.34	1.61	1.70	1.60	1.53
	0.2 - 0.3	1.57	1.52	1.46	1.48	1.40	1.57	1.72	1.67	1.51

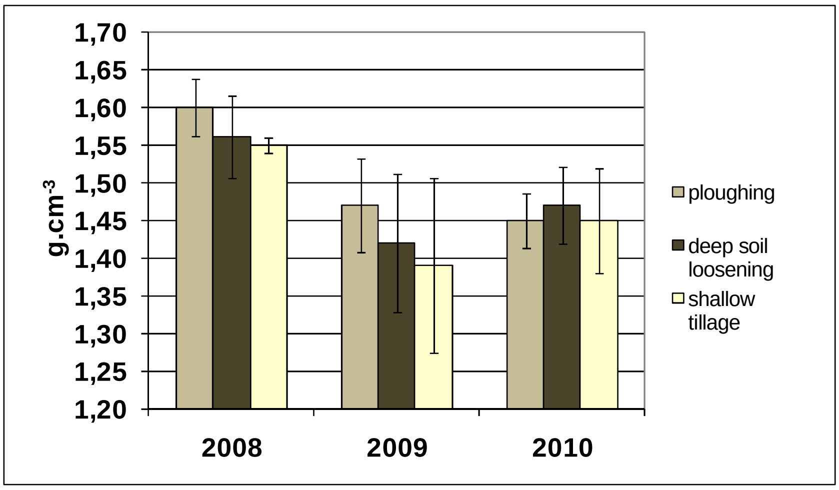

Figure 1: Average values of reduced bulk density with error abscissas as calculated for individual years under study – Hrusovany nad Jevisovkou

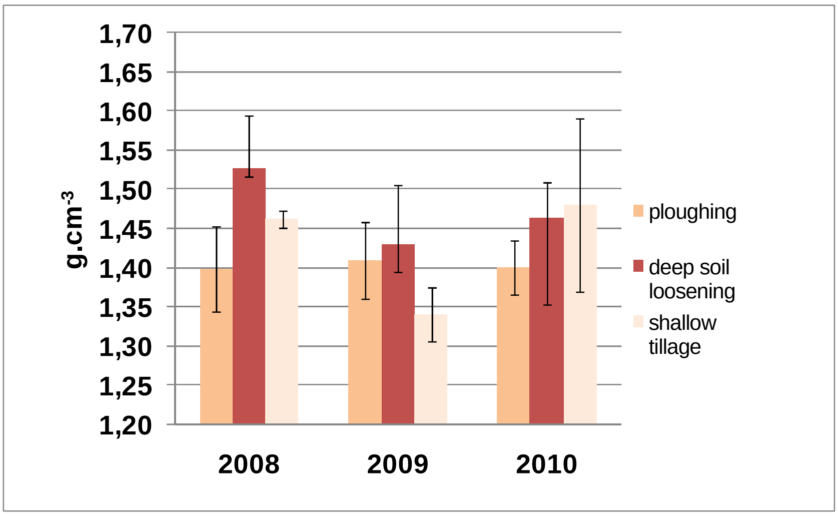

Figure 2: Average reduced bulk density values with error abscissas as calculated for individual years under study – Uncovice

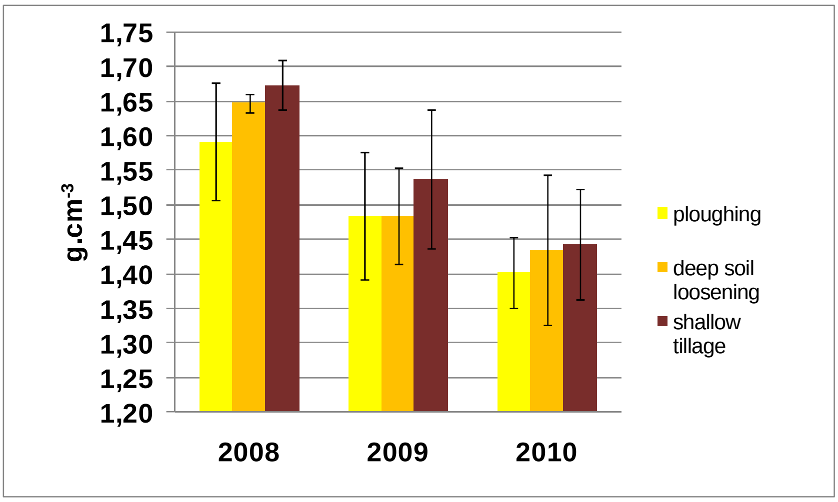

Figure 3: Average reduced bulk density values with error abscissas as calculated for individual years under study – Lesonice

Table 2: Crop yields (t.ha^{-1}) in variants with different methods of tillage

Variants	Hrusovany			Uncovice			Lesonice		
	2008	2009	2010	2008	2009	2010	2008	2009	2010
1	4.23	11.54	3.28	2.98	20.26	3.28	2.27	15.58	2.86
2	4.43	13.16	3.34	3.05	20.31	3.31	4.21	17.38	2.88
3	4.98	11.68	3.38	3.20	24.60	3.61	3.93	16.46	2.92

2008 – winter wheat (Hrusovany, Uncovice, Lesonice), 2009 – maize for silage (Uncovice, Lesonice), maize for grain (Hrusovany), 2010 - winter wheat (Uncovice, Lesonice), spring wheat (Hrusovany)

Yields of individual crops were influenced by soil tillage. As shown in Tab. 2, the lowest yields were recorded in Variant 1 in all three localities. In 2008, the highest yields were recorded in Variant 3, (Hrusovany and Uncovice) and in Variant 2 (Lesonice). In 2009, the highest yields in Hrušovany and Lesonice were in observed Variant 2 while in Uncovice in Variant 3. In 2010, the highest yields were recorded again in Variant 3 in all three localities. In the locality Lesonice, there was a significant difference in yields obtained in Variant 1 (conventional ploughing) and Variant 2 (deep loosening) in years 2008 and 2009. As mentioned by Vopravil et al (2010), degradation factors influencing the soil and its texture could be manifested rather differently.

The most important causes of compaction of the ploughing layer and subsoil are as follows: acidification, losses of organic matter and impaired biological diversity. These phenomena and their occurrence result in a decrease in production potential of soil and for that reason it is necessary to look for such methods of optimum tillage that correspond with given pedological and climatic conditions and assure the sustainability of soil fertility.

Conclusions

Within the framework of three-year experiments, the lowest soil damage was observed in the locality Uncovice because the values of reduced bulk density did exceed a critical limit. The only exception was observed in Variant 2 (deep soil loosening) in 2008. In Hrusovany and Lesonice, the measured degree of soil compaction (an above all of subsoil) was higher in all three variants of tillage. The obtained results indicate that these localities are more susceptible to soil degradation and for that reason it is necessary to pay increased attention to methods of tillage and crop turnover. Higher yields were recorded always in variants with zero ploughing.

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Increase in Penetrometric Resistance of Soil in Selected Localities in the Neighbourhood of the Brno City, Czech Republic

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Abstract
Processes of soil compaction were studied by means of the method of penetrometric resistance estimation within the period of 2009 – 2011. Measurements were performed on two plots in the cadastre of the village Blažovice (approximately 20 km eastward from Brno). Both plots were situated in the temperate, slightly arid climatic region. Soil type was classified as Chernozem developed on medium-heavy, loamy soil without skeleton. Penetrometric resistance was measured in intervals of 4 cm in the depth of 0.04 do 0.32 m. Individual measurements were performed on plots in a uniform manner to characterise the variability of soil condition on experimental plots. Obtained results indicated that the physical properties of soil were deteriorated after two years of tillage and that values of penetrometric resistance exceeded critical limits on both plots.
Keywords: Chernozem, penetrometric resistance, soil compaction

Introduction
Intensification of agricultural production is accompanied by an increased pressure on physical properties of soil. When using unsuitable methods of soil tillage, its physical, chemical and biological properties are damaged and deteriorated and just the soil compaction is one of very important indicators of its physical damage.
It is estimated that approximately 33 million hectares are compacted in Europe. In the Czech Republic, 45 % of agricultural soils are endangered by processes of soil compaction and of this approximately 15 % are showing a genetic compaction resulting from natural parameters of heavy soils. This primary, natural pedocompaction takes place within the framework of soil formation processes (soil genesis) and the hardened and compact horizons are the result. The anthropogenic pedocompaction is the result of operation of heavy machinery and off-road vehicles (Šarapatka *et al*., 2008). Although this technogenous compaction may affect soils of any texture, its effect on medium-heavy to heavy soils is more pronounced. Compaction reduces the effective depth of soil profile, limits infiltration of water, deteriorates the retention (i.e. water-holding) capacity of soil and accelerates erosion (Novák, P., 2000). Because compacted soils contain less water, nutrients and air, not only the development of roots and the growth of plants (Lowery and Shuler, 1991; Lipiec *et al*, 2003) but also the existence of various organisms in soil are negatively influenced and inhibited (Whalley *et al*., 1995).
Abu-Hamdeh (2003) studied effects of movement of off-road vehicles on soil compaction and found out that an increased soil compaction resulted in decreased yields of field crops on the one hand and increased soil bulk density on the other. Plants on compacted plots had a greater concentration of roots near the base of the plant compared with the plants on the zero-load plots.
Chernozem soils are a typical soil type in South Moravia. They cover 17.8 % of agricultural land and represent one of the most fertile types of soils in the Czech Republic. They are predominantly used as arable land for growing of the most demanding crops (e.g. maize and sugar beet).
In this study, we tried to follow changes in soil compaction occurring after two years of tillage.

Material and methods

Soil compaction was monitored on two plots in the cadastre of the village Blažovice at 246 m altitude (sugar beet growing region). Both plots were situated in the temperate, slightly arid climatic region. The average annual sum of precipitation here is 500 mm and average annual temperature is 8.4° C.

The soil type was classified as Chernozem developed on medium-heavy, loamy soil without skeleton.

On experimental plots, either a shallow disk tillage to the depth of 0.12 m of deep losening to the depth of 0.30 m were performed. Variants of crop and tillage combinations were as follows:

- Plot 1 – shallow disk tillage and winter wheat (2008 and 2009); deep soil loosening and sugar beet (2010) and again shallow disk tillage plus winter wheat (2011);
- Plot 2 – deep soil loosening for sugar beet (2008), shallow disk tillage and spring barley (2009), shallow disk tillage and maize for silage (2010), and shallow disk tillage plus winter wheat (2011).

The degree of soil compaction was monitored with the penetrometric electronic probe PN-010 (hereinafter mentioned only as penetrometer). Measurements were performed in the spring in years 2009 and 2011. Experimental plots were divided into a uniform network of control (sampling) points. The number of these sampling points was determined on the base of plot area (i.e. 3 per 10 hectares). In each sampling point altogether three probes were performed in a regular spacing (each in the distance of approximately 5 metres from the sampling point). On each plot, soil samples were collected from the depth of 0 – 0.30 m using a soil tube to estimate the content of moisture within the soil profile. The obtained values were used for the estimation of critical values of penetrometric resistance (tab. 1). The results were evaluated in Microsoft Excel programme and expressed by linear regression.

Table 1: Limit values of penetrometric resistance in MPa for compacted soils (Lhotský 2000)

Soil type	Penetration resistance (MPa)	Moisture (% weigh)
J	2.8 - 3.2	28 - 24
JV -JH	3.3 -3.7	24 -20
H	3.8 - 4.2	18 - 16
PH	4.5 - 5	15 - 13
HP	5.5	12
P	6	10

Note: J – clay; JV – clayey soil; JH – clayey-loamy soil, H – loamy soil;
PH – sandy-loamy soil; HP – loamy-sandy soil; P – sandy soil

Table 2: Classes of penetrometric resistance (Arshad et al., 1996)

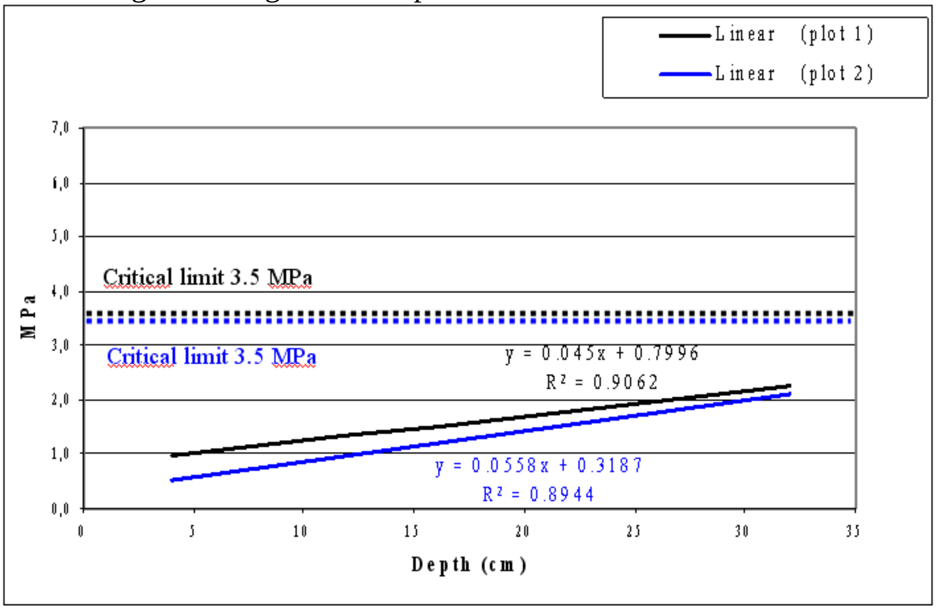
Class	Penetration resistance (Mpa)
extremely low	< 0.01
very low	0.01 -1
low	0.1 - 1
middle	1 -2
high	2 - 4
very high	4 - 8
extremely high	> 8

Results and discussion

Problems concerning soil compaction were studied by many authors and most frequently effects of various methods of tillage on cultivated crops were evaluated (Hao *et al.*, 2000; Moret *et al.*, 2007).

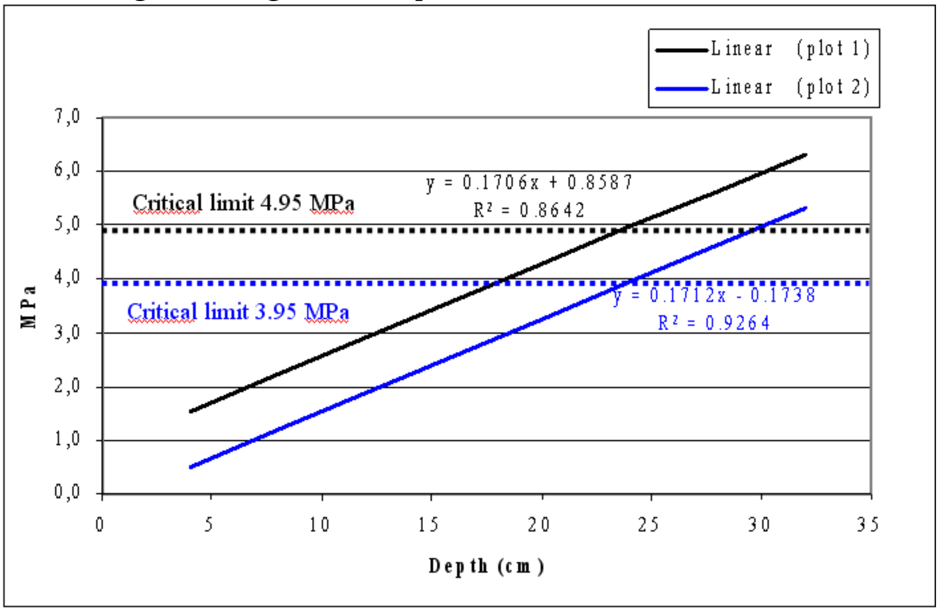
In the first experimental year (2009) measurements were performed under condition of optimum soil moisture content (17 and 18 weight %). On our experimental plots, values of penetrometric resistance gradually increased with the depth and ranged from 0.3 to 2.1 MPa (Fig. 1). The critical value of 3.5 MPa was not recorded. The penetrometric resistance of the ploughing layer was classified as low (approximately to the depth of 0.08 m) and medium (in depths below 0.08 m) (Arshad *et al.*, 1996).

Figure 1: Regression of penetrometric resistance in 2009



In the second experimental year (2011), the measuring of penetrometric resistance was performed in the same sampling points but under conditions of a decreased soil moisture content (12 and 17 weight % on Plots 1 and 2, respectively); due to this fact, the measurements were more demanding. Values of penetrometric resistance gradually increased with the depth of sampling on both plots. However, this increase in resistance reached the critical limit already in the depth of 0.2 – 0.24 m; on Plot 1 this values was equal to 4.95 MPa while on Plot 2 it was 3.95 MPa (Fig. 2). It was also possible to conclude that – as compared with the first year of measuring – there was a considerable increase in penetrometric resistance in individual depths of sampling. This increase could be caused by not only from a higher degree of soil compaction but also by measuring under less favourable moisture conditions (above all on Plot 1). According to Brtnický *et al.* (2008), the pedocompaction is a type of soil degradation with cumulative character and eventually the hardened layer forms.

Figure 2: Regression of penetrometric resistance in 2011



The penetrometric resistance can be classified as low only on the soil surface (down to 0.04 m and 0.08 m on Plots 1 and 2, respectively). On Plot 2, it was classified as middle and high in depths of 0.12 m and 0.16 m, respectively. Very high values of penetrometric resistance were classified below 0.16 m and 0.24 m on Plots 1 and 2, respectively. As compared with Plot 2, soil on Plot 1 was more compacted after the first measuring; two years later this situation remained to be unchanged but the difference between values individual values increased. On localities under study, shallow disk tillage to the maximum depth of 0.12 m was used most frequently and only for the sugar beet crop the depth of deep loosening to the depth of maximally 0.3 m was used. According to various authors, the minimum tillage of the ploughing soil layer resulted in its compaction (Lampurlanés and Cantero-Martinéz, 2003; Ledvina *et al*., 2004; Sidhu and Duiker, 2006).
Abu-Hamdeh *et al*. (1999) found out in their experiment that cone penetration resistance was affected by axle load and tillage treatments in depths of from 0 – 0.24 m. However, in depths of 0.24 – 0.48 m, cone penetration resistance was affected by tyre inflation pressure and axle load.

Conclusions

Results of penetrometric measurements indicate that within a period of only two years of tillage, the degree of Chernozem soil compaction of soil may be increased very markedly. On fields under study, critical values of compaction were recorded; this result indicated the selected method of soil management was not adequate. The surface soil layer should be loosened to greater depths of the soil profile and also the machinery and off-road vehicles have to selected with regard to the existing type of soil.

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Evaluation of water infiltration on grassland and her antierosion protection

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Abstract
In consequence of the increasing of the total level and productivity of agricultural production, the land area which is not utilised for food production is enlarged. With the help of the infiltration speed the influence of grassland regeneration due to additional grass seeding was evaluated. For the measuring a rain simulator with a measuring surface of 0.5 m^2 is used. At a rainstorm intensity from 50 to 100 $mm.h^{-1}$ the rainfall kinetic energy ranges from 19 to 27 $J.m^{-2}.mm^{-1}$. The balance infiltration speed and the beginning of the area surface runoff during an intensive rainfall are comparable parameter characteristics for defined soil properties and the measuring site. Under the simulated rain intensity of 87.78 $mm.h^{-1}$ the dependence of the water infiltration speed on the slope angle, the soil surface coverage and the soil water content was confirmed for the soil layer in the depths of up to 50 mm.
Keywordgrass, biomass, ecology, infiltration, soil

Introduction

Grassing has a significant influence upon the soil management system and the maintenance of the agricultural land potential in the Czech Republic. Grasslands occupy an area of 950 thousand hectars in the Czech Republic, i.e., 22.2% of the agricultural land. The vast majority of these grasslands is located in less favourable areas, which has an impact on their production potential and determines their non-production functions in the countryside (erosion control, transformation, landscape forming and the impact on biodiversity). Reduction of soil water infiltration leads to increasing the rainfall water surface runoff and soil erosion. Soil washing-out by water can cause soil degradation mainly in the slopped plots. Knowledge of water motion speed in the soil is of significant importance for agriculture and environment protection. Rainfall water transport from the soil surface to the groundwater surface is characterized by soil unsaturated hydraulic conductivity. The earth rinsing by rainfall water could have considerable effect on soil degradation mainly on slopped plots. On this and other determinate plots, mainly in marginal regions, is expected the energy crops growing. Among these crops also belongs the grassland.

Material and methods

For the monitoring of the water surface runoff during intensive rainfalls a rain simulator with a measurement area of 0.5 m^2 was used. At a rainstorm intensity from 50 to 100 mm h^{-1} and the rainfall kinetic energy at our equipment ranged from 19 to 27 J m^{-2} mm^{-1}. The balance infiltration speed and the beginning of the water surface runoff during intensive rainfalls are comparable parameters. The course of the surface runoff speed depending upon the time of the rainfall is influenced by the characteristics of the plot – the slope angle, cover abundance, soil surface roughness in the direction of the fall line and soil qualities – mainly the soil water content in the surface layer up to 0.1 m. For the water soil infiltration speed measurement in terrain are used both one- or two-cylinders infiltrometers. The principle is based on of monitoring of water level degrease in the measuring cylinder at regular time interval.
The jet rain simulators with by order higher measuring area (10 - 100 m^2) have a high need of construction labour under field conditions and as compared with the small-area simulators they showed a higher heterogenity of the measuring area sprinkling intensity. We have used the compromise approach when solving that problem, e.g. the rain simulator construction for

area of 0,5 - 1 m^2 under the following requirements:

- For determination of water vertical infiltration into soil and earth proportion in the surface runoff to measure continuously the sprinkling intensity and water surface runoff from the measuring area (soil surface slipping 2 - 7°),
- In the measuring area (and in order to avoid the horizontal infiltration effect also in its ambient to distance 50 % of measuring surface size), will be a high drops area density and regularity,
- Repeatability of sprinkling intensity will be with accuracy of ± 5 %,
- Sprinkling intensity within 40 - 200 $mm.h^{-1}$ will be constant during the whole measuring time,
- Limitation of the maximum sprinkling height to 1,5 m, what enable an effective protection against wind by means of side stops or natural rain by means of a shelter
- Limitation of the maximum sprinkling height to 1,5 m, what enable an effective protection against wind by means of side stops or natural rain by means of a shelter.

The basis of the sprinkler is a nozzle with the cone scattering in height of 1 m above centre of the measuring area. The square measuring area of 0,5 m^2 is bounded by the sheet barriers and is located in the site with a slight inclination (2 to 7°). At the bottom edge of the measuring area is situated collector gathering the runoff water into the pipe. Time course of defined constant sprinkling intensity and runoff water from the measuring site are the crucial parameters for determination of flood beginning and infiltration speed. For earth proportion determination in the runoff water can be also compared the soil surface water erosion with parallel performed measurements. For evaluation we have carried-out the comparative measuring: A- on the plot with permanent grassland 5 weeks after mowing, B- on fescue stubble 1 week after harvest and C- on free plot without crop - fallow stand. To determine the soil permeability for water and water surface runoff we have utilized method of infiltration speed measuring. The utilized artificial spraying equipment can adjust the measuring site spraying intensity on area of 0,5 m^2 with water, maintain that intensity on constant level during whole measuring period and read the water runoff from measuring site defined area in determined time interval. From the known spraying intensity and water runoff time course from the measuring area can be calculated the water infiltration speed into soil and water surface runoff speed.

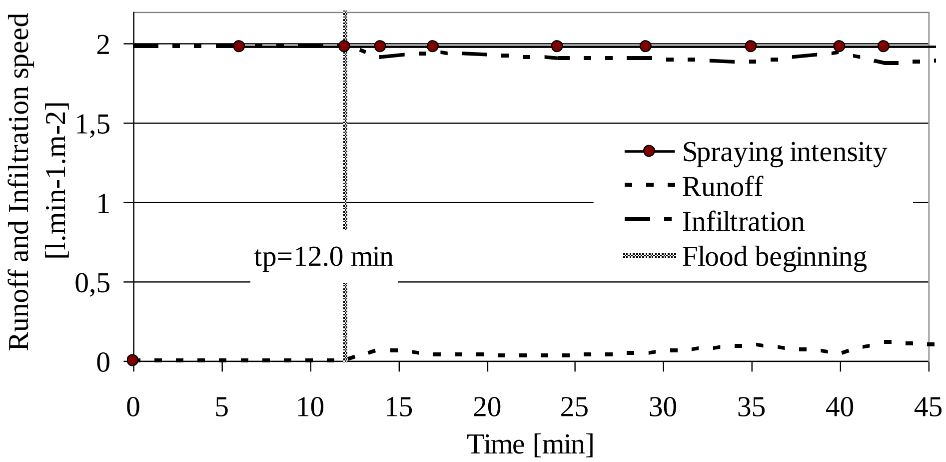

Figure 1: Example of graphical course in time of the water infiltration in the soil and water surface runoff speed with the marking of the beginning of the surface runoff tp for permanent grasslands. For the comparative measuring was chosen the spraying pressure of 200 kPa for

all variants with the spraying intensity 1.98 $l.min^{-1}.m^{-2}$. This corresponds with the regular rainfall of 118 $mm.h^{-1}$. The sites were chosen to vary as least as possible in plot inclination and type of soil. Moisture before spraying is at approx. identical level of 15 % by weight for the variants with permanent grassland and fallow without crop cover. For fescue that moisture is by almost 6 % lower. The soil roughness was evaluated only in the variant soil without crop cover.

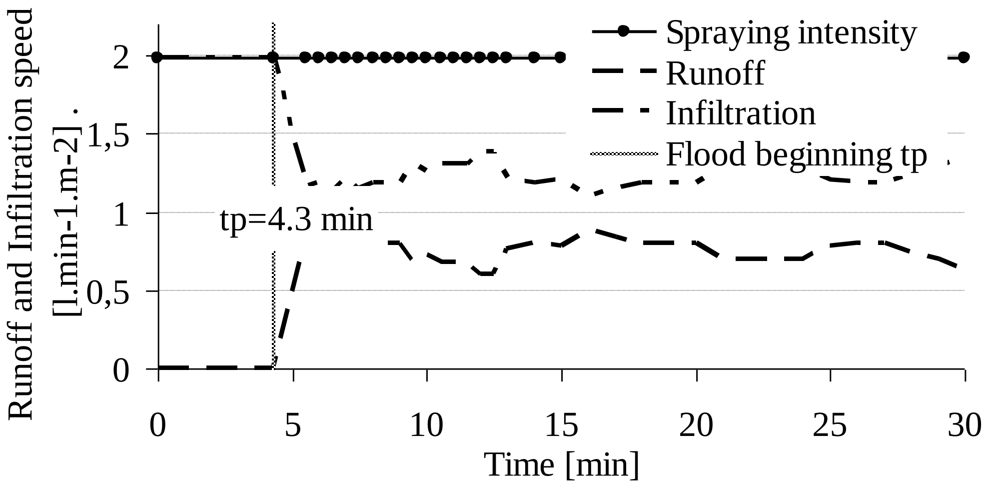

Figure 2: Example of graphical course in time of the water infiltration in the soil and water surface runoff speed with the marking of the beginning of the surface runoff tp for Fescue – monoculture

Results and discussions

The working place was equipped by the rain simulator of measuring surface of 0.5 m^2 and eligible sprinkling intensity from 40 to 150 $mm.h^{-1}$ for the purpose of infiltration speed measurement under the operational conditions. The infiltration speed is determined from the defined constant rain intensity within the whole measuring time and water surface run-off from the measuring area. These values are recorded in the regular time interval. The water run-off beginning from the measuring surface is given by the time of flood start. The measuring time is finished after the cultivation speed stabilization. The retained water surface run-off was read in interval of 30 s in measuring cylinders. Manual reading was carried-out by two people but the record accuracy has not been sufficient. This contributed to proposal and realization of the water surface run-off measuring by weighing with digital balance with weigh ability of 6 kg. The balance is with covering level IP 65 and is suitable for the field measuring conditions. The data are transferred automatically into PC through communication live RS 232. After the data evaluation from the digital balance to PC the program INVA was set up. This program enables to choose the reading interval from 1 to 9999 s, time data and water measured weight are recorded immediately in the memory medium. For control and visual assessment of the retained water run-off its increment is evaluated. It is possible to record accurately the beginning and course of the water surface run-off. The data are displayed continually on monitor.

For mutual comparison of water soil permeability (infiltration) and water surface runoff among the variants we have transferred the measured values to their instantaneous unit speed during the recorded time intervals. This method will enable to compose also the values of measuring which have not identical measuring interval. Besides the runoff and infiltration speed the important indicator is the flood beginning, i.e. the surface water outflow to the measuring vessel. For the permanent grassland with fully connected crop stand and root system the water permeability was 4-time higher in comparison with the black fallow and almost twice higher as compared with the fescue monoculture under identical conditions, where water flows into the gaps between unconnected hills and its runoff is accelerated.

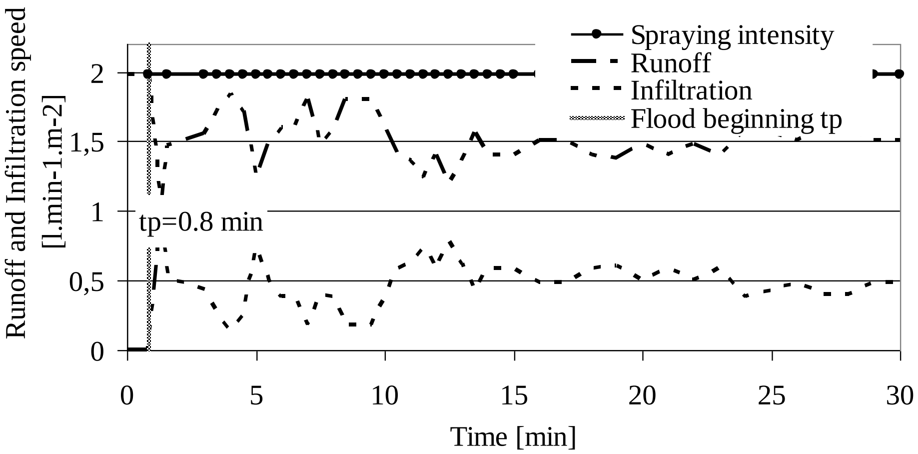

Figure 3: Example of graphical course in time of the water infiltration in the soil and water surface runoff speed with the marking of the beginning of the surface runoff tp for Fallow - free land without crop stand.

The hydraulic conductivity of soil environment can be determined from the infiltration speed. For the infiltration measuring in operational conditions the rain simulator with measuring area of 0.5 m^2 was used. The infiltration speed was determined from the defined rain intensity and water surface runoff from the measuring area recorded in regular time interval within the whole measuring time. The water runoff beginning is given by the fool start. The time of measuring is finished after infiltration speed consolidation. The consolidated infiltration speed is characteristic comparable parameter for defined soil properties in the measuring site (e.g. Fig. 1 3).

From the results of the statistical analysis is most interested the significance of the dependence of the infiltration in the 15th, 30th and 45th minute of the rainfall I15, I30, I45, and of the beginning of the surface runoff upon the entry parameters – the slope angle of the surface, the cover abundance and the soil water content in the soil layers in the depths from 0 to 50, 50 to 100, and 100 to 150 mm.

It results from the table that the level of statistical significance at the designated or at a better level can be assumed for the following pairs:

99%: Soil water content V5 - Infiltration I45

95%: Slope angle - Infiltration I15
Soil water content V5 - Infiltration I30
Cover abundance - Runoff beginning tp
Soil water content V10 - Infiltration I30
Soil water content V10 - Infiltration I45
Soil water content V15 - Infiltration I30
Soil water content V15 - Infiltration I45

90%: Slope angle - Infiltration I30
Soil water content V5 - Infiltration I15
Soil water content V10 - Runoff beginning t_p
Soil water content V15 - Runoff beginning t_p

Conclusions

It can be concluded, that the measurements have confirmed a favorable effect of grassland on hydro-mechanical soil properties. The highest infiltration was reached for mixed grassland. The fescue monoculture (long term planted) has an excellent protection against water soil erosion, but its water infiltration is low. The next measurements will be focused to other tall grass monocultures as festuca arrundinacea or brome. The evaluation results related to water infiltration into the soil, surface water runoff and also soil washing off are utilizable at proposing of ecologically suitable procedures in soil cultivation and as well at specification of principles of good agricultural practice for conditions of the Czech Republic. There is evident necessity to ensure the differentiated approach to the corrective measures as there are medium-deep and deep soil loosening with symptoms of undesirable soil compaction in the part of soil profile under the level of annual shallow soil cultivation. The results can be used at proposing of technologies dealing with soil care and in addition to it for the deeper research of factors influencing the retention of water in soil under the conditions of current technologies of cultivation, which are connected with adjoining negative effects of agriculture machinery.

Acknowledgement

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Carbon sequestration in soils under different management systems

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Abstract

The content and properties of the orga nic matter are conditioned not only by the soil parent material and climatic conditions, but also the methods of soil management. Undoubtedly the change in the kind of soil management (post-arable land forestation, agricultural use of forests) results in changes in their properties. This paper shows main factors determining status and stocks of organic matter in soils.

Keywords: soil organic matter, soil protection, carbon sequestration

Introduction

Soil organic matter (SOM) is of a very complex origin and shows differentiation in composition. The origin is realted to the biomass production in ecosystems (e.g. agricultural, forestry). However, fertilizers (manures, slurries, biowastes, composts) are an important sources. Organic matter is both an important soil constituent and the main source of food and energy for soil organisms.

SOM consists of different fractions: partially decayed plant residues, humus (colloidal compounds, humic substances), micro-organisms, microflora and above- and below-ground necromass. Soil organic matter influences many soil properties: chemical (sorption capacity, complex formation, buffer capacity), physical (colour, water retention, soil aggregation) and biological (energy and nutrient source for plants and soil organisms). SOM plays an important role in the environmental context: stimulates the cycle and quality of water, can be a source of greenhouse gases (carbon sequestration), has a strong links with the erosion and desertification. Basic properties and basic functions of soil organic matter are well known and were the starting base for EU Soil Thematic Strategy (Reports of the Technical Working Groups..., 2004).

Organic matter content in soils depends on a lot of factors. The most important factor influencing OM status in soil are: natural (habitat, ecological: soil parent material, climate, topography, land cover) and anthropogenic (land use, farming system, land degradation) factors. The soil type and soil properties are important and explain initial organic content. Sandy soils are usually low in organic matter. Climate (temperature and humidity) has a critical influence on humification and mineralization processes resulting in accumulation on organic matter in soils. This influence explains the existence at a certain scale of a climatic gradient north-south with high organic matter content in the northern part of Europe and low content in the southern part. With the development from natural to agricultural soils an important loss in carbon stock in soils has occured, and then an equilibrium seems to be reached which depends of the crop residues, organic fertilizers and organic matter management.

The sequestration of the atmospheric carbon into the soil organic carbon pool plays a key role. Considering the land environment, soils are up the main reservoir of carbon (ca. 2,000 Gt), much larger than the biomass (mainly forests, ca. 650 Gt) and atmospheric resources (mainly CO_2, ca. 750 Gt). Studies have proved that on average of 2 Gt C per year is bound in soil organic matter. The importance of soil organic matter highlights the comparison with the amount of anthropogenic C, which is emitted into the atmosphere (8 Gt / year).

Agricultural practices and soil organic matter stocks

Soil management is one of the major factors to determine the status of organic matter in soils. Transition of the usage from natural (forest, grassland) into agricultural one (arable) give significant decrease in organic carbon content as early as in initial several years. Establishing balance of the soil environment depends only on the plant and soil cultivation systems (Figure 1).

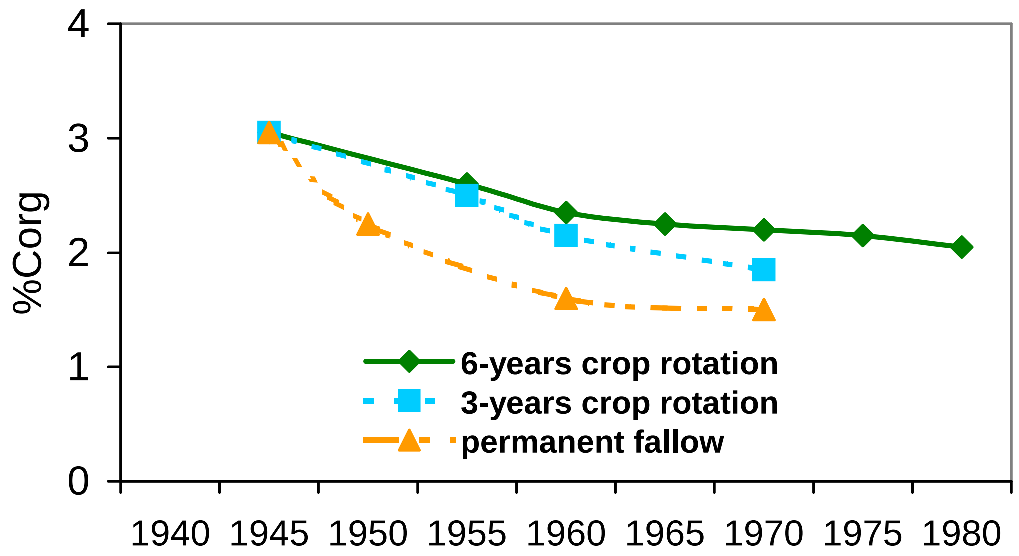

Figure 1. Soil management impact on the organic carbon content, following transition from grassland usage (Poulton 1995)

Forests cover ca 32% of soils in Europe. The organic carbon stocks in forest soils are large (100-200 t/ha), including the aboveground biomass, which represents about half of the carbon resources (70-100 t/ha). Critical phenomena for the dynamics of organic carbon in these soils are deforestation and losses from fires. Afforestation of agricultural land resources, in general increases soil organic matter stocks.

Grasslands and pastures are very important storage of organic carbon; the carbon resources are similar or higher than in the forest soils. The soils of grasslands and pastures are characterized by high biodiversity. The acreage of Polish grassland soils decreases, which results in reduction in carbon resources.

The transition of the land usage from forest or grassland into arable one result in reduction of organic matter at 30-60% (Figure 2). Long-term plant cultivation can preserve or even slightly increase the carbon and nitrogen contents on the resultant level; however it will still be lower than in the “natural” soil.

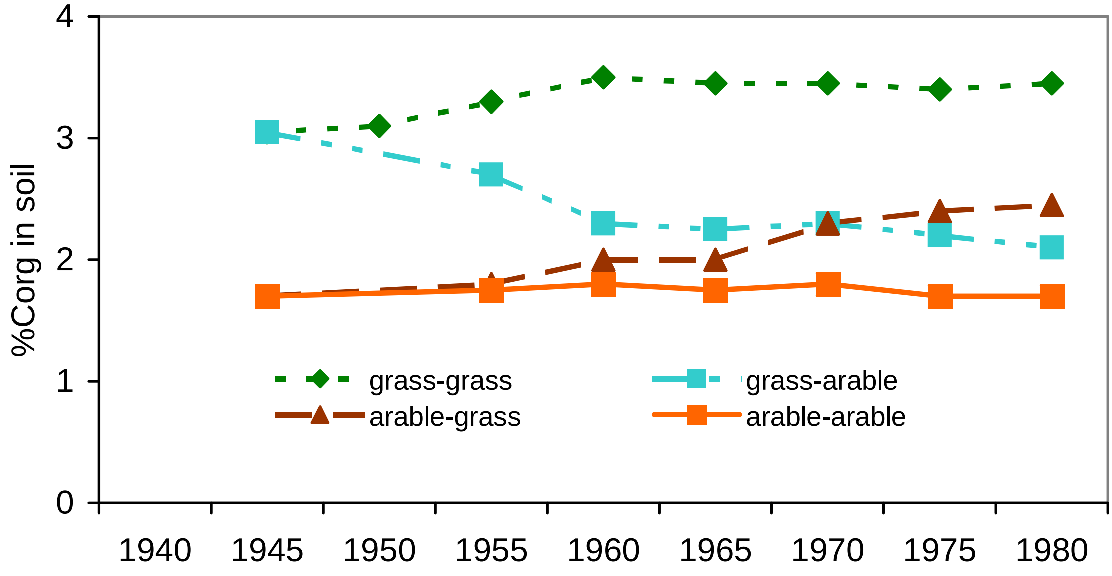

Figure 2. Data for organic carbon content from Rothamsted long-term field experiment (Poulton 1995)

The results of many long-term fertilization and cultivation experiments have shown that the main determinants of the organic matter content in soils are: fertilization (Figure 3), crop rotation and cultivation techniques. Obviously, the regular application of organic fertilizers, manure, liquid manure, green manures, composts and other organic materials results in a positive balance of soil organic matter.

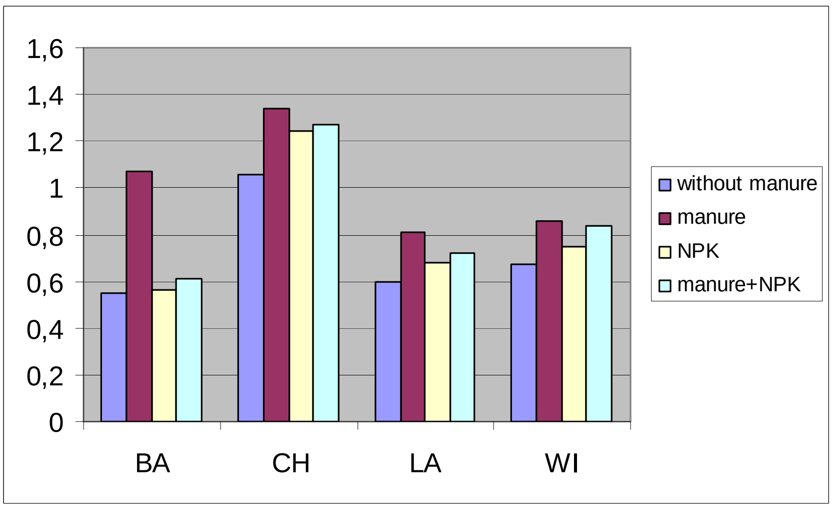

Figure 3. Organic carbon content (in %) in soils of long-term fertilization experiments (BA-Baborówko, CH-Chylice, LA-Laskowice Oławskie, WI-Wierzchucinek) (Gonet 1989)

The content and quality of soil organic matter also depend on the crop rotation type, which is related to the quantity and quality of the post-harvest residues in the field. The humus-forming crops, meaning those that, when grown, enrich the soil in organic matter include grasses, pulses, and legumes. Much smaller amounts of post-harvest residues in soil result from cereals, and the smallest – from root plants. The above mentioned dependencies were used to develop so-called rates of decomposition and renewal of organic matter in soils (Table 1).

Table 1. The reproduction and degradation index (t/ha) of the soil organic matter (Good Farming Practice Code 2002)

Crop or organic fertilizer	Unit	Reproduction (+) or degradation (-) ratio for soils			
		light	average	heavy	black earths
Root plants	1 ha	-1,26	-1,4	-1,54	-1,02
Maize	1 ha	-1,12	-1,15	-1,22	-0,91
Cereals, oil-bearing	1 ha	-0,49	-0,53	-0,56	-0,38
Pulses	1 ha	+0,32	+0,35	+0,38	+0,38
Grasses in fields	1 ha	+0,95	+1,05	+1,16	+1,16
Legumes, mixes	1 ha	+1,89	+1,96	+2,10	+2,10
Manure	10 t	+0,70			
Liquid manure	10 t	+0,28			
Straw	10 t	+1,80			

Also, the tillage system (e.g. ploughing) largely affects the soil organic matter resources. Transition from conventional (including ploughing) way of cultivation into no-till one with limited number of tillage procedures can increase organic matter stocks at as much as 15% (Figure 4).

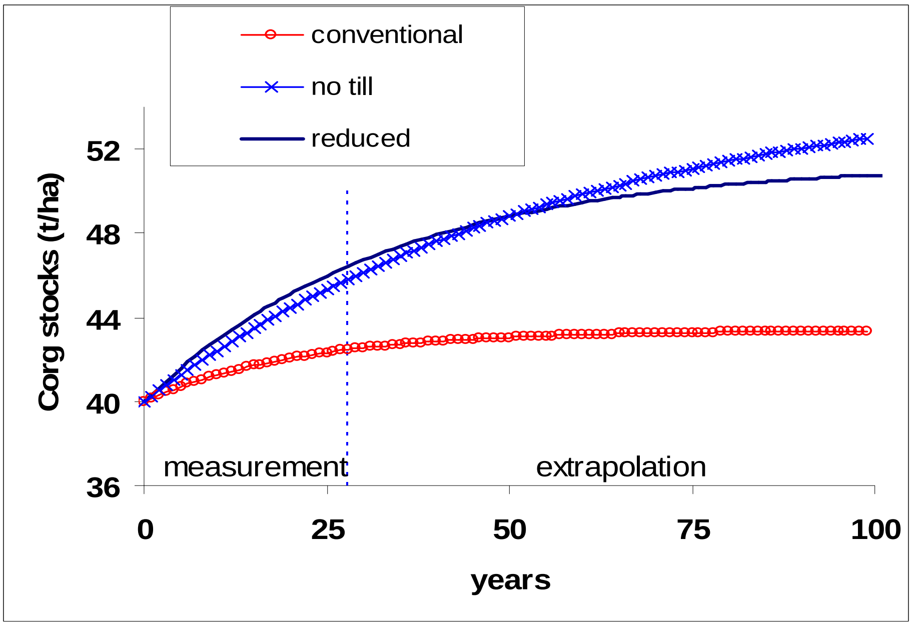

Figure 4. The effect of tillage on carbon stocks of arable soils (Arrouays et al. 2002)

Carbon sequestration and protection of soil organic carbon stocks

The soil carbon can be considered both, storage of organic matter and source of CO_2. In the last century, the soils were sources of CO_2 due to alteration of their usage from forest and

grassland into agricultural (arable) one. That requires urgent determination whether and to what extent this process can be reversed, and what procedures and regulations should be undertaken to increase carbon sequestration in the soil environment.
At the Conference in Rio de Janeiro (1992), in the context of global climate change, it was decided to stabilize greenhouse-gas emissions. Based on the Kyoto Protocol (1997), the European industrialised countries are obliged to reduce emissions and take actions aimed at the carbon sequestration. The European Climate Change Programme shows that the carbon sequestration policy should compensate for 5-8% of CO_2 emissions.

In the structure of land use in Europe, the grounds used for agricultural purposes constitute 40% (24% of arable lands, 16% grasslands and pastures), forests 42% (with a trend of increasing of forest usage). Considering a positive impact of the organic matter on the soils functioning and the necessity of limitation of the organic matter mineralization (reduction of greenhouse-gas emissions to the atmosphere), it seems obvious to stabilize and/or increase the organic matter stocks. In general, good management of organic matter is consistent with good management of soil biodiversity, while management of organic matter and biodiversity is a key aspect of sustainable usage of soils and the environment.
In order to increase carbon sequestration in the environment and increase its resources in the soils, two ways should be taken:
- cover by policy protection the soils with a high content of Corg (> 6%, “hot spots soils”), particularly in terms of potential mineralization of their organic matter. Especially, it pertains to peat soils, natural bogs and other hydrogenic soils, alpine soils, forests and natural grasslands. Peat soils should be excluded from agricultural usage, use of peats should get discontinued, leaving them in conditions under natural vegetation,
- in soils used for agricultural purposes (particularly arable ones) actions aiming at increasing the content of Corg should be taken, especially in soils with poor in organic matter contents and degraded ones (and after reclamation), for instance preferring to use them as grasslands.

Conclusion

All of these actions should foster carbon sequestration in the soil and favour the creation of so-called eco reserve. Therefore, in terms of good agricultural practice, the following procedures should be recommended, especially towards arable lands:
1. Use crop rotations to enrich the soil with organic matter, including legumes, grasses and catch crops. Such procedure may lead to reduction in nutrient losses and improvement of the soil structure. The application of green manures is likely to be limited by the water availability (within the competition between green manure and the primary yield). On the other hand, improving the soil structure, also in deeper layers, and increase of organic matter content, result in better retention of water, which is available for crops. Such a strategy is particularly suitable for protecting the soil surface susceptible to erosion and beneficial for reduction of nitrogen losses caused by leaching on light soils.
2. Creating buffer zones on the border of farmlands will not only contribute to the accumulation of organic matter, but will promote prevention of erosion, limitation of nutrients and pesticides transport to surface waters and contribute to the biodiversity development. Similarly to the buffer zones, due to the same benefits, ecological lands should be disseminated. For the same reasons, and especially in order to limit the erosion processes, a permanent full coverage of the land surface with crops should be ensured.
3. Leaving the maximum possible amounts of post-harvest residues in the soil. The post-harvest residues are not contaminated, valuable sources of nutrients and organic matter. In accordance with this directive, actions like straw and stubble burning should be limited. It is estimated that the burning of 30% of annually delivered straw from all cereals for energy

purposes brings a loss of about $9 \cdot 10^6$ t of organic matter, which does not get to soils, plus in a short time, emits large amounts of CO_2 into the atmosphere.

4. Implementation of simplified soil cultivation techniques, focusing on introduction of preservative systems. Although the preservative system has little effect on the growth of organic matter content, but it also reduces organic matter mineralization and water erosion, improves the soil physical properties, biodiversity and economic efficiency of agriculture. This system is obviously unusable in such crops as sugar beet or potato, but it is recommended for the growing of cereals in monoculture.
5. Foster the development of eco farming as a production system which involves an increase of humus content in soils, and in addition: reduced emissions of contaminants to the environment, increased biodiversity and food safety.

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CONTENT

Tillage effect on saturated hydraulic conductivity of the topsoil and upper subsoil

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Abstract

Saturated hydraulic conductivity of the topsoil and upper subsoil was determined using the Guelph permeameter for four years from 2007 to 2010, in three farms in southern Moravia. Saturated hydraulic conductivity of the topsoil was not affected by different tillage generally nor in any of the sites. Use reduced tillage decreased the saturated hydraulic conductivity of the upper subsoil compared with conventional tillage. This effect is observed in various locations in varying degrees: in the Hrušovany nad Jevišovkou the difference is statistically insignificant; in Lesonice significant ($P < 0.05$) and in Unčovice highly significant ($P < 0.01$). Effect of deep tillage on the saturated hydraulic conductivity of the subsoil was observed at each location in a very different way: in Hrušovany nad Jevišovkou was determined insignificant difference under deep tillage and under reduced tillage; compared with deep tillage, reduced tillage significantly reduced the value of saturated hydraulic conductivity of the subsoil in Lesonice; saturated hydraulic conductivity was under deep tillage and under reduced tillage very low (Němec, 1975) and almost identical in Unčovice.

Keywords: Conventional tillage; Deep tillage; Reduced tillage; Saturated hydraulic conductivity

Introduction

Appropriate tillage practices are needed for sustainable crop production without affecting soil physical health and the environment (Iqbal et al., 2008). Saturated hydraulic conductivity is a fundamental physical indicator of soil quality and health (Amirinejad et al., 2011, Chakraborty et al., 2010, Iqbal et al., 2008, Núñez-Regueira et al., 2006). Tillage-induced soil compaction is a concern because it affects soil health and productivity of plant production. (Steber et al, 2007). One of the consequences of soil compaction is the reduction of saturated hydraulic conductivity. The objective of the present study was to assess the impact of different tillage techniques - conventional (mouldboard ploughing) (CT), deep (DT), and reduced tillage (RT) - on the saturated hydraulic conductivity of the topsoil and upper subsoil.

Material and methods

Henry Darcy (Darcy, 1856) found that the volumetric flow rate per unit cross-sectional area through a sand filter of a given thickness was proportional to the total head gradient across the sand. He called the proportionality constant saturated hydraulic conductivity. It is the most important soil parameter for saturated flow. Saturated hydraulic conductivity of the topsoil (depth 6-22 cm) and upper subsoil (depth 23-40 cm) was determined using the Guelph permeameter in three farms in southern Moravia: in Hrušovany nad Jevišovkou and Unčovice in chernozems, and in Lesonice in luvisol. Measurements were made for four years, in 2007 for one term during October and November, and in subsequent years 2008, 2009 and 2010, always in three times, each time in three replications. Statistical analysis was performed using the one-way ANOVA Tukey's HSD test (Statistica 9).

CONTENT

Results and discussion

Hrušovany nad Jevišovkou - The highest average value of saturated hydraulic conductivity (below Kfs) of the topsoil 1.1143 m.day^{-1} was determined under reduced tillage, the lowest

Tab. 1: Saturated hydraulic conductivity of the topsoil (m.day^{-1})

Locality	Deep tillage		Reduced tillage		Conventional tillage			
	x	SD	x	SD	x	SD	x	SD
Hrušovany n. J.	0.8194	0.7838	1.1143	0.8678	06906	0.7113	0.8811	0.8036
Lesonice	0.7752	0.8021	0.4877	0.7909	0.5758	0.6029	0.6142	0.7435
Unčovice	0.7815	0.9125	0.6471	0.7074	0.5144	0.5244	0.6507	0.7354
Variant of tillage	0.7922	0.8245	0.7497	0.8269	0.5936	0.6143		

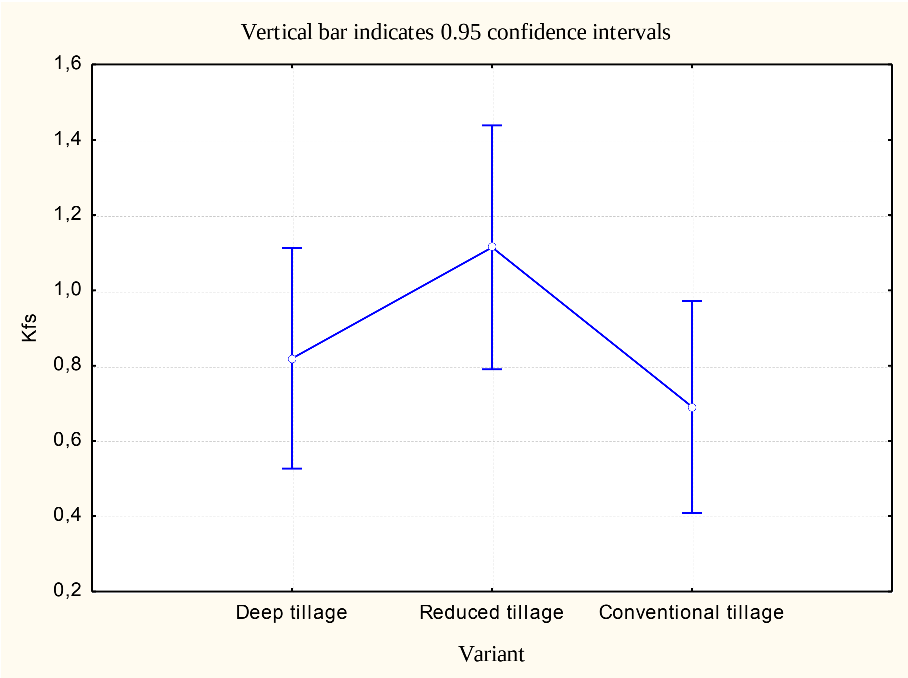
x – arithmetic average

SD - standard deviation

Tab. 2: Saturated hydraulic conductivity of the upper subsoil (m.day^{-1})

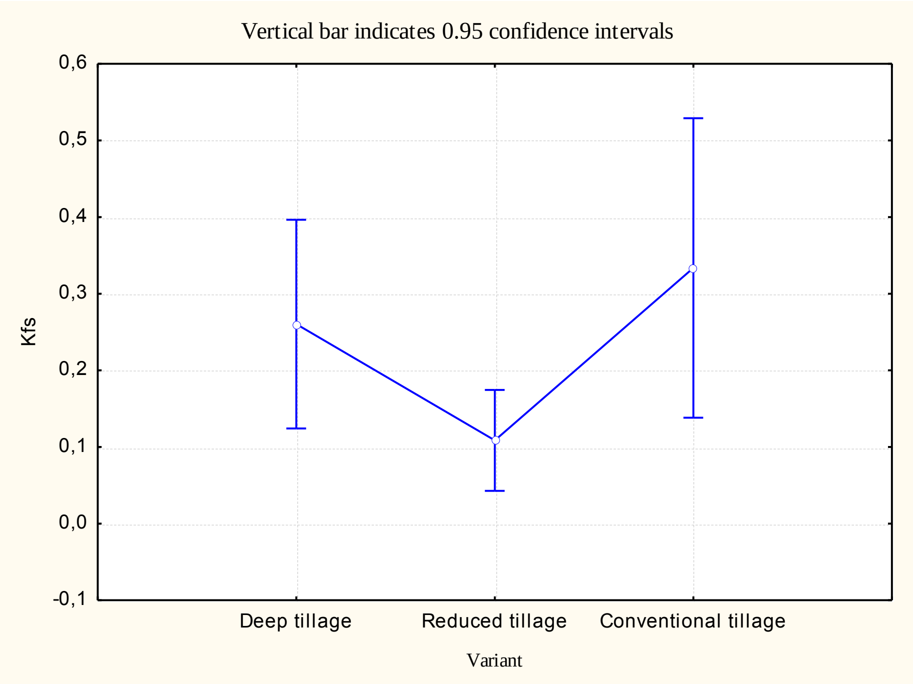
Locality	Deep tillage		Reduced tillage		Conventional tillage			
	x	SD	x	SD	x	SD	x	SD
Hrušovany n. J.	0.2604	0.3647	0.1086	0.1763	0.3337	0.5233	0.2342	0.3894
Lesonice	0.1166	0.1137	0.0462	0.0369	0.1181	0.1123	0.0936	0.0995
Unčovice	0.0664	0.0601	0.0932	0.1017	0.2551	0.3495	0.1396	0.2287
Variant of tillage	0.1487	0.2368	0.0826	0.1213	0.2356	0.3757		

Graph 1: Hrušovany nad Jevišovkou: Saturated hydraulic conductivity of the topsoil. (m.day^{-1})

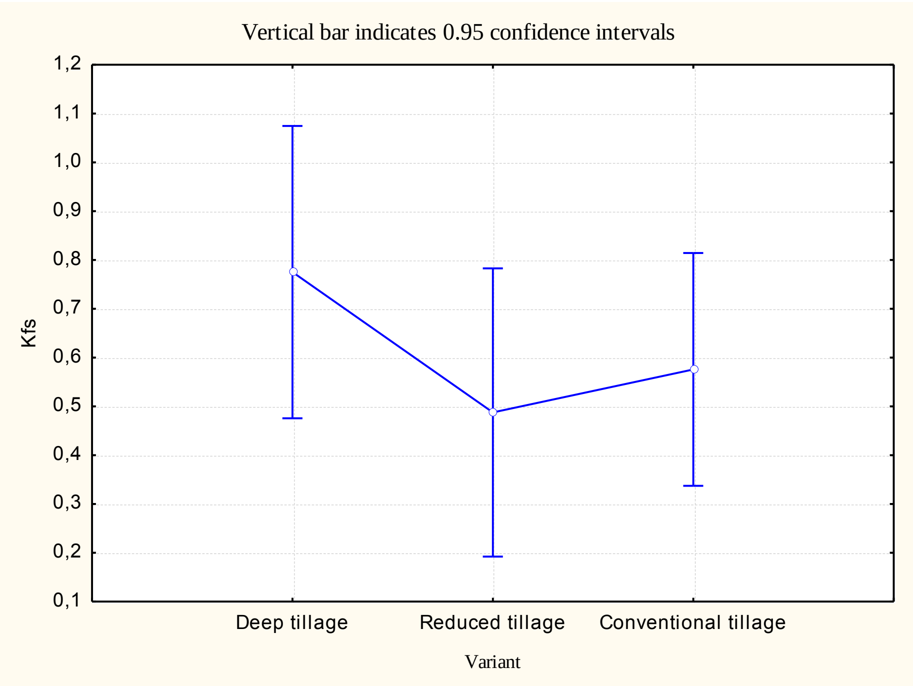


0.6906 m.day^{-1} under conventional tillage, see Table 1. Differences between average values of Kfs are statistically insignificant, see Graph 1. The highest average value of Kfs of the upper subsoil 0.3337 m.day^{-1} was determined under conventional tillage and the lowest 0.1086 m.day^{-1} in reduced tillage variant, see Table 2. Even in the subsoil are insignificant differences, see Graph 2.

Graph 2: Hrušovany nad Jevišovkou: Saturated hydraulic conductivity of the upper subsoil. (m.day^{-1})

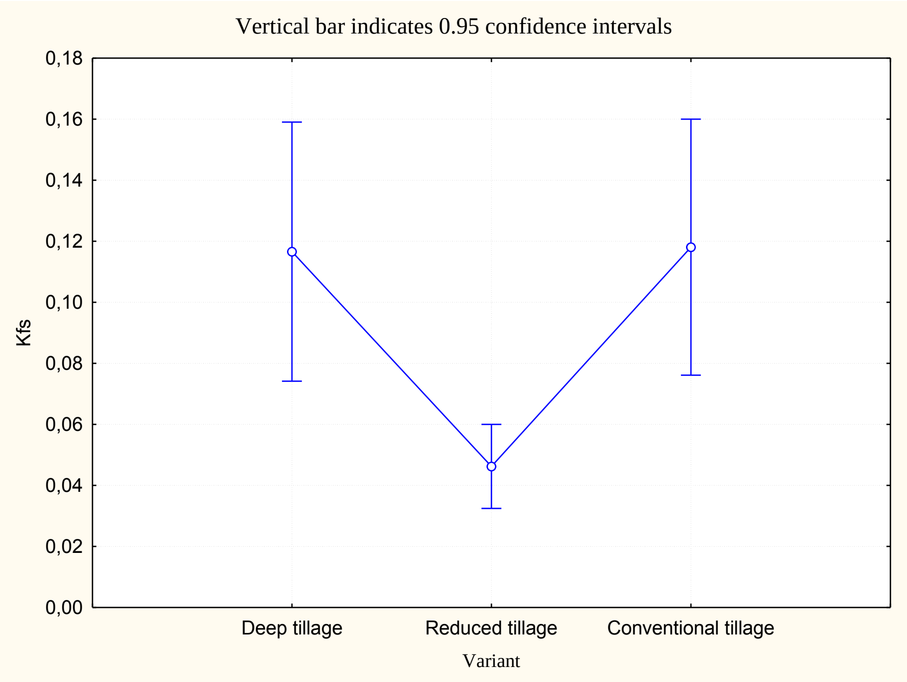


Graph 3: Lesonice: Saturated hydraulic conductivity of the topsoil. (m.day^{-1})

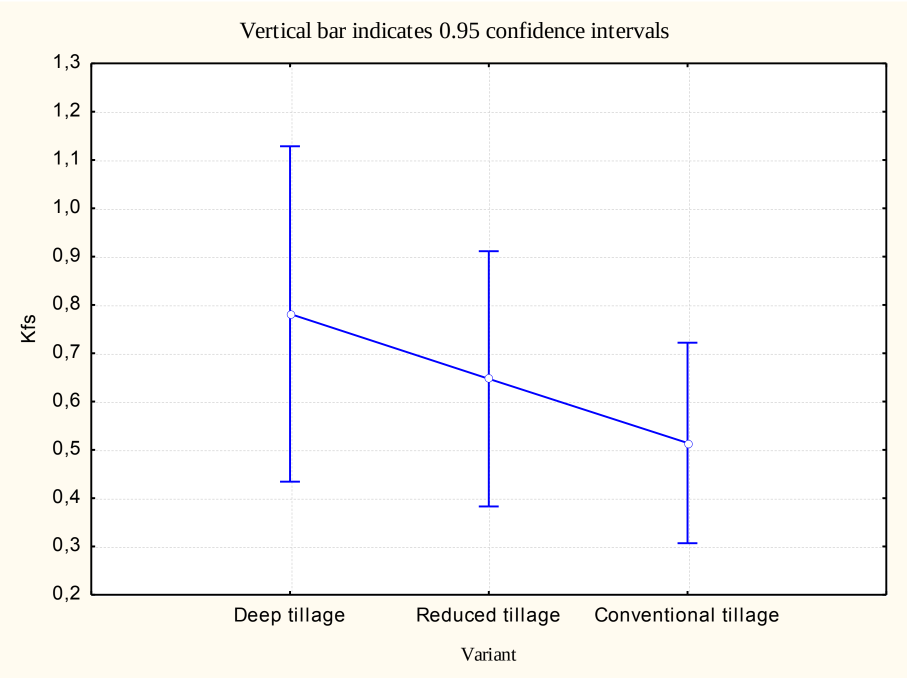


Lesonice - The highest average value of Kfs of the topsoil 0.7752 m.day^{-1} was determined under deep tillage, the lowest 0.4877 m.day^{-1} under reduced tillage, see Table 1. Differences between the average values of Kfs are insignificant, see Graph 3. Higher average values of Kfs of the upper subsoil 0.1166 m.day^{-1} and 0.1181 m.day^{-1} were determined under deep tillage and conventional tillage, the lowest 0.0462 m.day^{-1} in reduced tillage variant, see Table 2. Both differences are significant, see Figure 4.

Graph 4: Lesonice: Saturated hydraulic conductivity of the upper subsoil. (m.day^{-1})

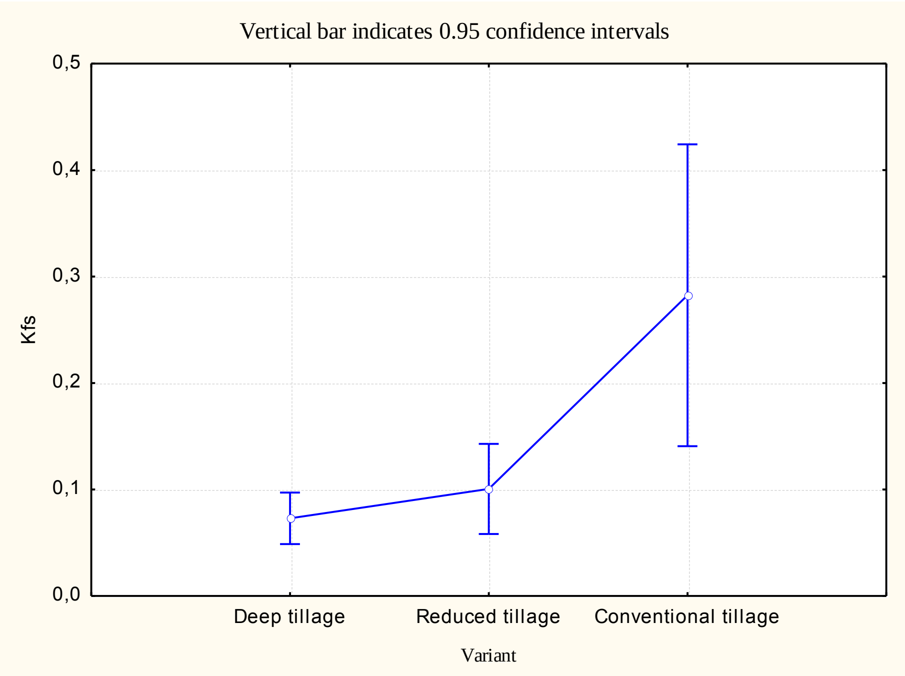


Graph 5: Unčovice: Saturated hydraulic conductivity of the topsoil. (m.day^{-1})



Unčovice - The highest average value of Kfs of the topsoil 0.7815 $m.day^{-1}$ was determined under deep tillage, the lowest 0.5144 $m.day^{-1}$ under conventional tillage, see Table 1. Differences between the average values of Kfs are insignificant, see Graph 5. The highest average value of Kfs of the upper subsoil 0.2825 $m.day^{-1}$ was determined under conventional tillage and the lowest 0.0729 $m.day^{-1}$ under deep tillage, see Table 2. Very low value of Kfs 0.1006 $m.day^{-1}$ was determined under reduced tillage. Differences between the average values of variants deep tillage and conventional tillage are highly significant ($P < 0.01$), differences between the average values under reduced tillage and conventional tillage are significant ($P < 0.05$), see Graph 6.

Graph 6: Unčovice: Saturated hydraulic conductivity of the upper subsoil. ($m.day^{-1}$)

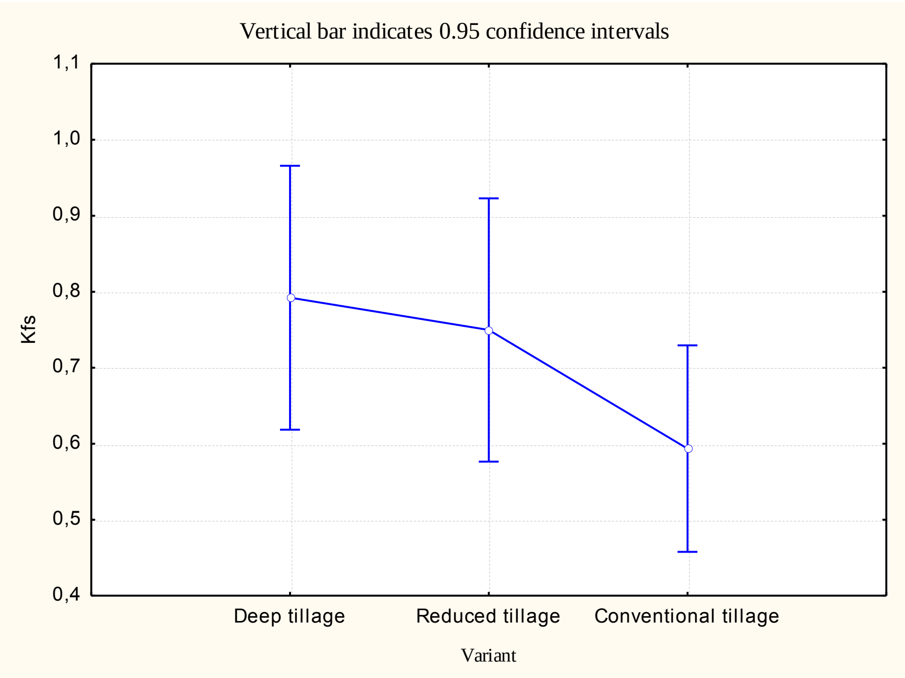


Topsoil. Higher average values of Kfs of the topsoil 0.7922 $m.day^{-1}$ and 0.7497 $m.day^{-1}$ were determined under deep tillage and reduced tillage, the lowest 0.5936 $m.day^{-1}$ in conventional tillage variant, see Table 1. Differences between the average values in the above-mentioned variants are insignificant, see Graph 7. Insignificant differences Kfs of the topsoil under different tillage variants, including conventional tillage and reduced tillage also determined DE CASTRO et al. (2010) and HE et al. (2009). In contrast, JABRO et al. (2010) finds significantly higher Kfs under conventional tillage, compared with reduced tillage. The highest average value of Kfs of the topsoil 0.8811 $m.den^{-1}$ was measured in Hrušovany nad Jevišovkou, lower values 0.6507 $m.day^{-1}$ and 0.6142 $m.day^{-1}$ were determined in Unčovice and Lesonice. The differences between these average values are also insignificant. The highest average value of Kfs of the topsoil 0.9764 $m.den^{-1}$ was determined in 2009, the lowest 0.4098 $m.den^{-1}$ in 2010. In 2008 was the average value of the topsoil 0.7760 $m.den^{-1}$. The difference between the average values in 2008 and 2010 is significant between the average values in 2009 and 2010 highly significant.

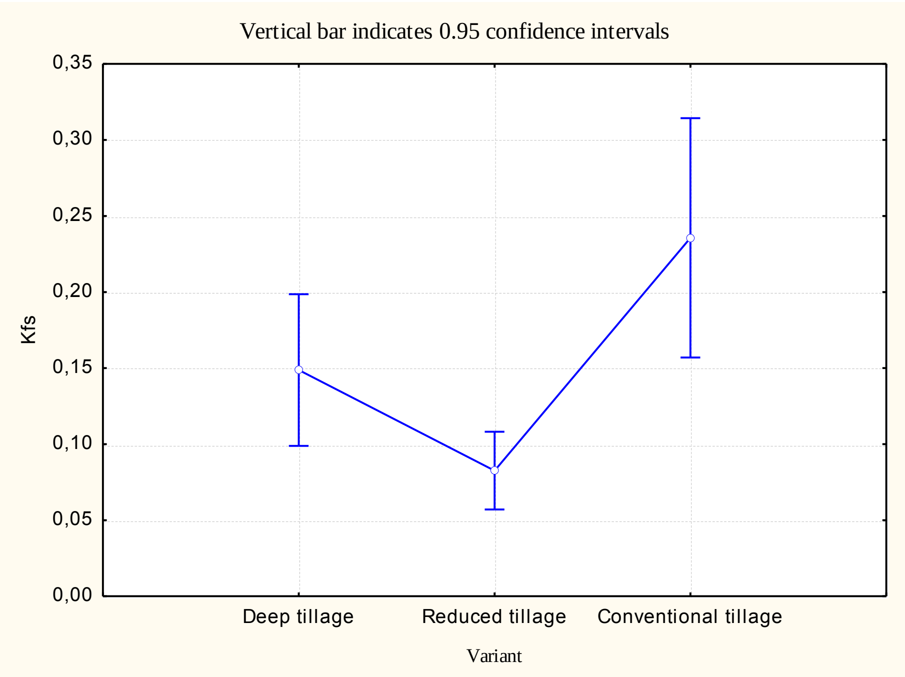
Upper subsoil. The highest average value of Kfs of the upper subsoil 0.2356 $m.den^{-1}$ was determined under conventional tillage, the lowest 0.0826 $m.den^{-1}$ in reduced tillage variant, see Table 2. This is a highly significant difference, see Graph 8. This is in contrast to the results VOGELER et al. (2009) notes that higher Kfs is after reduced tillage in comparison with conventional tillage. The highest average value of Kfs 0.2342 $m.den^{-1}$ was measured in

Hrušovany nad Jevišovkou, the lowest 0.0934 m.den^{-1} in Lesonice. The differences between these average values are highly significant. The highest average value of Kfs 0.2678 m.day^{-1} was determined in 2008, the lowest 0.0827 m.den^{-1} in 2010. In 2009 the average value of

Graph 7: Saturated hydraulic conductivity of the topsoil. (m.day^{-1})

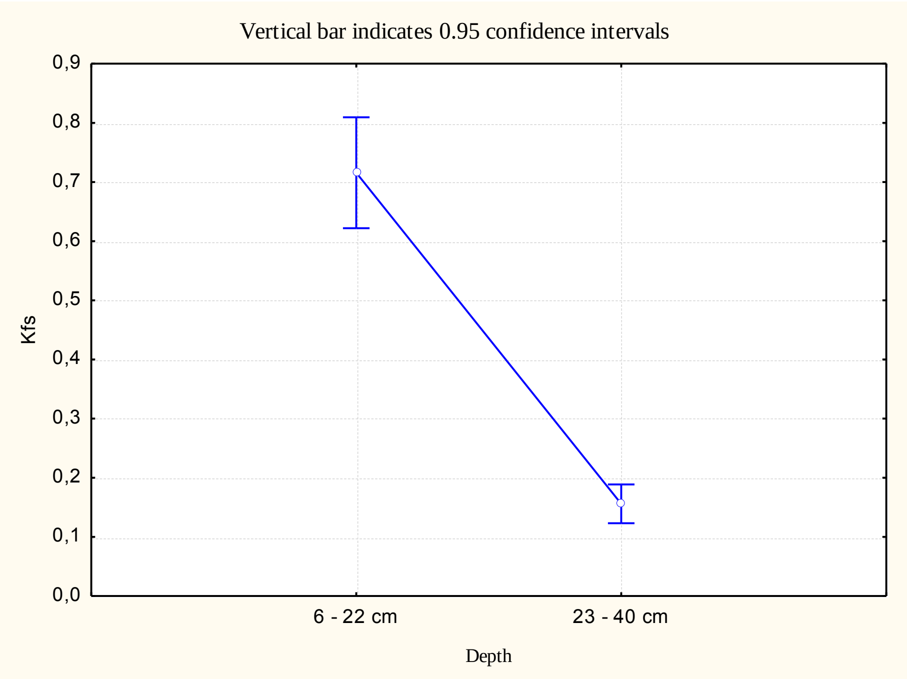


Graph 8: Saturated hydraulic conductivity in the upper subsoil. (m.day^{-1})



0.1304 m.day^{-1}. The difference between the average values in 2008 and 2009 and the average values in 2008 and 2010 was highly significant. We established a highly significant difference in the values of Kfs of the topsoil (0.7156 ± 0.7678 m.den-1) and subsoil (0.1559 ± 0.2727 m.day^{-1}), see Graph 9.

Graph 9: Saturated hydraulic conductivity in different depths (m.day^{-1})



Conclusions

Saturated soil hydraulic conductivity of the topsoil was not affected by different tillage generally nor in any of the sites.

Use reduced tillage decreased the saturated hydraulic conductivity of the upper subsoil compared with conventional tillage.

Deep tillage effect on saturated hydraulic conductivity of the upper subsoil was observed at each location in a different way: in the Hrušovany nad Jevišovkou was determined insignificant difference under deep tillage and under reduced tillage**,** in Lesonice the saturated hydraulic conductivity of the upper subsoil under deep tillage was significantly higher than under reduced tillage, and saturated hydraulic conductivity was under deep tillage and under reduced tillage very low and almost identical in Unčovice.

We established a highly significant difference in the values of Kfs of the topsoil (0.7156 ± 0.7678 m.day^{-1}) and subsoil (0.1559 ± 0.2727 m.day^{-1}).

Saturated hydraulic conductivity values are strongly influenced by year the determination.

Acknowledgements

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CONTENT

LONG -TERM EFFECT OF CONSERVATION TILLAGE ON DYNAMICS OF YIELDS AND SOME SOIL PROPERTIES

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Abstract

Production of plant cultivated and various soil properties have been studied throughout 15-year duration of field experiment on Luvisol, clay-loam soil where different tillage methods of conservation technologies were used in comparison with conventional tillage. There was found the significant and still persisting yield increase in conservation variants comparing with classic one after 10 years from the start of the trial. It was in connection with soil fertility increase because of the similar trends of soil fertility indicators. Improvement of soil physical properties in conservation treatments was found as well.

Keywords: conservation tillage, crop yields, physical soil properties, carbon sequestration

Introduction

Sustainable agricultural systems are based on their stability and capability to utilize climatic, ecologic, technologic, economic and other changes for their own development, eventually to be resistant against them without damages and losses. After decennaries of the experience with conservation soil management both in Europe and in America and in other continents, it is possible to declare responsibly that these systems represent the important benefit for sustainable development of agricultural production, thereby they raise the hope for possibility of food sufficiency for the growing wide range of the world human population at the same time.

Seeing that conservation soil tillage technologies have been under research from the various points of view and have used in farming practice as well relatively for a long time, there are known the basic traits of their short-term and long-term effects. These effects can varied depending on the site conditions an on their mutual interactions therefore ongoing research can give continuously the new information.

Naturally, conservation soil tillage methods for crop stand establishment influence, above all, on the soil, especially its physical (e.g. Rasool et al., 2008, Castro Filho et al., 2002 etc.), chemical (Matowo et al., 1999; Vogeler et al., 2009 etc.) and biological (Balota et al., 2004; Kostopoulou, Zotos, 2005) properties. Positive effects of conservation technologies improve the properties above mentioned thereby increase soil fertility.

Higher soil fertility as a set of properties ensuring the optimal conditions for growth and development of plants must have, of course under favourable meteorological conditions, stimulation effects on the crop production. Assessment of the influence of the soil microorganisms on production of the selected crops under different methods of conservation soil tillage during 14-year duration of the field experiment in Prague-Ruzyne is the aim of this contribution.

Materials and methods

A field experiment has been running from 1995 at site with soil of clay-loam texture (Orthic Luvisol, FAO Taxonomy) 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.. It was established as a rotation of winter wheat, spring barley, and white mustard. A split-plot method, with four replications, was used. 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) Minimum tillage (MTS), i.e. shallow tillage (about 0,1m deep) and chopped straw with post harvest residues of forecrop incorporating; 4) No tillage + mulch (NTM), i.e. direct drilling into no tilled soil covered with forecrop post harvest residues and chopped straw. In MTS treatment the straw of cereals was incorporated into soil with nitrogen (ammonium form) in dose 1 kg per 100 kg straw. 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 harvesting plot. All crop stands (including CT) were sown with a John Deere 750A drill machine. Representative soil samples were taken from winter wheat plots immediately after harvest from all treatments and selected soil depths. The samples for analyses of soil physical properties were taken by Kopecky-ring method.

Results and discussions

In the Fig. 1 and 2, the time trends of grain yields of winter wheat and spring barley, cultivated in the field trial in the period 1997, respectively 1998-2010, are shown. Variability of the individual trends is caused by conditions in the concrete years, especially by the weather course and its influence on the growth and development of plants and on the yield formation in the crucial phases. Marked yield falls are obvious in the CT treatment, especially in spring barley (Fig. 2). They are namely caused by drought periods (years 2000, 2003, 2007). From the Fig. 2 it is evident both higher sensitivity of spring cereals to the lack of soil moisture early in spring comparing with more rooted winter crops and it is evident that in the conservation treatments there are as not so much strong reaction on stress conditions as under conventional soil tillage treatment. From the time flow of yield curves of both crops it is evident that the year 2010 has been still the most favourable from the production standpoint because just in this year up to now yield records were exceeded in the both cereals.

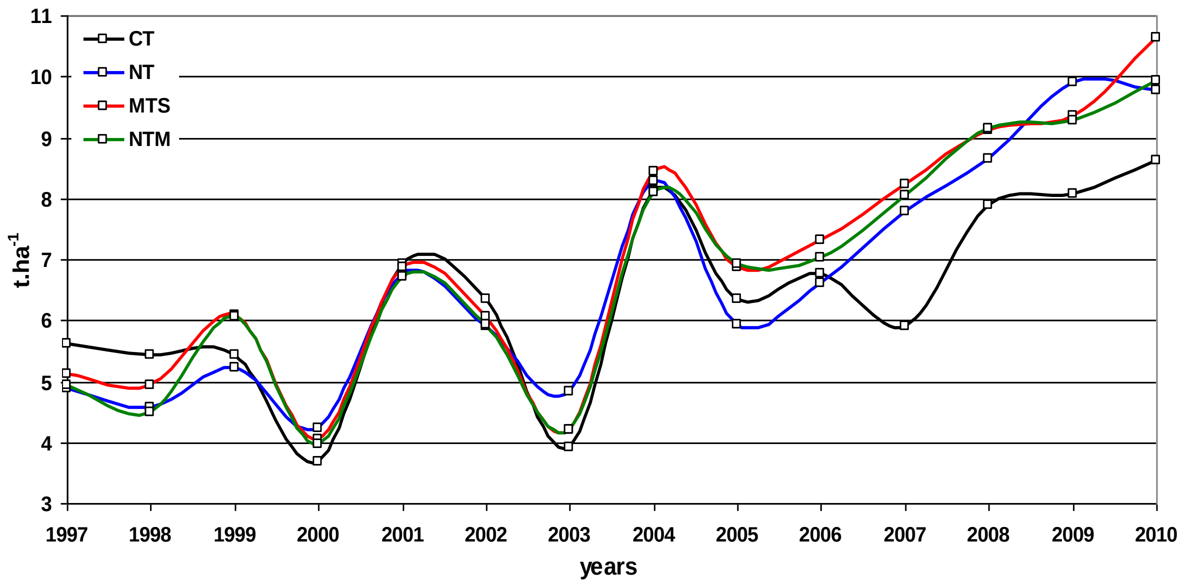

Fig.1: Time lines of yields of winter wheat cultivated under different soil tillage

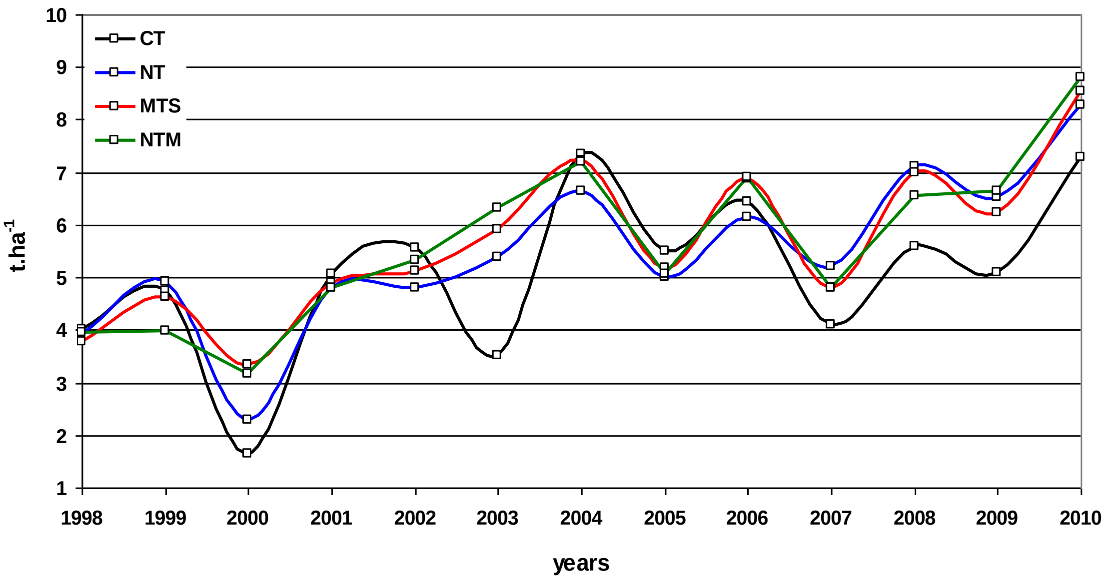

Fig.2: Time lines of yields of spring barley cultivated under different soil tillage

From the year 2006, i.e. 10 years after the trial establishment, there is obvious separation of yield trends of all conservation variants from CT treatment yield curve and their faster increase. It corresponds with findings of some authors (Arshad et al., 1990; Kladivko, 2001 and others) who declared that after implementation of conservation technologies, their impacts develop till after certain time interval when stabilizing processes of soil environment, connecting with tillage method change, take place. This interval length depends on range of factors, especially on the basic soil fertility and on site conditions.

On the basis of up to now results of crop production studies in the conservation tillage systems, it is shown that after conservation tillage technology implementation improvement of soil properties and increase of soil fertility gradually turn up which leads to yield increase and to mitigation of stress effect on yield formation.

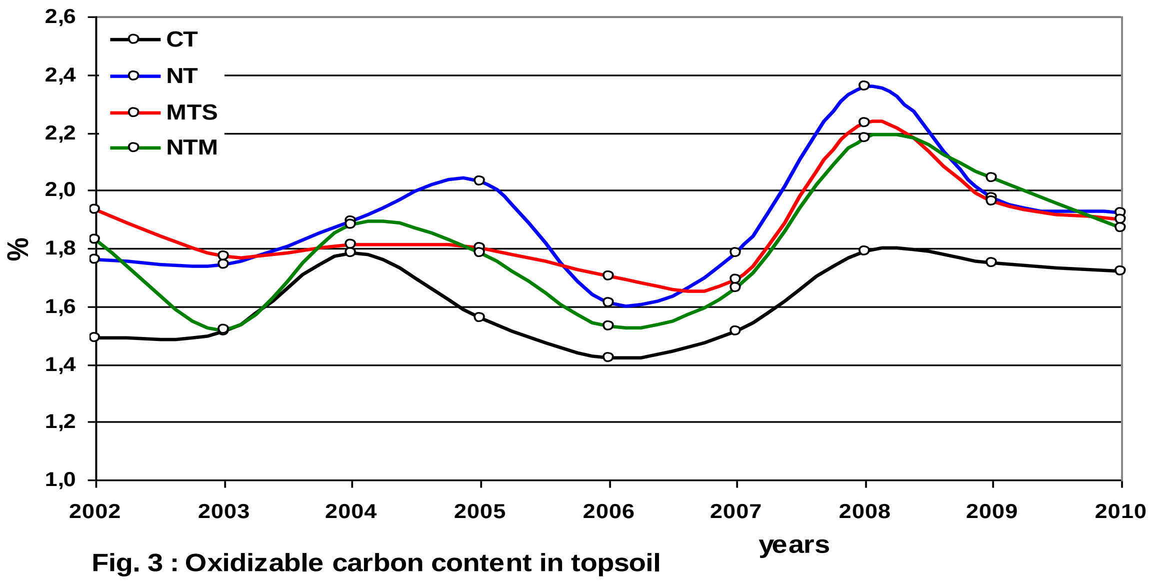

Fig. 3 : Oxidizable carbon content in topsoil

As an indicator of soil quality, oxidizable carbon content in topsoil was monitored. Dynamics of this parameter in tested tillage variants in the period 2002 – 2010 is visible in the Fig. 3. From the year 2005, similarly as in yield figures, curves of conservation treatments are running in higher levels than the curve of conventional tillage. It means that C sequestration in soils, as a consequence of organic matter management, under conservation technologies is much more intensive.

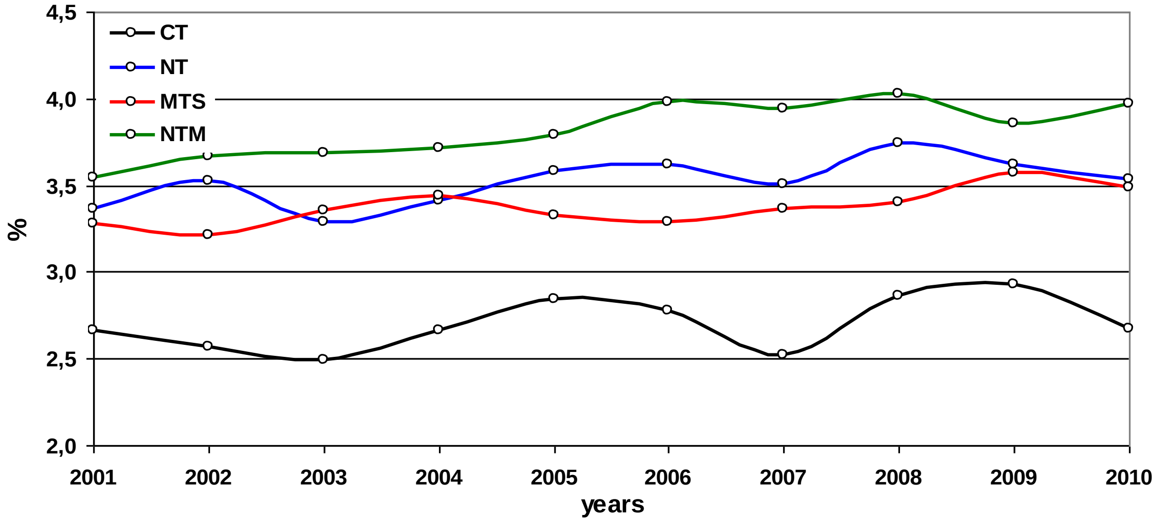

Fig. 4: Content of humus in topsoil layer 0,0-0,1 m

Humus content in the upper layer of topsoil was the further monitored indicator of soil fertility. Trends of development of this parameter in studied treatments in given length of time are shown in the Fig. 4 and it is evident, that in conservation treatments the soil was richer in humus substance in comparison to conventional tillage. It shows evidence of higher soil fertility and higher presumption for crop yield increase.

Since 2001 choice soil physical properties have been observed on the plots of all treatments after winter wheat harvest. It is known that reduced loosening causes increase of bulk density, total porosity decline and influences further soil physical properties which mean deterioration of soil conditions for growth and development of crop root system. In the Fig. 5, it is possible to see the time lines of soil bulk density (SBD) in all tillage treatments in the given time period.

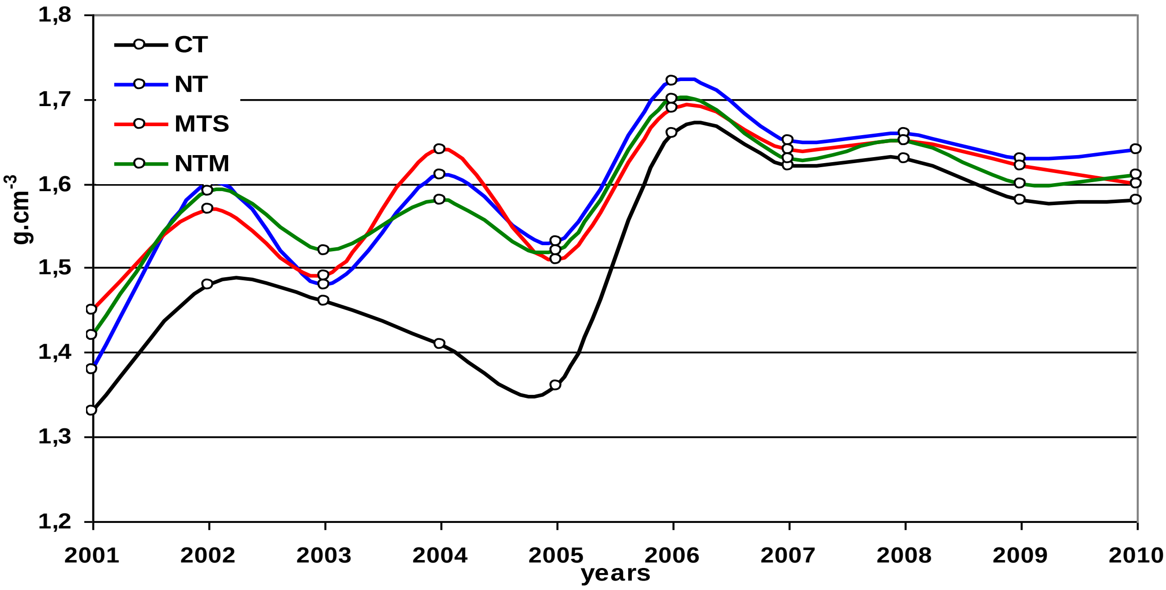

Fig. 5: Effect of different soil tillage method on soil bulk density dynamics in the period 2001-2010

The values in the figure are averages of measurement in two topsoil layers (0,0 - 0,1 and 0,1 – 0,2 m). Above all, it is necessary to take notice of general variation of values depending on the year conditions, especially on the weather course. Until the year 2006, SBD values in the variant of conventional tillage (CT) were significantly lower than in other treatments. In the next period, the differences among all treatments were found insignificant.

In the observed variants, the trends of maximum capillary water capacity (MCWC) show the similar time flow – their running after year 2006 were found without significant differences, although before it the curve of CT treatment showed higher variability than curves from conservation treatments. The results of study of soil physical properties certified that the handicap of soil physical quality deterioration in conservation tillage technologies can disappear after c. 10 years from reduced soil tillage implementation and the values of these parameters were equalized to conventionally tilled soil. It leads to idea on the connection of the results with the yield trends above presented (Fig. 1, 2). The favourable influence of organic matter and its long-term effect on soil physical parameter improvement in variants with reduced tillage was one of the suppositions of our studies.

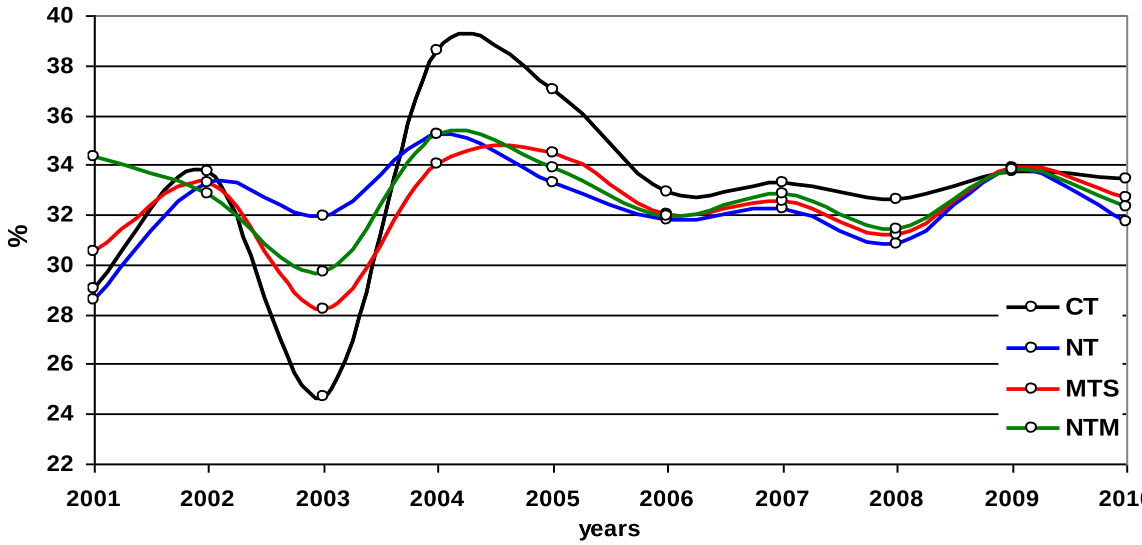

Fig. 6: Effect of different soil tillage method on dynamics of maximum capillar water capacity in the period 2001- 2010

Rasool R. et al. (2008) documented also in their long-term experiments gradual increase of total porosity and bulk density decrease as a consequence of a higher content of organic matter in soil and they found out a higher nutrient uptake by plants. But Logsdon and Karlen (2004) do not consider bulk density usable soil quality indicator and mild soil compaction due to reduced tillage has not been considered by them as a significant factor that could influence yields of growing crops.

The results presented confirmed the favourable impact of conservation tillage technologies and residue management on growth of soil fertility. It caused higher yield increase of cultivated crops in comparison to conventional tillage technology. Nevertheless, this effect did not become evident immediately but after some time of stabilizing of soil conditions from tillage technology change (Kimetu et al, 2009) when the processes, targeting to higher soil quality, were proceeded. It takes a different time depending on the site conditions, especially on natural soil fertility. Some authors mention that significant difference of soil fertility, (subsequently of yield increase), can be achieved after more than 20 years (Kladivko, 2001).

Conclusions

In 15–year field experiment under parallel growing of winter wheat in three-crop rotation with different method of crop stand establishment on Luvisol in sugar beet production region there was found out still persistent significant production increase in the treatments of conservation tillage comparing with conventional tillage variant after 10 years from the start of the trial.

The basic share of soil quality improving in conservation variants on this crop yield increasing was documented by dynamics of soil fertility indicators (C sequestration and humus content increase). As a consequence of higher soil quality, the differences in soil physical parameters among conventional and conservation treatments, resulting from the tillage reduction, were adjusted.

Acknowledgements

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EFFECTS OF SOIL TILLAGE ON QUALITY OF SOIL LOSS

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Abstract
Quantity and quality of soil loss was measured on Stagnic Luvisol during the 15-year investigation cycle (1995-2010). The trial involved the following tilling treatments: 1. Control; 2. Tillage up and down the slope; 3. No-tillage; 4. Tillage across of the slope; 5. Very deep ploughing and 6. Subsoiling + tillage across of the slope. The goal was to establish whether there is a difference between the soil texture and chemical properties of not eroded soil and erosional drift removed from the trial plots. The results obtained point to the conclusion that erosional drifts were richer in colloids, that is to say in clay particles. Since more colloid fraction particles were determined in the texture of erosional drift, and since due to its large active surface the colloid fraction is the main nutrient carrier in soil, it is realistic to expect great diversity of chemical properties. A higher soil pH, soil organic matter and a larger amount of available phosphorus and potassium were determined in erosional drift.
Key words: Tillage erosion, Physical and chemical property of soil loss

Introduction

Soil erosion proceeds in three stages; the first involving separation of soil particles by the energy of raindrop impact, which is followed by transport of these particles by surface runoff along the slope. At the moment when the transport energy wears away, the third and last stage of the process sets on i.e. deposition of erosional drift. An important theoretical, but also practical question is whether the overall soil mass is separated in the first stage and then unselectively taken away by erosion or whether certain fractions of soil particles prevail in erosional drift. If the most active, colloid fraction, to which cations of biogenic elements, but also major mineral and organic pollutants (heavy metals, pesticide residues, etc.) are bound, prevails in erosional drift, a selective distribution of nutrients and pollutants occurs in the surface layer. In that case, zones of soil loss removal would be poorer in nutrients and less polluted than the zones of its accumulation.
Our aim was to find out which material in different tillage systems on Stagnic Luvisol was predominantly transported into watercourses and deposited on their bottoms. Especially we want to investigate whether and how erosion participates in this process, whether there are differences in soil removal due to the tillage method direction of soil tillage, and to which extent erosion may be reduced or prevented by the direction of tillage, all in order to find out the optimal tillage method for Stagnic Luvisol.

Materials and methods

The experiment was carried out in Daruvar in central Croatia (N: 45°33'48" E: 17°02'06", altitude 133 m) and initiated on Stagnic Luvisols, following the oil seed rape harvest in the summer of 1994. Runoff and soil loss were measured according to the USLE (Universal soil loss equation - Wischmeier and Smith, 1978) protocol, which specifies a plot area of 41.3 m^2 (22.1 long and 1.87 wide) on a 9 % slope. Six different tillage methods were investigated:

- **The control plot (black fallow)** tillage up and down the slope. Tillage practices applied included: ploughing at a depth of 30 cm, seedbed preparation with a harrow, but the soil was kept bare at all time. The weeds were suppressed by total herbicides.

- **Ploughing up and down the slope at a depth of 30 cm.** Seedbed preparation with a harrow and sowing were performed in the same direction.
- **No-tillage** sowing with a special seeder into the dead mulch up and down the slope. Two to three weeks before sowing weeds were suppressed using total herbicides.
- **Ploughing across the slope at a depth of 30 cm** was done in the same way as the ploughing up and down the slope method, except for the different ploughing and sowing direction.
- **Very deep ploughing across the slope at a depth of 60 cm.** In contrast to all other ploughing which was done with multi-furrow ploughs, a single-bottom plough was used in this method.
- **Subsoiling at a depth of 60 cm** subsoiling tines spaced 60 cm apart**,** with ploughing across the slope at a depth of 30 cm.

Filtration equipment was set up at the lower end of each plot and was designed for volume measurement of water and sediment yield transported by surface runoff. After each runoff-producing rainstorm, water and erosional drift were collected. Water and erosional drift were taken into the laboratory for the analysis of the investigated physical and chemical characteristics.

The crops on each experimental plot (apart from the control plot) were grown in a crop rotation that is typical for this agricultural area: maize (1995; 2000 and 2008), soybean (1996; 2001; 2005 and 2009), winter wheat (1996/97; 2001/02 and 2005/06), oil seed rape (1997/98; 2002/03 and 2006/07) and double crop - spring barley with soybean (1998/99; 2003/2004 and 2009/10).

Results and discussion

The soil type of the experimental station is classified as Stagnic Luvisol (FAO, 1990), formed on non-carbonate Pleistocene loam as parent material, with A_{ch}+E_{cg} – E_{cg} +B_{tg} – B_{tg} sequence of soil horizons. Due to its physical (high content of fine sand and silt, low aggregate stability) and chemical properties (calcium deficiency, low content of soil organic matter), this soil type is very erodible.

Figure 1 shows an average texture of non eroded soil and erosional drift during the 15 years of investigation. Since the soil is eroded from a certain area, the texture should be the same in the non eroded soil as in the erosional drift. The conducted investigation carried out during a 15 years of investigation have shown that in most cases this is not so. The difference in texture has been determined between the non eroded soil and erosional drift from the experimental plots. In all tillage treatments approximately the same amount of coarse sand has been observed in the non eroded soil as in the erosional drift. In terms of fine sand content, sometimes more of these smaller particles was observed, and sometimes less of theme were observed in the erosional drift. The silt was in most cases more present in the erosional drift compared to the natural, non eroded soil. In particular, this applies to the particles of clay. Namely, in most cases the particles of clay were more frequent in the erosional drift than in non eroded soil.

The differences in the quality of erosional drift were not observed in the control plot. In this variant, both non eroded soil and eroded soil, on average, had a loam soil texture. In the variant with the ploughing up or down the slope in the non eroded soil silt loam texture was determined, while erosional drifts from this variant, on average, have a clay loam texture. In no-tillage treatment the same texture of non eroded soil was determined, while the erosional drifts had a loam to clay texture. In ploughing across the slope treatment the non eroded soil texture was silt loam, and the erosional drift in this variant is, on average, a loam texture. Variants with very deep ploughing and subsoiling across the slope had a loam soil texture in non eroded soil, while, on average, the erosional drift in these variants had a clay loam texture.

It is important to emphasize that the difference in texture between the natural soil and the erosional drift was inversely proportional to the increase in the total quantity of the erosional drift.

Since more colloid fraction particles were determined in the erosional drift, and since it is due to its large active surface the main nutrient carrier in the soil, it is reasonable to expect that the differences in chemical characteristics were established between non eroded soil and erosional drift from the experimental plots. In most cases in the erosional drift a higher value of soil pH was determined, as well as a higher soil organic matter (Figure 2) and a larger amount of available phosphorus and potassium (Figure 3). The highest soil organic matter, that is, the greatest differences between the investigated parameters were determined in the variant with no-tillage. The justification for this situation is found in the soil treatment method. It is a variant in which the seeding is done in a direct way, without any tillage treatment. The plant material that is located on the surface of the soil is carried away with the water that runs off and comes in the erosional drift. Likewise, extremely high amounts of plant available phosphorus and potassium were determined in this variant. Since no tillage was done on this variant, all nutrients that are added remain in the first few centimetres of the plough layer. The water that moves over the surface carries the nutrients in a slightly higher amount in comparison to other versions where they are by means of the applied tillage method incorporated into a complete plough layer.

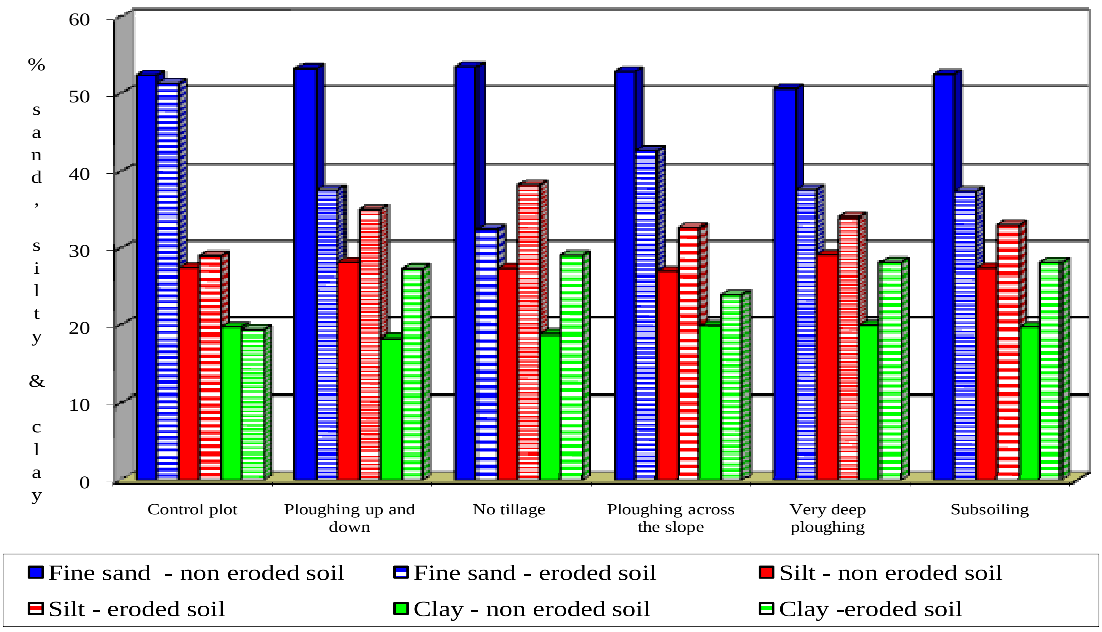

Figure 1. Average content of fine sand, silt and clay in non eroded soil and erosional drift

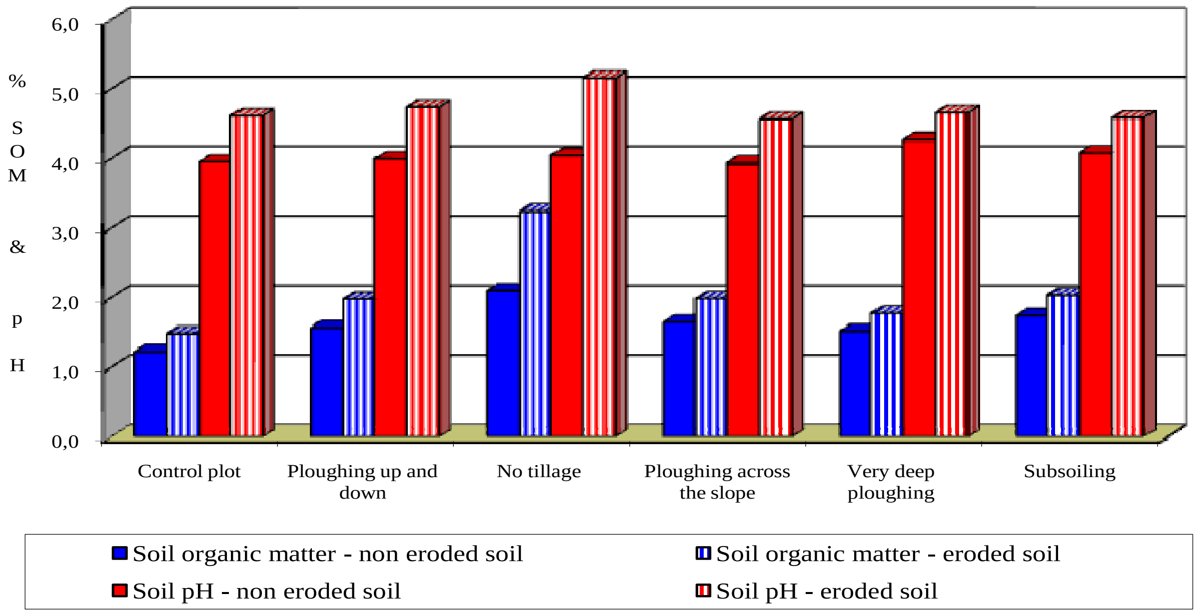

Figure 2. Soil organic matter and soil pH in non eroded soil and erosional drift

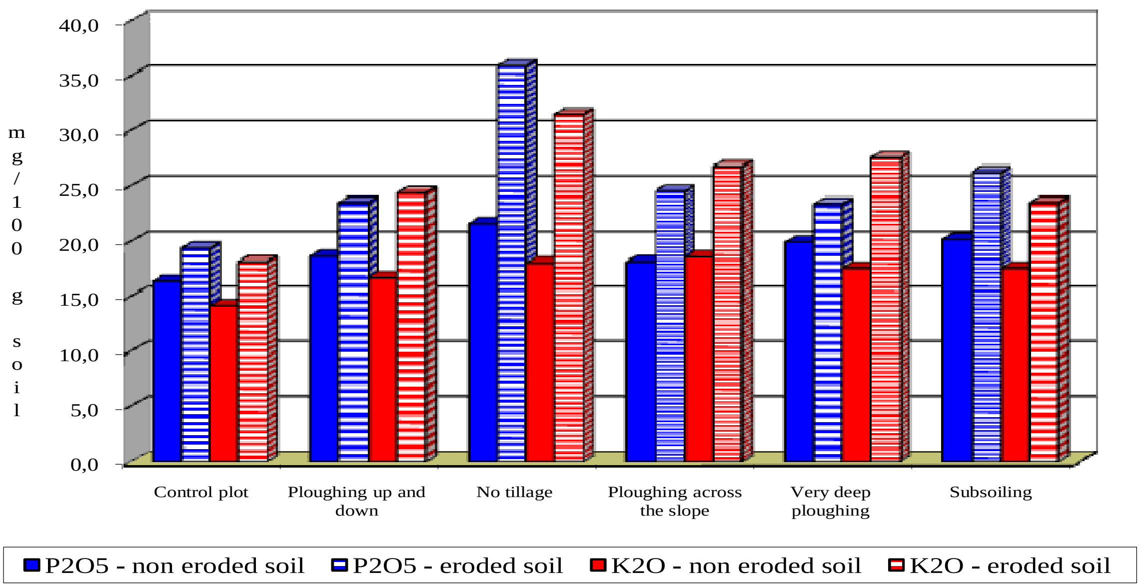

Figure 3. Plant available phosphorus and potassium in non eroded soil and erosional drift

Conclusions

Comparison between the particle size distribution in non eroded soil and in erosional drift after 15 years stationary investigations in different tillage treatments on Stagnic Luvisol points to the following conclusions:

- Soil erosion by water does not remove all soil particles equally. The removal is selective in that more of the most active, good quality particles - clay particles are taken away. The content of fine sand was generally lower in erosional drift than in non eroded soil. In contrast, erosional drift contains more silt and clay particles than non eroded soil. The highest content of clay particles was recorded in erosional drift from no tillage treatment.

- A higher content of soil organic matter, higher levels of available nutrients (phosphorus and potassium) and more favourable soil pH were recorded in erosional drifts than in non eroded soil.

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Soil Physics and Climate Change

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Soil and Tillage Research - Editor in Chief, Czech Republic

Introduction

I have found an increasing number of papers submitted and published in the journal Soil and Tillage Research where the aim of the research on soil tillage and related processes has been directed more to the problems of climate change, therefore to climatology than to soil science. The emissions of CO_2 due to the variation in soil technology have been determined and those values were taken as decisive in climate change. There is no doubt about the importance of the study on the dynamics of C org. content in soils, where the research brings a better understanding on these processes. However when the authors of papers are under the influence of massive propaganda on global warming due to the human activity and due to the increase of CO_2 concentration in the air, they have the tendency to study in detail the CO_2 emissions and the nature of C org. soil dynamics is more or less underestimated. I am considering this deviation from the basic aim of soil science as unfortunate for two reasons. First, our knowledge on C org. dynamics under various conditions of soil technology is still not adequate and the transformations of plant residues have not been studied at the adequate depth. The comparison or statistics of C org in soils influenced by various tillage practices can not substitute scientific analysis of processes. And second, we as soil scientists are aware of the climate changes in the past as they were reflected by soils and as the soil scientists specialized in paleopedology teach us. My essay will be directed therefore to the problems of climate change as they should be studied by soil scientists.

Recent global warming

The recent climate change started in the year about 1850. The estimation is a matter of general agreement and it is not strictly equal to local or regional observations. In all recent studies the climate change is characterized by the global temperature, while other climate characteristics are only sometimes mentioned or more frequently ignored. The temperature increase in the 20th century was estimated as 0.74^{o}C and the rate of its rise is increasing according to the Fourth Assessment of the Intergovernmental Panel for Climate Change (IPCC 2007). Since 1850, eleven of the twelve years (1995 to 2006) rank among the 12 warmest years in the instrumental record of global surface temperature. The warmest years in the instrumental record of global surface temperatures are 1998 and 2005 for time period ending in 2007 (Trenberth et al., 2007). The Goddard Institute for Space Studies acknowledged the error and now 1934 is considered the warmest year on record, not 1998. Measured temperature of the global ocean has increased to depths of at least 3000 m in the last 40 years. The energy balance shows that the ocean absorbs more than 80% of the heat added to the climate system.
With the rise of the global temperature being an average value of 0.74^{o}C, its value has been greater over land than that over the oceans owing to the smaller thermal capacity of the land. Because the continents occupy a larger area on the northern hemisphere, there has been a tendency for a higher temperature rise in the northern than in the southern hemisphere (Trenberth et al., 2007). The rise is very small in the equatorial regions and increases with the latitudes on both hemispheres. The geographical position on a continent is also important.
The temperature rise was not monotonous – the average temperature rise was higher in the period 1920 to 1940 than it is today and there was even a period of temperature decrease. The estimation of the global temperature from the surface meteorological stations has been a difficult task. During the last 29 years, the instrumentation in satellites was applied to measure

the Earth's global surface temperature. These methods of measurement are considered by meteorologists to be the most objective proof of global warming. The global temperature during the last decade was no longer rising (Easterling and Wehner, 2009) in spite of still rising atmospheric content of CO_2.

The majority of climatologists in state institutions, mainly in meteorological state services, are working with the hypothesis that the climate warming during the last two centuries was caused dominantly by the greenhouse effect of CO_2 released by burning fossil fuels. In brief, **the greenhouse gas hypothesis was formulated claiming that the recent global warming is caused by the rise of CO_2 in the atmosphere.** Before the industrial revolution, which started by using the energy from coal, oil and gas, the concentration of CO_2 in the atmosphere ranged from 250 to 280 ppm (parts per million). Today's value is close to 390 ppm. A simple correlation performed several decades ago showed a very high correlation coefficient between the global temperature and CO_2 atmospheric concentration. Later on, physical models on global warming were presented with dominant greenhouse gas (GHG) forcing.

However since the correlation between temperature and CO_2 content is inconsistent and weak for the three decades of temperature measurement from the satellite, it shall be revealing to test the hypothesis about the CO_2 influence on Holocene's climate oscillations. If we are using the Popper´s epistemology taking Popper as the most prominent philosopher studying the rational essence of sciences, we start the study of the GHG hypothesis by falsifying it.

If we don't find agreement between the primary information and the prediction based upon the hypothesis even in just a single case, the proposed hypothesis must be rejected and judged generally not acceptable. The same conclusion must be made for numerical modeling whenever even a single inconsistency exists between the results of the model and primary information.

Experiments Performed by Nature

The best way to falsify a certain hypothesis is to repeat an experiment with slightly modified boundary conditions. Experimentation with the planet Earth and its atmosphere is possible only in our imagination or in science fiction novels. However it does not mean that we are helpless to know how to falsify the hypothesis on global warming caused by an anthropogenic increase of CO_2 in the atmosphere. Nature itself performed a number of experiments and it offers the information on past climate change and on the concentration of atmospheric CO_2. I am restricting our discussion to the late Pleistocene and Holocene, the last 250,000 years – the time period of Homo sapiens existence. It does not mean that the earlier geological epochs and periods would not offer reliable arguments for our discussion. Quite opposite, I could literally flood this essay by further facts, but it is just the restriction of the space that I am omitting them.

Indisputable data are available from the deep drilling in Greenland glacier and in Antarctic glaciers on stations VOSTOK and EPICA. Based on isotope ratios of $^{2}H/^{1}H$ and $^{18}O/^{16}O$ in thin ice layers, the temperature has been estimated with relatively high precision. Accurately measured contents of CO_2 in the air enclosed in the pores of ice are also available. From a detailed analysis we know that the CO_2 peaks show a delay of about 300 to 800 years behind the temperature peaks in the second half of Pleistocene. Hence, the CO_2 reacted after the temperature had already changed.

The values of temperature change - taking the recent average value as reference - and the CO_2 content in ppm for VOSTOK (Petit et al., 2001) are shown for our studied period of time in the bottom of Figure 1. The oldest part of the graph is on the right at the late Mindel, the third glacial before present. The interglacial Mindel/Riss (Preillinoian) follows in the period about 240,000 to 225,000 years BP. Next is the Riss (Illinoian) glacial, after which comes the Riss/Würm interglacial (Eem, or Sangamon, 130,000 to 115,000 BP). The two interglacials were significantly warmer than our recent period. Next, the Würm (Wisconsin) glacial lasted until 11,500 years BP, the time from which our present Holocene interglacial has lasted. These relatively regular changes back and forth from glacials to interglacials are caused dominantly by the Milankovitch eccentricity of the Earth's orbit.

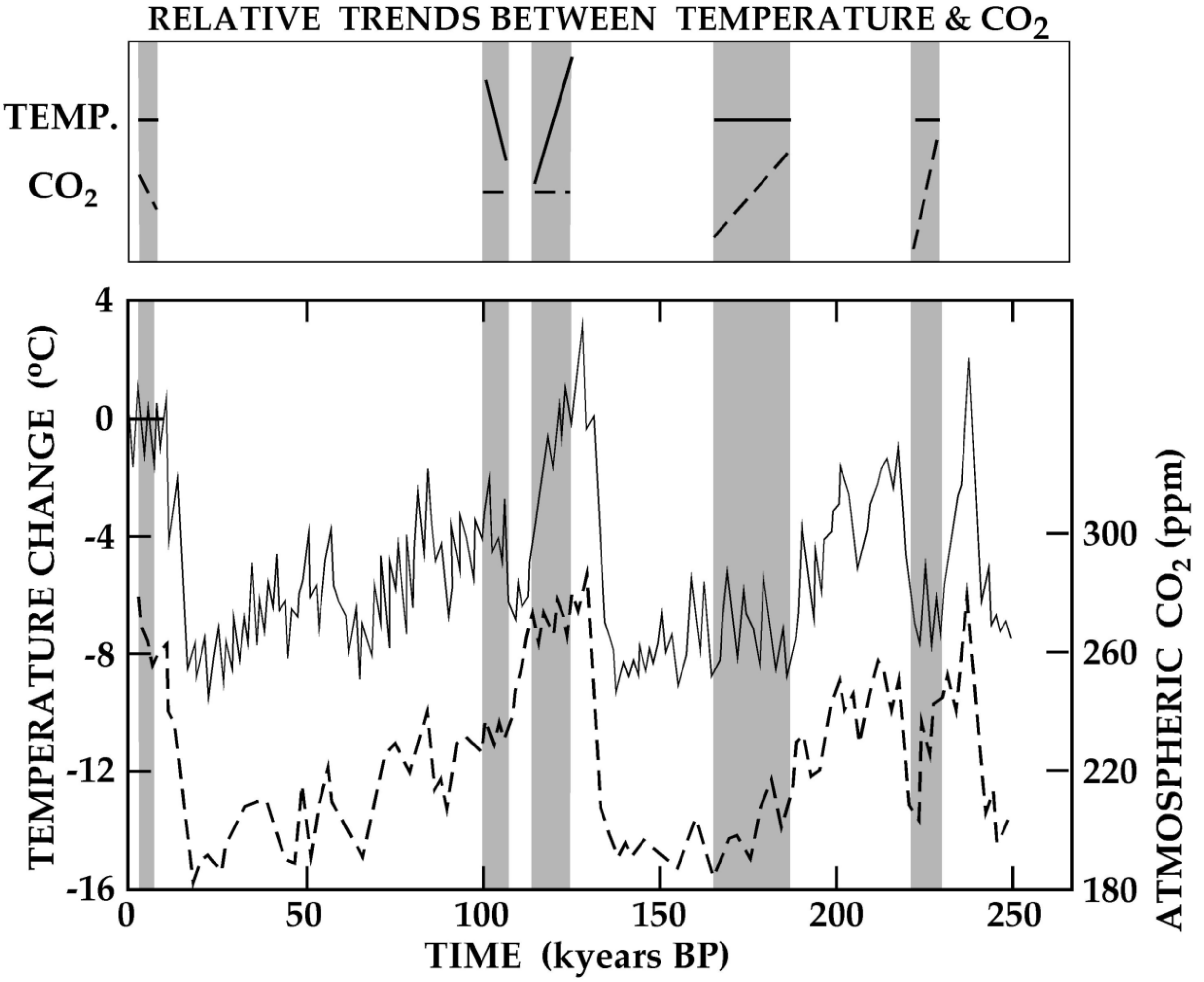

Figure 1. Evaluation of the Vostok ice core drilling data by Klemeš (2009, personal communication). Time periods denoted in grey are those during which the temperature change or temperature constancy does not correspond to the assumed greenhouse effect of CO_2 concentration, see the top part of the Figure (Kutílek and Nielsen, 2010, their Fig. 21). Full line is for temperature, dotted line is for CO_2 concentration.
Source of ice core data: http://en.wikipedia.org/wiki/File:Vostok-ice-core-petit.png.

Under the title *Relative trends between temperature & CO_2* in the top part of Figure 1, I am presenting a simplified illustration of the changing magnitudes of the two variables. There were five distinct time intervals when the relations between temperature and CO_2 were not only different from their expected correlation, but also acted against the hypothesis on GHG effect.

We can find a lot of publications of paleosols as documents about the past climate since the paleosols reflect among other factors the climate existing at the time of genesis of former soil which was preserved e.g. by burial underneath alluvium or loess. I am including here just a couple of examples. Smolíková (1984) and (1990) found chernozems of Eem age buried in loess, in some instances with slight indication of B horizon. She deduced a warmer and more humid climate than the recent one. Paleosols terra rossa and terra fusca on limestones and travertines indicate a warmer and more humid climate in the last Eem interglacial. Achyuthan

(2007) derived from the stabile isotopes in soil calcretes below the recent cover of desert Tsar that the climate of the interglacials was more humid. Ložek (1964) has derived that the temperatures in Eem interglacial were higher than the recent by 3°C at least in Central Europe. Nývlt et al. (2003) detected steps and related paleosols in recent interglacial in region of the river Ob where recently tundra exists only. Zhao (2003) found paleosols typical for temperature by 4°C to 6°C higher than recent in loess of the interglacial before Günz glacial. Olsen (1998) found in Norway paleosols of the last interglacial formed under a warmer climate than the recent. Many loess sections in Chinese Loess Plateau contain "fossil soils" (paleosols) which generally seem to be a trace of warmer and wetter climatic conditions corresponding to interglacial periods in contrast to the cold-arid environments during glacial periods in which the loess accumulated (Heller *et al*., 1991). CO_2 concentration in all mentioned events was below 300ppm and was not the driving factor of the climate change.
The Northern Hemisphere climate is closely related to temperature estimations derived from isotope ratios of ^{18}O measured in the Greenland glacier. Assuming that the Holocene climate (of the last 11,500 years) was decisive for the cultural and technological evolution of mankind, I am using the evaluation of data of Alley (2004) by Koutsoyiannis (2008) for a more detailed discussion on climate oscillation in this period (Figure 2). Using 20-year moving averages, the measured data offer a full explanation of warm and cool climate periods related to the scale of our observation of recent climate. Neglecting the secondary, smaller oscillations in this discussion, we count 9 main peaks of warm periods with temperatures at least 1°C above the recent average temperature. Among the 9 peaks were 3 peaks having temperatures 2.6 to 2.8°C higher than the recent average temperature. The atmospheric CO_2 concentration derived from VOSTOK was in ranges from about 255 ppm for the temperature peak around 7,800 years BP to 275 ppm for the temperature peak around 3,300 years BP.

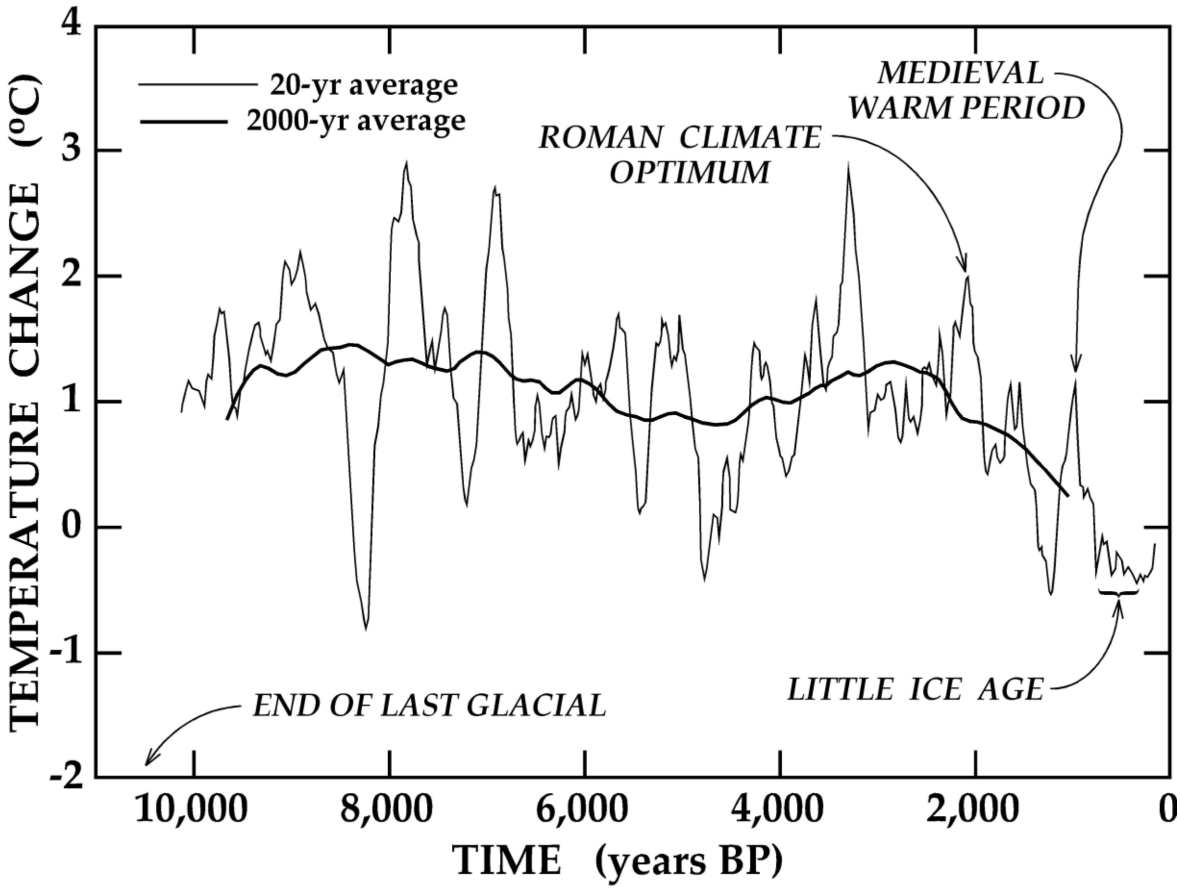

Figure 2. Temperatures in Holocene according to ice core drilling in Greenland glacier (Koutsoyiannis, 2008, modified, data from Alley, 2004). The measured data were "smoothed"

by the method of moving averages. The recent average temperature is denoted as 0^oC on the vertical time scale. We are still below the 2,000-year averages of the Holocene and below all warm peaks of the 20-year averages.

There was no indication of CO_2 change close to and around the warm peaks. It follows that the greenhouse gas gradient did not cause the significant change of the temperature. Except for its recent rise, the atmospheric CO_2 concentration during the entire Holocene ranged from 250 to 285 ppm. Interestingly, and with unanswered curiosity except for a few scenarios made for the last millennium, there has been no attempt to test the otherwise broadly used climatic models against the great majority of Holocene maxima and minima.
An evaluation of measured data using 2000-year moving averages brings information on the scale of the geologic epochs. The Holocene temperature optimum lasted to about 7,000 years BP and then the decrease was well correlated to the drying phase observed also in Egypt and Mesopotamia. The secondary temperature maximum reached its highest values around 3,000 years BP and then a rapid decrease followed. One of probable causes was the expansion of agriculture and the change of native vegetation causing the change of albedo and other microclimatically important characteristics. The change of CO_2 atmospheric concentration had an increasing tendency instead of expected decrease of CO_2 concentration according to GHG hypothesis. All climate changes in Holocene mean that we have to refute the greenhouse gas hypothesis.

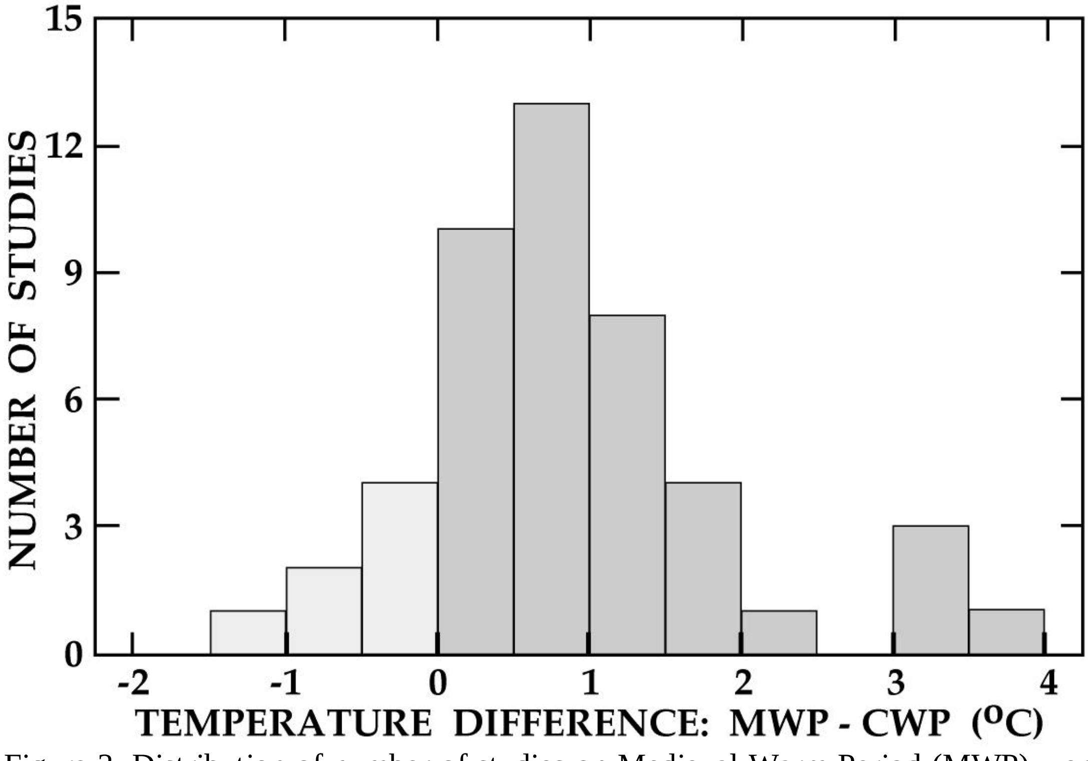

Figure 3. Distribution of number of studies on Medieval Warm Period (MWP), vertical axis, and the temperature estimated as proxy and plotted on horizontal axis as MWP – CWP where CWP is the Contemporary Warm Period. Most frequent was the temperature higher than the recent in ranges of 0.5 and 1^oC.

Source: http://www.co2science.org/data/mwp/quantitative.php, also Kutílek and Nielsen (2010), their Figure 8.
The climate in the last millennium is characterized by two main oscillations – the Medieval Warm Period (about 800 to 1,300 AD) and the Little Ice Age starting sometime in the 14th through 17th century AD and ending around 1850 AD with a sharp increase of temperature

after 1850 AD. With the atmospheric CO_2 concentration being below 285 ppm, the greenhouse gas forcing was again absent. The Figure 3 documents that the average temperature during the Medieval Warm Period was 0.5 to 1°C above the recent global value according to number of proxies in the great majority of published data. From the shape of the 20-year averages in Figure 2 it follows that the recent warming is actually a form of a gradual returning from Little Ice Age to temperature values typical for Holocene, but not yet reaching those levels nor even those of the relatively mild Medieval Warm Period.

False Hypothesis

There are all global climate oscillations in both Late Pleistocene and Holocene without active greenhouse effect forcing. The models developed on the assumption that greenhouse gases have a dominating role upon recent global warming are not applicable for Holocene or Pleistocene.

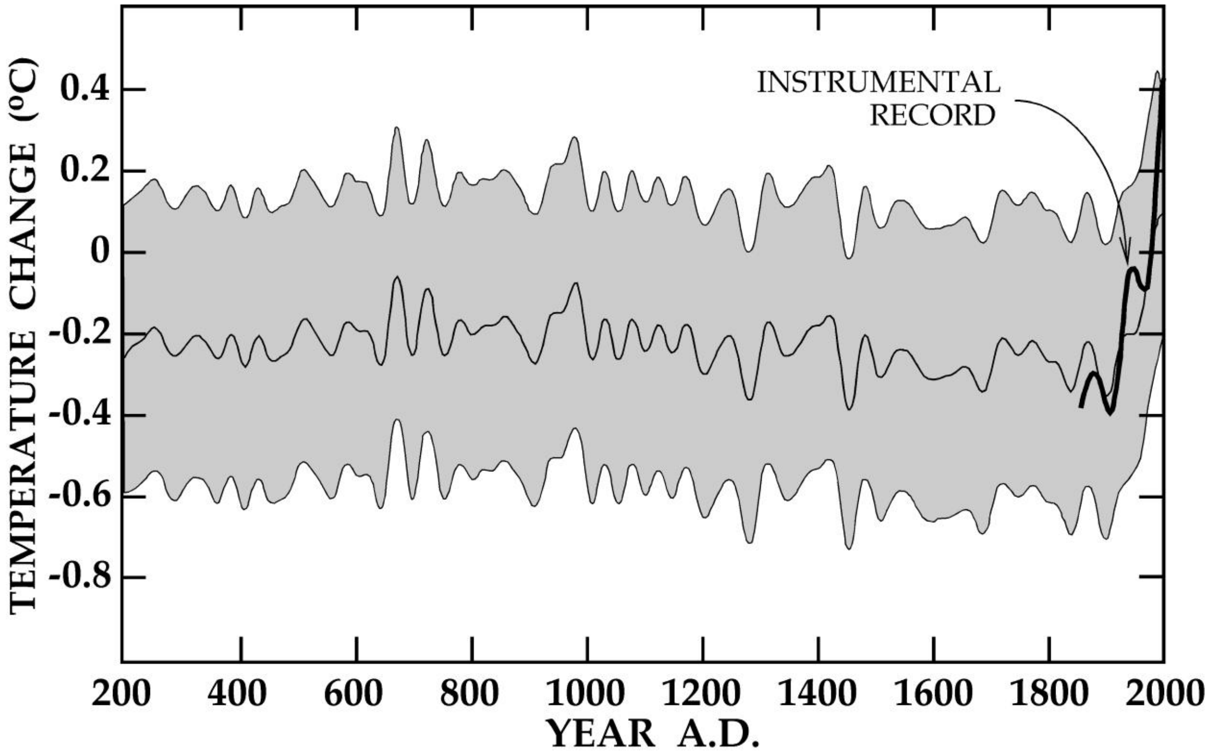

Figure 4. Temperature changes in the last two thousand years by numerical model with uncertainties indicated by the grey area. A modified graph of Mann and Jones (2003) and http://www.ncdc.noaa.gov/paleo/pubs/jones2004/fig5.jpg

See also Jones and Mann (2004).

As an example of failure of frequently used numerical models I compare the modeled global surface temperatures during the past two millennia in Figure 4 (Mann and Jones, 2003) with the measured data, i.e. with the distribution of temperature according to ice core data in Figure 2, where is a distinct temperature peak in Middle Ages and a deep sink thereafter in the Little Ice Age. The evaluation of the Medieval Warm Period was also shown in Figure 3 where temperatures have a mean between 0.5 to 1.0°C above the recent global temperature. On the other hand, in the results of numerical model in Figure 4 there is neither a Medieval Warm Period with the temperature maximum nor a distinct Little Ice Age minimum. This comparison manifests the failure of the model that is based on the hypothesis of a dominant greenhouse effect influence. More similar computed models are in IPCC reports.

Douglas et al. (2008) compared predictions of 22 widely used climate models with actual readings by surface stations, weather balloons and orbiting satellites over the past three

decades. From their findings and from other examples in the literature (e.g., Kutílek and Nielsen, 2010), it is evident that results from computer models do not agree with observations. Being based merely on the assumptions of their creators, such hypothetical scenarios were never successfully tested against long periods of the past climate change. Their lack of reality hinges not only on the underestimation of other forcing factors, but also on feedbacks diagnosed from only relatively short-term satellite datasets, regardless that may have nothing to do with primary feedbacks involved in long-term processes.
When we summarize the information in the previous paragraphs and that on models based upon the greenhouse gas hypothesis, not comprehensively cited here for brevity, we find that the assumption on the dominant greenhouse gas effect is false and not acceptable when we deal with the recent global warming and that **the greenhouse gas hypothesis is not valid.** In all models, differing only in specific details from one another, other factors influencing the climate change were neglected or underestimated, like solar activity, vegetative cover, aerosols, thermohaline circulation and possibly Earth magnetic field.

Irrational threats

It is without a shadow of a doubt that global warming exists. I tried to demonstrate that the climate change in both the human and geologic past was the consequence of the action of several factors and that the scientific community has the proof that many climate changes occurred not only in the geologic history, but even during the last ten thousand years which were so decisive for mankind. The natural climatic change can be compared to a staircase moving rapidly upwards (an escalator). Let us walk on our imaginative escalator either in the direction of its movement up or down against its direction. With the velocity of the escalator being very high, even if we try to run down, the escalator is carrying us up. And if we run up, we are merely able to shorten the time of our arrival at the top. In our analogy, the escalator represents the global warming due to natural factors. The words natural factors are all of those mentioned earlier except anthropogenic greenhouse gases. Our walking on the escalator represents the change of the concentration of greenhouse gases due to human activity. The change of our position with respect to the non-moving surroundings is slightly influenced by our walking: we reach the top somewhat faster than the steps of the escalator if we walk up. The reality of our analogy is that increased CO_2 concentration will contribute only slightly to the general increase of the global temperature. Or, if we try to walk down the rising escalator, we still arrive at the top, but with a slight delay compared to the arrival of the escalator steps. It means we could only slightly decrease the natural global warming. But if the escalator runs really very rapidly, we are never able to run to the bottom end of the escalator. We have no chance to reverse the run of temperature, to change completely the climate according to our wish.
The defenders of the greenhouse gas hypothesis use all possible tools to persuade the public. Various scenarios on catastrophic events are very efficient in their fight against scientific correctness and integrity. Here, I summarize them. The next general statements have a global validity while local exceptions could occur – like the different distribution of rains accompanied by their high intensity in some regions, local existence of increased dryness or overwetting, extinction of some organisms or their shift to a nearby region with different climate characteristics, etc. The variability of local change is a typical feature of the permanent variation of natural processes.
The change of the atmospheric CO_2 concentration had the consequence of starting glacials and interglacials in Pleistocene.
The statement is not correct. The processes started quite the opposite. The strong cooling at the beginning of glacials was caused by Milankovitch cycles with the consequence of slowing down biological processes that decreased atmospheric CO_2 concentration. Similarly, the start

of the interglacial was also the result of the action of Milankovitch cycles. The increased temperature had a stimulating effect upon biological processes and only then did the CO_2 concentration rise.

The contemporary high concentration of atmospheric CO_2 has no parallel in history.

This is a poorly formulated statement. It is correct for the Pleistocene in the last two millions years when the atmospheric CO_2 concentration was below 300 ppm. In the long-lasting geological history of the Planet Earth the CO_2 atmospheric concentration was substantially higher even by more than one order of magnitude. CO_2 value was well above 500 ppm in the geologic periods known by the maximum biodiversity. However, the general tendency in the Earth history (and in the forecasted future) is a decrease of CO_2 concentration with time.

The increase of CO_2 atmospheric concentration beyond a certain limit will lead to extinction of many living genera.

Not true. Mass extinctions never occurred due to the high CO_2 concentration in the whole history of living multicellular organisms in Phanerozoic, even if CO_2 concentration was more than ten times higher than today (Rohde and Muller, 2005)

The contemporary global temperature is higher than it has ever been during the entire Holocene (the last 11,500 years).

This declaration is not right. The temperature was 2 to 3°C higher in the early Holocene (approx. 9 to 6 thousand years BP). On several occasions it was 1 to 2°C higher than it is now, e.g. in the Roman Warm Period (closely before and at the start of our Christian calendar) and in the Medieval Warm Period (between 850 to 1200 AD), see Figure 2.

The contemporary global temperature is the highest in the last 500 years.

Because the time limitation is arbitrary, this assertion cannot be taken seriously as a compelling argument. Moreover, with the Little Ice Age being included at the beginning of the last 500 years, the temperature was already well below the Holocene average. Hence, there was little difficulty asserting the recent temperature is at its highest value since the start of Little Ice Age.

The recent catastrophic rate of temperature rise has no analogy in the past.

The statement is false. The rate of temperature rise was roughly the same at the transition from the last glacial to our recent interglacial and in two events the rate of warming was distinctly higher than our recent warming according to analysis of core ice samples from Arctic (Kutílek and Nielsen, 2010).

Disastrous hurricanes arrive due to continuity in global warming

Hurricanes are natural disasters and the physics of their evolution belongs to atmospheric sciences. Inasmuch as tropical cyclone activity seems to rise and fall in cycles lasting for many decades, the study of their long-term trends is made difficult by this variability. The question of whether global warming is affecting tropical cyclones was given a nonconclusive reply by those attending a WMO workshop in 2006.

In spite of such ambiguity, climatologists belonging to the group working for IPCC ascribe the alleged increasing strength and frequency of tropical cyclones to global warming. They found a positive correlation between sea surface temperature and Atlantic tropical cyclone frequency from 1871 to 2005 and modeled the hurricane existence in a same way as the global warming for last 2000 years was modeled (Mann et al., 2009). Their results are dubious for three reasons. First, the structure of models was identical to models on climate change, and we have shown that the latter models have never been successfully tested against the temperature data of the past. Such modeling of cyclones carries the burden that the results have yet to be confirmed with reality. Second, Pielke et al. (2008) using normalized damage as the scale of hurricane force for more than a century (1900-2005), found multidecadal variability but no tendency of a continuously increased force of hurricanes with the increase of global temperature. Third, another complicating consideration is that changes in climate

can also change the potential paths of tropical cyclones – they could preferentially remain either on the ocean or strike on the land.
From another point of view, there is no argument against the general rule that the occurrence of hurricanes is strongly reduced or probably even absent during the long-lasting cool periods of glacials. However, the strength of winds or wind storms on continents was much higher in those cool periods compared with that of recent experience. This statement is also supported by the evidence of dust storms in the last glacial (Harrison et al., 2001) and by the deposited layers of thick loess that originated in glacials. The probable absence of hurricanes in glacials is not a proof that the rising temperature at climate oscillation in warm period of the Holocene would bring an increased occurrence of hurricanes.

Floods
According to IPCC authors, river flood regimes are related to man-made climate change. The long-term data on river discharge and on flood frequency indicate that there is no relation between floods and climate change on a centenarian scale. However, the hydrologists found a tendency of clustering floods (Brázdil et al., 2005) and paleorecords show that floods due to excessive rainfall or snowmelt are very sensitive to modest changes of climate smaller than changes expected from IPCC future global warming in the 21st century. Frequencies of large floods have increased when there are increases in the number of air waves and their amplitudes in the middle and upper tropospheric circum-polar circulation (Knox, 2000). Nevertheless, owing to changing air circulation systems, flash floods restricted to small regions could appear more frequently without the opportunity of being predicted well ahead of their occurrence.

The catastrophic rise of the sea level
With the warming and thawing of inland ice, the volume of sea water increases. With warming, the volume of sea water increases further because of its thermal expansivity being temperature dependent. Hence, both processes cause the sea level to rise. Although the IPCC prognoses its rise from 38 cm up to 1 m, some prognoses parallel conditions during the last Eem interglacial when the sea water level was 4 to 6 m above the recent level. The latter assertion is easily invalidated because the time for melting is not comparable. The Eem temperature being 3 to 5^{o}C higher than our recent lasted for thousands of years compared with our recent perturbation that has thus far lasted only for less than two centuries. With the rate of recent rise of sea water level ranging from 1.5 to 2 mm per year, the most extreme rise by 2100 will be less than 20 cm. Although potentially troublesome, protecting coastal areas from such rises is not much more demanding than that already commonly achieved today against tides frequently associated with local, short-lasting storms.
Global warming leads to the increased of aridity and to desertification
IPCC states that due to the global warming and drying the menace of drought increases and that the decreased precipitation is the dominant factor in the aridization process. Studies of the geological near past, i.e. of the last two interglacials that had higher average temperatures by 3 to 5^{o}C provide unambiguous results on increased precipitations and on either the disappearance of great deserts or at least on the substantial restriction of their areas. Even at the first quarter of Holocene the majority of the recent Sahara desert was covered by savanna when at that time, it was warmer than now (see Figure 2) and also relatively humid. On the other hand, the cooling of the climate in glacials caused an increase of deserts. For instance, in the Sahara the southern boundary of its sand dunes shifted by about 400 km to the south compared to the recent situation in our Holocene (Roberts, 2004). Similar expansions occurred in other desert zones. The regions of middle latitudes suffered extreme aridity with strong dust storms contributing to aridity in the cool climate of glacials, whereas the climate

in the interglacials was generally warmer and more humid judging from the existence of paleosols (Smolíková, 1990; Kutílek and Nielsen, 2010). Therefore, if desertification is detected in some regions, it cannot be the consequence of global warming – the only perpetrator is human society with its inability to harmlessly coexist with arid and semi-arid environments without transforming them into super-aridity by extreme exploitation of inadequately available local natural resources.

Menace of famines

According to publications of IPCC and some climatologists within its sphere of influence, a prognosis of increased aridity has the consequence of the menace of famines. They ignore the multitude of experiments performed since the end of 19th century verifying the positive influence of CO_2 upon photosynthesis and upon the yields. The first ideas on "atmospheric fertilization" appeared in several of twenty volumes on Agricultural Physics edited by E. Wollny (Forschungen an dem Gebiete der Agrikultur-Physik) starting from 1878 and the first monograph on this theme was published in 1926 by Rheinau. Since that time the theory of photosynthesis has greatly advanced together with the closely related topic of the plant water regime. The experiments were shifted outside of greenhouses and photosynthesis, plant water regime and transpiration were studied simultaneously together in the field with atmospheric CO_2 concentrations controlled at various levels (Kimball et al., 2002, Kirkham, 2005 and 2011). Transpiration is influenced by an increase of atmospheric CO_2 in several ways. First, the number of stomata openings decreases mainly in C_3 plants if they grow within elevated concentrations of atmospheric CO_2. The plants have no need of high number of stomata openings through which CO_2 is accepted. Through them the physical loss of water by evaporation from the plant is realized, too, and reduced under the higher CO_2 concentration just to the decreased number of those openings. Moreover, the diffusional resistance of the stomata increases with the increase of CO_2 concentration since they change their shape more closely to that of a crescent, which further reduces transpiration. Owing primarily to these two mechanisms, the amount of water needed for the production of one unit of mass of organic material is reduced when CO_2 concentration increases. In other words, plant yield increases when CO_2 concentration rises while water consumption is practically not increased. Or, in some instances, the increase of water consumption is small and less than proportional to the increased yield. These same relations are even more pronounced if the temperature is increased. Generally, the rise of temperature and the rise of atmospheric CO_2 concentration act positively upon food production and upon efficient soil water management. The menace of famines is therefore reduced.

The change of climate will cause the decline and termination of our civilization.

The exact opposite is correct. The cradle of civilization is placed at the start of Holocene with its warmer and more humid climate. Changes of climate were participating in human evolution and in the rise of ancient cultures. There were also instances of declines of civilizations attributed primarily to the internal weakness of social systems to mobilize enough forces to protect them when the climate deteriorated and cool periods bound to aridization were installed.

I could provide more evidence (opposed to climate model predictions based on the false theory), that the recent and future size of global warming and of CO_2 concentration increase does not cause increased human mortality. It does not bring plant and animal extinctions. It does not decline vegetative productivity. It has no influence upon more frequent and deadly coral bleaching. It does not result in marine life dissolving away in acidified oceans.

In those and in many other areas we find the referenced papers reporting that the global warming and rising CO_2 levels have biosphere-friendly effects.

Conclusions

The hypothesis on the dominant role of greenhouse gas CO_2 upon the recent climate change characterized by the global warming and the acts of IPCC by proclaiming this hypothesis as scientific theory was clearly established as false. The main arguments are climate oscillations in the Holocene where the role of CO_2 upon them was not proved. As the oscillations were caused by the action of other factors, there is no reason and no proof that those factors stopped their influence. Than we have to accept a real fact that the recent warming is a process bringing the extremely low temperatures from the Little Ice Age back to the average temperature of the Holocene and possibly above them without a generally harm. The climate change could cause a shift in upper tropospheric circumpolar circulation and thus influence a different distribution of rains from the patterns obtained by statistical studies in the last century. However the new patterns are not predictable. We can state only that there is no danger of aridization and that the rise of evapotranspiration will not act upon deterioration of agricultural plants yields or upon extremes in depletion of soil water storage.

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CONTENT

Differences in microbial characteristics, organic carbon and nutrients contents and CO_2-fluxes in soils under different tillage practices

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Abstract

The selected microbial characteristics, organic carbon contents, concentrations of nutrients and CO_2-fluxes were determined in field experiments in Prague – Ruzyně (Czech Republic) with conventional (CT), reduced (RT) and no-tillage (NT) practices. The adoption of RT and NT increased in comparison with CT the microbial characteristics and soil organic carbon contents in the surface layer of the soil profile and consequently in the soil profile 0-30 cm. Contents of P, K and Mg, but not Ca, accumulated in the surface layer of the soil profile in RT and NT. CO_2–fluxes were determined in regular intervals after ploughing in 2008, 2009 and 2010. Warm and wet weather increased CO_2-fluxes under CT in August 2008, lower CO_2-fluxes were found under RT and NT. Hot and dry weather in August 2009 decreased CO_2-fluxes. Later ploughing in September 2010 decreased CO_2-fluxes from soils.

Key words: Tillage practices; nutrients; soil organic carbon; microbial activities; CO_2-fluxes

Introduction

The conservation tillage technologies are still more used due to their positive effects on soil physical and biological characteristics. The knowledge about the soil carbon balance is important for knowledge about possibilities of improving the soil quality, restoration of organic matter in soils (SOM) and decrease of CO_2-fluxes from soils. In fact, changes in frequency and intensity of soil tillage modify soil properties, distribution of nutrients and SOM in the soil profile. These changes become stabile with time. Soil quality is largely governed by SOM content, which in turn effectively responds to the changes in management. Conventional tillage affects the properties of the soil by mixing and inverting the soil layers as well as by incorporation of the crop residues into deeper layers of the soil profile. Conventional tillage promotes a loss of SOM, leads to a disruption of soil aggregates, contributes to erosion and CO_2 increase in the atmosphere (Roldán et al., 2003; Dong WenXu et al., 2009). Maintaining or increasing SOM content improves the capacity of the soil to sustain crop growth. It also can be considered to be a possible source for the sink of the atmospheric CO_2-C (Lupwayi et al., 1999). The changes in management from conventional tillage to conservation tillage agriculture may with time increase SOM content (Dao, 1998) and decrease sinks of the CO_2-C from soils (Al-Kaisi a Yin, 2005). In addition, it has potential for increasing the nutrient supply to crops (Doran, 1987) through changes in the mineralization and immobilization of nutrients by soil microbial biomass.

Long-term conservation tillage management alter the depth distribution of soil bulk density and the distribution and concentration of crop residue, organic C, total N, extractable P, CEC, pH, and residual NO (Salinas-Garcia et al., 1997). Higher concentrations of available P, Ca, and K and organic C and N in soils under no-tillage were found by more authors. No-tillage resulted also in a stratification of Ca, P and K with soil depth, as compared with reduced tillage and conventional tillage (i.e. Salinas-Garcia et al., 1997; Hickman, 2002).

The aim of this study was to determine changes of organic carbon, microbial activities and the distribution of nutrients within soil profile at conventional, minimum and no-tillage practice. The effect of soil operations in different tillage practices on CO_2-C fluxes was also evaluated.

Materials and methods

The field trials were carried out in Prague – Ruzyne (a beet production area; altitude 340 m; latitude 50°05' N; longitude 14°20' E; annual precipitation 472 mm; annual average temp. 8.4°C; Orthic Luvisol (IUSS/ISTRIC/FAO (2006); clay-loamy texture, pH (KCl) 7.0, pH (H_2O) 7.8; SOC 1.4%; available nutrients (extracted by Mehlich III method): P – 66 mg kg^{-1}; K - 213 mg kg^{-1}; Ca - 3897 mg kg^{-1}; Mg – 154 mg kg^{-1}; CEC – 227.6 mmol kg^{-1}). The experiment was started in 1995, when three tillage practices: conventional tillage (CT = mouldboard ploughing down to 22 cm), reduced tillage (RT = chisel ploughing of the surface soil layer to a depth of 10 cm), and no-tillage practices (NT = without tillage) have been applied. Each tillage practice was carried out on 10 m wide and 95 m long field and was subdivided to plots (10 m x 3.5 m). The experimental soils were sampled from plots with following fertilizing - 140 kg N as NH_4NO_3 with lime in two rates of 70 kg before sowing and during vegetation, 60 kg of P_2O_5 and 80 kg of K_2O before sowing. The ploughing in CT was carried out in the autumn, at the agrotechnically correct period for the given crop. The crop rotation was alfalfa – *Medicago sativa* (1995 and 1996), pea – *Pisum sativum* (1999, 2001, and 2007), spring barley - *Hordeum vulgare* (2003), oil seed rape - *Brassica napus* (2005, and 2009), and winter wheat – *Triticum aestivum* (1997, 1998, 2000, 2002, 2004, 2006, 2008 and 2010). The stubble and other crop residues were incorporated in to the soil under CT and RT and leaved on the soil surface under NT.

Sampling dates for microbial biomass C, organic carbon (Corg) and varied in the years 2008-2010 between the 14th and the 26th of May. The soils were collected from 0-10 cm, 10-20 cm, and 20-30cm layers. The soil samples were sieved at 2mm sieve and roots and animal debris were removed. Soil samples were analysed the week following sampling to determine soil organic carbon (Corg) (Sims and Haby, 1971), microbial biomass (Vance et al., 1987), dehydrogenase activity (Nannipieri et al., 1990) and concentrations of nutrients (P, K, Mg, Ca) by the Mehlich III method. CO_2-C evolved was determined after harvest by means of the LI-COR 8100 instrument equipped with a multiplexer Li-COR 8150 and three chambers Li-8100-104. The measurements of CO_2-fluxes started always two days after ploughing at the CT practice (the 14th August 2008, the 13th August 2009 and 6th September 2010). The measurements of CO_2-C were always carried out in an open-closed system in the morning between 9 – 11 a.m. for 2:30 min at four replicated sites of each tillage system. The regular measurements in intervals at about 1 week (according to weather conditions) continued till the end of October 2008 – 2010.

Results and discussion

NT and RT practices in the surface layer decreased soil pH in comparison with CT (Fig 1a). Soil pH increased with the increasing depth under RT and NT. The decrease of pH under no-tillage systems was reported for example by Salinas-Garcia et al. (1997) or Juo et al (1995). One of possible explanations could be that the increase of microbial activities in soils could cause the acidification of soils as the response of their metabolism (Giller et al., 1998). Soil acidification could be also the explanation of lower Ca concentrations in the surface layer (Fig. 1b) of soil as showed also Juo et al. (1995). However, our soils contain also arenaceous marl rich of lime substances and Ca in non-ploughed soils was possibly transported into lower layers of the soil profile due to rainfalls. In fact, calcium concentrations increased with the soil depth under RT and NT whereas the ploughing and soil inverting in CT maintained the Ca concentrations more equilibrated (Fig 1b). The K and P concentrations in soils were greater in the top layer of RT and NT as compared with CT (Fig 1c,d). The K and P concentrations decreased with the soil depth under RT and NT whereas an increase was observed under CT. Similarly, concentrations of Mg showed different trends for CT, RT and NT (Fig. 1e). Mg concentrations were the highest under the no-tillage system and decreased in correspondence to the soil depth, whereas an increase was observed under CT and RT. The observed distribution of nutrients in RT and NT was the most probably caused by the fertilizing on the soil surface and only slow incorporation by rainfall and other meteorological events into lower depths of the soil profile. The ploughing practiced under the CT practice incorporated better the fertilizers. With increasing area of reduced or no-tillage systems the nutrient balance in the soil profile and decreasing nutrient concentrations in deeper parts of the soil profile the new systems of fertilizing will need to develop.

Fig. 1: The pH values (a), concentrations of K (a), P (b), Mg (c) and Ca (d) under conventional (CT, reduced (RT) and no-tillage (NT) practices. The data represent average values in the years 2008 – 2010. The vertical bars represent the standard deviation error.

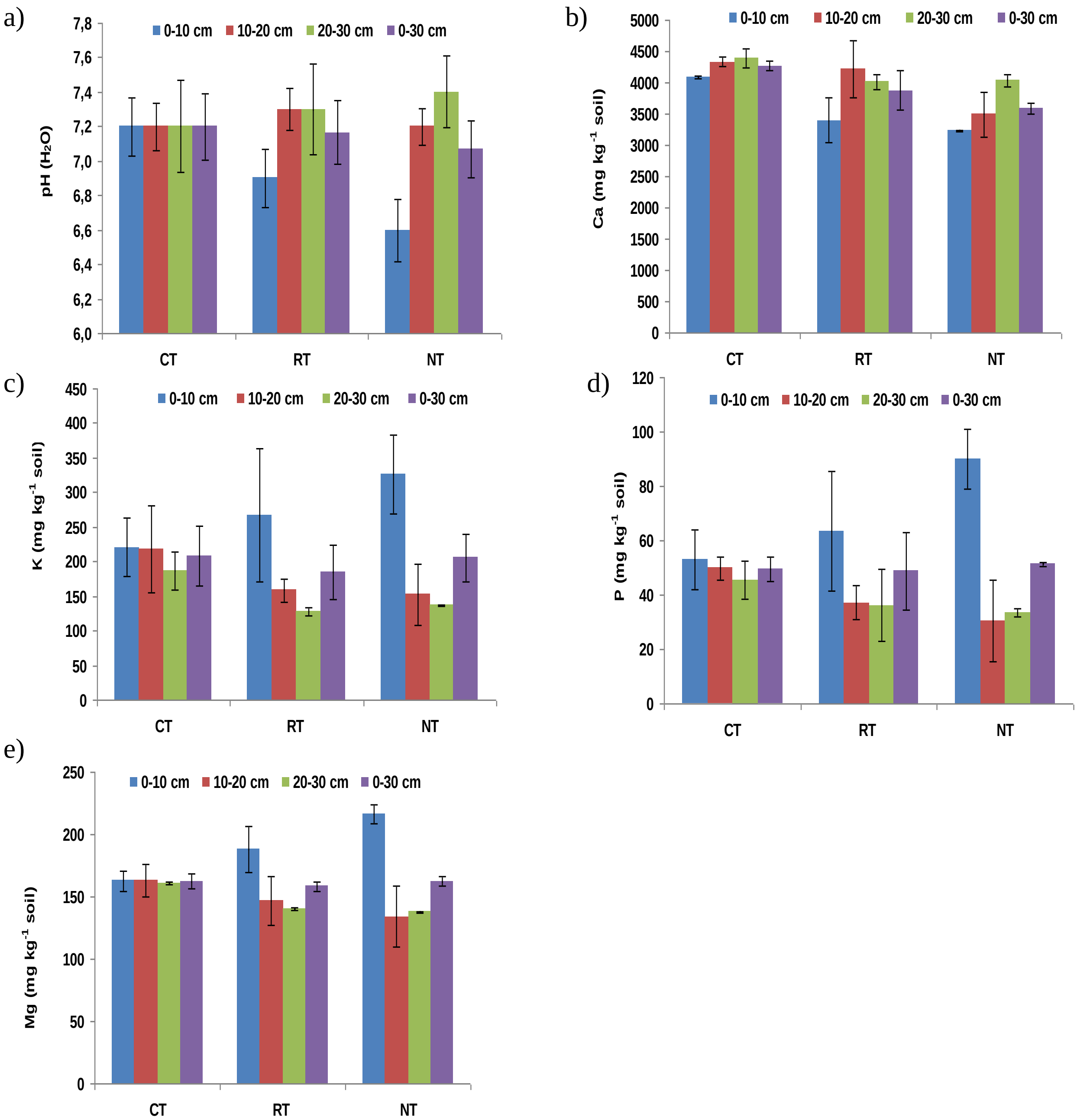
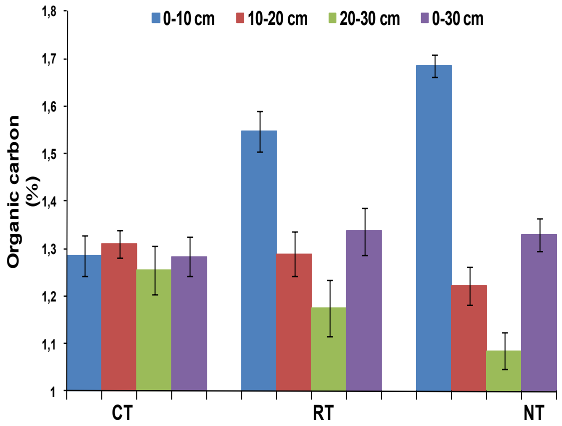
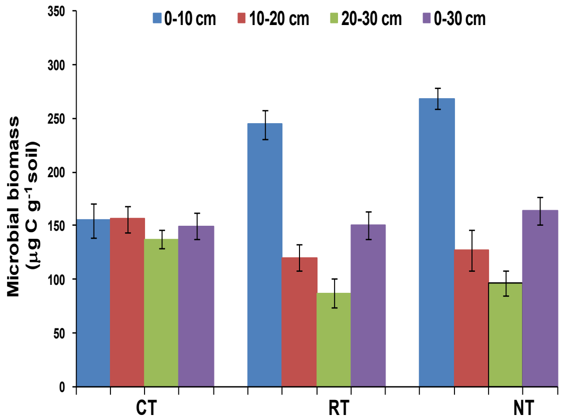


Fig 2: Average values of organic carbon (a), microbial biomass contents (b) and dehydrogenase activity (c) in the years 2008 – 2010. The vertical bars represent the standard deviation error.

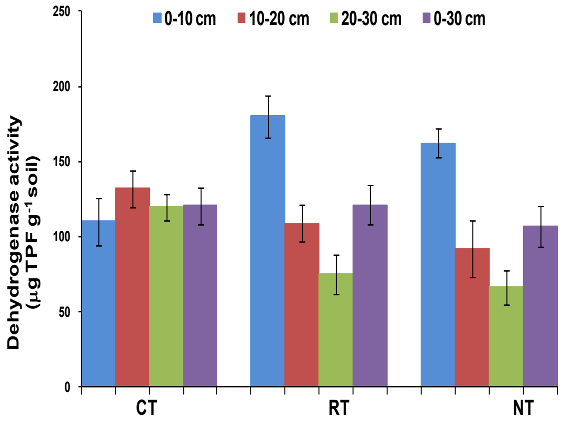
a)



b)



c)



Corg content differed according the tillage treatment (Fig. 2a). The conventional tillage caused a decrease in the organic carbon content in comparison with the reduced tillage (RT) and, especially, the no-tillage treatment (NT). Distribution of Corg within the soil profile differed between treatments. The highest Corg content was found in the surface layer under NT, followed the Corg under RT and the Corg content under CT. In this last case, Corg was distributed rather uniformly within all the layers. RT and particularly NT lead to an evident stratification of the soil organic carbon and to its decrease with depth in soil profile. Similar to Corg, the microbial biomass was more uniformly distributed within the soil profile in CT; possibly due to the distribution of crop residues in the deeper soil layers from the ploughing.
The microbial biomass was higher in RT and NT (where the post-harvest residues remained either within the top layer or on the soil surface) in accord with Salinas-García et al. (2002), and it clearly stratified within the soil profile. A rapid decrease of microbial populations due to the loss of readily decomposable substrates in deeper layers of a soil profile was also reported by Beare et al. (1993). The microbial biomass C in CT showed the lowest amounts in the top layer of all three tillage practices, but had more uniformly distributed values in the entire soil profile, than was found in RT and NT (Fig. 2b). The largest microbial biomass C was found in 0 - 10 cm layer using NT, a smaller quantity in RT, with the smallest in CT. The microbial biomass was more uniform within the three tillage practices studied. The microbial biomass was more uniformly distributed within the soil profile in CT possibly due to the distribution of crop residues in the deeper soil layers from the ploughing. A stratification of organic carbon in the soil profile in RT and NT systems, and a rapid decrease of microbial

populations due to the loss of readily decomposable substrates, was also reported by Beare *et al.* (1993).

Soil enzymes are good indicators of soil fertility, since they are involved in the cycling of the most important nutrients (Roldán et al., 2003; Balota et al., 2004). Similar to the microbial biomass C, the dehydrogenase activities were found to be more uniformly distributed in CT within the soil profile, in comparison with RT and NT, where a higher stratification in the soil profile was also registered (Fig. 2c). The mostly greater dehydrogenase activity in the top layer using RT and NT, in comparison with CT, corresponds to the results of Omidi *et al.* (2008) who found the enzymatic activities of alkaline and acid phosphatase and dehydrogenase to be significantly affected by NT at a depth of 0 - 10 cm. In our case, the dehydrogenase activity was higher in RT compared to NT probably due to higher oxygen supply in the top layer caused by chiselling. A decrease of the dehydrogenase activities in the deeper layers of the soil profile, in comparison with the surface layer, was observed in RT and NT.

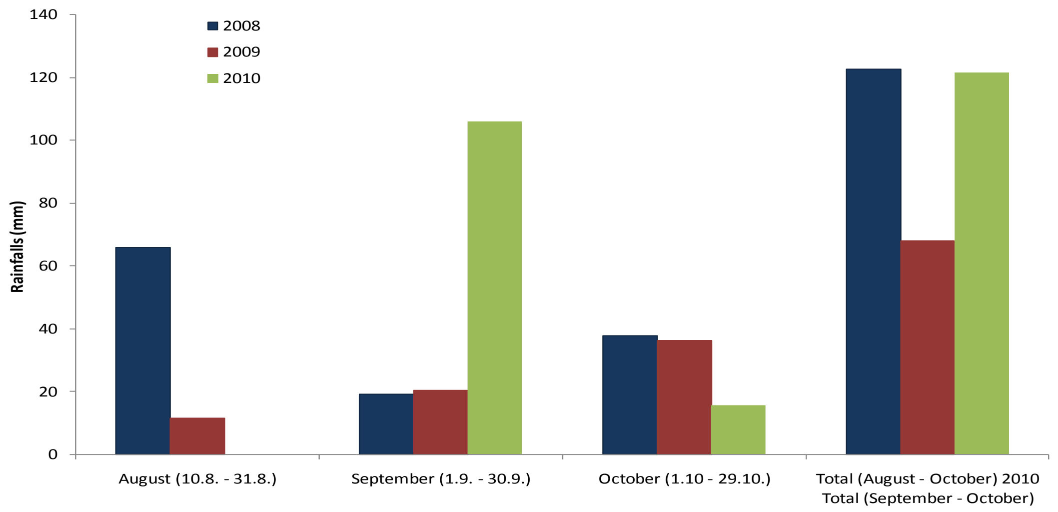
Table 1: The CO_2-fluxes from CT, RT and NT soils during summer – autumn period in the years 2008, 2009, 2010. The data represent the average values ± standard deviation. The abbreviation n.m. means that data were not measured due to later soil ploughing in 2010.

CO_2-fluxes (µmol CO_2 m^{-2} s^{-2})								
	August		September			October		
Measurement	1	2	3	4	5	6	7	8
Soil practice								
CT-2008	3.42±0.38	7.92±0.84	5.23±0.81	4.24±0.62	2.05±0.60	2.72±0.73	2.69±0.25	1.39±0.34
CT-2009	4.68±0.88	5.78±0.83	3.17±0.30	3.10±0.42	2.53±0.13	2.93±0.53	3.42±0.55	1.15±0.46
CT-2010	n.m.	n.m.	n.m.	0.94±0.49	1.93±0.71	3.13±0.80	1.56±0.47	2.02±0.55
RT-2008	4.60±1.40	2.99±0.86	4.78±0.41	2.59±0.14	1.93±0.31	1.86±0.23	2.39±0.20	1.24±0.30
RT-2009	4.49±0.34	3.66±0.18	1.83±0.18	2.35±0.12	1.90±0.17	1.40±0.33	1.74±0.23	0.90±0.14
RT-2010	n.m.	n.m.	n.m.	2.18±1.18	1.87±0.16	2.42±0.67	2.35±0.55	0.81±0.43
NT-2008	2.04±0.24	2.28±0.63	4.91±0.55	2.39±0.65	1.51±0.10	1.77±0.18	2.28±0.31	0.96±0.15
NT-2009	5.02±1.18	3.25±0.53	2.97±0.64	3.27±0.35	2.41±0.20	1.66±0.71	2.40±0.57	1.22±0.45
NT-2010	n.m.	n.m.	n.m.	2.23±1.23	2.23±0.76	2.27±0.52	3.27±0.09	1.15±0.31

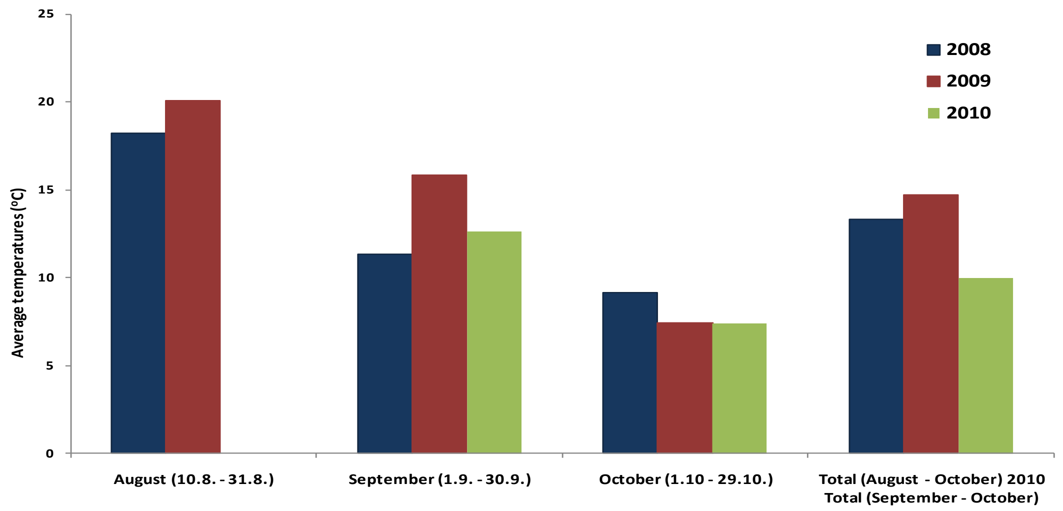
CO_2-C fluxes from soils were determined in regular intervals between summer ploughing (14th August 2008, 13th August 2009) or early autumn ploughing (6th September 2010) and the end of October (Table 1). The first measurement was carried out two days after ploughing. Typically, the ploughing decreased CO_2-fluxes in the first two days (1st measurement) probably due to soil inverting and damaging of microbial cells. The maximum release of CO_2-C in the CT practice was in the years 2008 and 2009 observed approximately a week later (2nd measurement), whereas in the year 2010 after two weeks from ploughing during the 3rd measurement. The CO_2-C release from soils differed between treatments and between years. August 2008 was characterised by a warm and wet weather (Fig. 3 a, b) and the highest CO_2-C release was found under CT 9 days after ploughing, whereas lower CO_2-C concentrations were found under RT and NT treatment (Table 1). CO_2-C concentration decreased with time under all tillage practices. August 2009 was characterised by a hot and dry weather. In consequence, the CO_2-C fluxes were in the same measuring period lower than in 2008. The most significant decrease of CO_2-C evolved was observed in the CT treatment. Later, the CO_2-C concentrations under NT and CT became similar, whereas the CO_2-C concentration under RT was lower in comparison with CT and NT. This effect was caused the most probably by the higher water content of soils under NT offering more favourable conditions for crop residues decomposition. The later ploughing in September 2010 did not cause so high increase of CO_2-fluxes from soils under the CT practice as in the precedent years. Lower temperatures played probably an important role in CO_2-fluxes in this period as the water supply by rainfall was sufficient during the measuring period. Therefore no limitation of CO_2-fluxes due to the eventual dryness could be expected in 2010.

Fig. 3: The rainfall (a) and temperatures (b) in the years 2008 – 2010. The month average values are reported.

a)



b)



Conclusions

The conversion to reduced and no-tillage practices led to the clear stratification of nutrients and with exception of Ca to their increase in the top layer of the soil profile. The conservation tillage practices (RT and NT) sequestrated the soil organic carbon and increased microbial biomass and dehydrogenase activity in the top layer of soils. The ploughing increased significantly the evolution of CO_2-C from soils. The sequestration of soil organic carbon was accompanied by lower CO_2-fluxes from less worked conservative soil technologies. However, the timing of field operations on soil and weather conditions played an important role in CO_2

losses from soil. The soil temperature and humidity affect the CO_2-C fluxes from soils under CT, RT and NT practices differently. The summer ploughing before sowing of oil seed rape can intensify the mineralization processes in soils and in consequence increase the emissions of CO_2-C from conventionally worked soils. Therefore, the summer ploughing was the most hazardous operation for the CO_2-fluxes because possible rainfall with high temperatures can increase the CO_2-fluxes form soils and affect the biological processes in soils in this period. The conservative tillage practices led to the decrease of CO_2-fluxes from soils and in this way helped to the sequestration of the organic carbon in soils.

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Effect of various tillage intensity on yield and content of N-compounds in kernels of spring barley

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Abstract
Systems of soil processing and establishment of individual crops represent an important part of growing technologies of cereals. They influence the essential elements of crop structure, i.e. future conditions for yield formation and quality..
The effect of various tillage intensity on yields and content of N-compounds in kernels of spring barley was studied in experiments established on chernozem in the sugar-beet-growing region within the period of 1990 – 2009. Spring barley was grown after sugar beet, which followed in the experimental cropping system after winter wheat. Established and evaluated were four variants of tillage (i.e. ploughing to the depth of 0,22 m – Variant 1; ploughing to the depth of 0,15 m – Variant 2; direct sowing without tillage – Variant 3 and shallow disk tillage to the depth of 0,10 m - Variant 4).
The highest and the lowest average yields were obtained in Variant 2 and Variant 1, respectively. As far as the content of N-compounds in kernels of spring barley was concerned, their highest average concentration was recorded in the variant with the highest intensity of tillage (Variant 1) while the lowest one was observed in Variant 2.
The obtained results indicate that under the given pedo-climatic conditions a reduction of intensity of soil processing for spring barley represents a suitable alternative of conventional ploughing to the depth of 0,22 m (Variant 1)
Keywords: spring barley, soil processing, yield of grain, content of N-compounds in kernels

Introduction
Requirements concerning quality of barley result from its use for malting and beer making. It can be said that they involve both quality and quantity of extract substances, enzymatic activities necessary to transform them into a soluble form, and production of taste and aroma compounds necessary for making good beer.
Yield, quality and health safety of malting barley (and of all other crops) in general are influenced not only positively but also negatively above all by the variety (cultivar) and the environment. This means that parameters of quality are to a great extent dependent on interactions existing between the variety and the so-called agro-ecological factors.
When growing and producing barley meeting quality requirements of not only maltsters but also growers, it is necessary to take into account many factors, e.g. suitability of the variety and the degree of its adaptation to a given pedo-climatic region, proper methods of tillage and growing, good health condition of crops during the whole growing season etc. *(Onderka et. al., 2001, Mucha, Novotný, 2008).*
The aim of this study was to evaluate effects of various methods of tillage on grain yield and content of N-compounds in kernels of spring barley grown after sugar beet on chernozem soil in the sugar-beet-growing region.

Material and methods
Field experiments were performed within the period of 1990 - 2009 on plots of the Research Institute of Crop Production in Ivanovice na Hané, Czech Republic.

Characteristics of the experimental site

The experimental site is situated in a sugar-beet-growing region at the altitude of 225 m. The soil is a typical loamy chernozem and the depth of humus horizon ranges between 0,40 and 0,50 m. Soil reaction is neutral. Reserves of Ca, K, Mg, and are good and humus content is 2,6 % .

Climatic conditions

The locality Ivanovice na Hané is situated in the climatic region T2 (warm, temperate and semiarid). The average annual temperature and sum of precipitations are 9,13 °C and 539,91 mm, respectively (20-year average).

Variants of spring barley tillage

Variant 1 - Ploughing to the depth of 0,22 m
Variant 2 - Ploughing to the depth of 0,15 m
Variant 3 - Direct sowing without tillage (zero tillage)
Variant 4 - Shallow disk tillage to the depth of 0,10 m

Position of spring barley in the crop rotation

Within the framework of crop rotation, spring barley was grown after sugar beet, which followed in the cropping system after winter wheat.

Application of mineral fertilizers

In all four experimental variants, the method of dressing and doses of mineral fertilisers were the same:

N – 40; P - 30; K – 60 (in kg of pure nutrients per hectare)

Grown cultivars

1990 – 1996 Rubín, 1997 – Akcent, 1998 – 2007 – Kompakt, 2008 – 2009 – Jersey

Results and discussions

Yields of spring barley within the period of 1990 - 2009. Contents of N-substances in kernels of spring barley were estimated in years 2004, 2005, 2007 and 2009. Results obtained in 2006 are not presented because in this year the experimental stand of spring barley was seriously damaged due to a high sum of precipitations within the period of crop ripening.

Table 1: Average yields of spring barley ($t.ha^{-1}$) grown within the period of 1990 to 2009

Period (1990-2009)	**Variants of tillage**				**Average**
	1.	**2.**	**3.**	**4.**	
Average	6.46	6.60	6.56	6.55	6.54

dt (soil tillage) p=0,05 - 0,142 p=0,01 - 0,173

Within the framework of crop rotation system winter wheat – sugar beet – spring barley, the highest average yield of spring barley grain (6,60 $t.ha^{-1}$) was recorded in Variant 2 with ploughing to the depth of 0,15 m; next were Variant 4 with a shallow disk tillage to the depth of 0.10 m (6,56 $t.ha^{-1}$) and Variant 3 with direct sowing without tillage (6,55 $t.ha^{-1}$). The lowest yield (6,46 $t.ha^{-1}$) was recorded in Variant 1 with ploughing to the depth of 0,22 m

Table 2: Contents (%) of N-substances in kernels of spring barley (2004 – 2009)

Year	Variant of tillage				Average
	1.	2.	3.	4.	
2004	11.09	9.97	9.83	10.62	10.38
2005	12.01	11.41	11.61	11.54	11.64
2007	12.05	10.51	11.16	11.88	11.40
2009	11.32	10.50	10.95	10.97	10.94
Average	11.62	10.60	10.89	11.25	11.09

dt (soil tillage) p=0,05 – 0,309 p=0,01 - 0,429

The highest average content of N-substances (11.62 %) was found out in Variant 1; next was Variant 4 (11.25 %), which was followed by Variant 3 (10.89 %). The lowest content of N-compounds was determined in Variant 2 (10.60 %). This result was probably associated with a dilution of nitrogen in biomass of kernels due to the highest average grain yield.

Conclusions

The highest average yield of spring barley grain was obtained in Variant 2 with ploughing to the depth of 0,15; next were Variant 4 (shallow disk tillage) and Variant 3 (direct sowing). The lowest average yield of grain was recorded in Variant 1 with ploughing to the depth of 0,22 m.

As far as the effect of various tillage intensity on contents of N-compounds in kernels of spring barley was concerned, the highest and the lowest levels of nitrogen were found out in Variant 1 (ploughing to the depth of 0,22 m) and Variant 2 (ploughing to the depth of 0,15 m), respectively. It can be concluded that variants with less intensive processing of soil showed generally lower contents of N-substances in kernels.

When considering and selecting individual technologies of tillage, several factors should be taken into account; the most important of them are site (pedo-climatic) conditions, machinery plus technological lines and position of spring barley within the system of crop rotation *(Procházková et. al., 2003, Chloupek et. al., 2005, Zimolka et. al., 2006)*.

In general, our results indicate that under given pedo-climatic conditions (i.e. in the sugar-beet-growing region with fertile Chernozem), the minimisation technologies of tillage represent a suitable alternative of conventional method of ploughing to the depth of 0,22 m.

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Qualitative evaluation of farmed luvic chernozem soils in central Moravia

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Abstract
On six fields of the identical soil quality in district of the Kroměříž, soil samples were taken after harvest winter wheat from the depths of 15 – 20 and 45 – 50 cm for physical, chemical and biological analyses. Analyses of the topsoil and subsoil samples of luvic chernozem soils in the Kroměříž district showed that their bulk density exceeded the agroecological limit of 1.45 $g.cm^{-3}$, that the minimum air content was below the limit of 10 %, and that the humus quality was low (HA:FA was less than 1). As compared with historical data, the relative saturation of adsorption complex was markedly decreased (from 90 % to 73 %). The calcium saturation of adsorption complex was insufficient (63 % vs. required 65 %), the basal respiration in topsoil was also low (0.59 mg CO_2 per 100 $g{\cdot}h^{-1}$) and there was a relative lack of easily degradable organic substances in soil.
Key words: soil quality, soil characteristic, humus quality, saturation of adsorption complex, basal respiration

Introduction

The region of Haná (Central Moravia, Czech Republic) was selected for an evaluation of long-term physical, chemical and biological properties of topsoil and subsoil using the system of Evaluated Soil Ecological Units (BPEJ 3.02.00). In our opinion, it was appropriate to select a region with valuable and intensively managed land because it was in the centre of interest of experts already in the past so that it was possible to compare the present soil quality with earlier data. The evaluation of variability of evaluated luvic chernozem was also important because they represented 90.58 % (9,407 ha) of all chernozem soils in the district of Kroměříž (Kupský, 1965). This study also contains an evaluation of some economic parameters (yields, fertilisation).

Historical sources:

- Probably the first survey was published in the half of 1920' (Novák, 1925) and contained some detailed characteristics of soil texture (mechanical composition), exchange and active soil reaction and even of biological activity of soil (expressed as its catalytic power). This study described soil profiles and in its general characteristics contained among others: *"From the viewpoint of agricultural practice it is possible to highlight the following: The physical condition of the subsoil is ideal, as well as that of the top layer; it is only necessary to pay a little attention to its maintenance. The physical condition of this soil is really suitable for barley growing. Its depth assures that the roots can penetrate into the depth".* Further it is written the following: *"Its virtues cannot be explained only on the base of nutrient reserves. They are influenced also by a very favourable physico-chemical and biological condition of this soil and it will be necessary to study them in detail".*
- In a similar report about the condition of the adsorption complex of Moravian soils, Maláč (1933) presented results that were obtained directly in the region under study (Tab. 1) and concluded that the adsorption complex was fully saturated and that the content of exchangeable Ca was higher than 80 %.

Tab. 1 Selected characteristics of soil in the locality Hulín

Depth	Exchange reaction	Total adsorption capacity	Relative saturation of the adsorption complex	Contents of exchangeable	
				calcium	magnesium
(cm)	*(pH_{KCl})*	*($mmol.kg^{-1}$)*	*(%)*	*(%)*	*(%)*
0 - 33	7	296	95.2	81.8	12.8
33 - 50	7	253	92. 8	85.4	9.88

- Results presented by Kupský (1965) were obtained within the framework of pedological research known as „Complex Soil Survey“ (CSS) in the locality Třebětice (Tab. 2). The soil was classified as degraded chernozem, of medium texture (i.e. loamy), with the humus content > 2%, neutral soil reaction, and fully saturated adsorption complex.
-

Tab. 2 Selected soil characteristics, probe n°112 (Třebětice), CSS

Depth *(cm)*	Content of clayey particles *(%)*	Humus content *(%)*	Exchange reaction *(pH_{KCl})*	Total adsorption capacity *($mmol.kg^{-1}$)*	Relative saturation of adsorption complex *(%)*
0 - 29	35.2	1.99	6.8	190	91.6
29 - 68	41.9	1.26	6.6	200	86.6

- Synthesis of selected characteristics of the major soil unit 02 was published by Vašků (2008). As far as their texture was concerned, they were classified as sandy-loamy to loamy soils. Their humus content ranged from 2 to 5 %, the exchange soil reaction was weakly acid to neutral, and the adsorption complex was fully saturated. Data concerning their physical characteristics are very important. Percentages of their porosity and field water capacity ranged from 37 to 45 % and from 22 to 34 %, respectively (Tab. 3).

Table 3 Some selected characteristics of the main pedological unit (CSS)

Content of clayey particles	Porosity	Field water capacity	Humus content	Exchange soil reaction	Total adsorption capacity	Relative saturation of adsorption complex
(%)	*(%)*	*(%)*	*(%)*	*(pH_{KCl})*	*($mmol.kg^{-1}$)*	*(%)*
20 - 40	37 - 45	22 - 34	2.0 - 5.0	6.4 – 7.0	180 - 220	90 - 100

Material and Methods

In Kroměříž district, soil samples for physical, chemical and biological analyses were collected on twelve plots (BPEJ 3.02.00) after the harvests of winter wheat in September 2007 and 2008; the depths of sampling were 15 – 20 and 45 – 50 cm.
- After the excavation and preparation of probes, individual layers/horizons were opened and soil samples were collected using stainless steel Kopecký cylinders. In each horizon, all samplings were performed in three replications. Loose soil from the neighbourhood of cylinders was sampled for chemical and biological analyses;
- Of chemical parameters, the following were estimated: humus content (using *Walkley – Black method as modified by Novák - Pelíšek*), humus quality (using *$Q_{4/6}$ method*), cation exchange capacity (*extraction with ammonium acetate*), contents of exchangeable cations (*K, Ca, Mg*), actual and exchange reaction, content of total nitrogen, conductivity, and content of

phosphorus (according to *Egner*). The ratios C:N and K:Mg were calculated using the obtained results;

- Of physical parameters, the following were estimated and calculated: bulk density, specific density, porosity, total water retention capacity, maximum capillary capacity, and minimum air-filled porosity. The texture analysis and evaluation of heterostructure were carried out using the densitometric method;
- By means of biological tests (i.e. *respirometric tests according to Novák*), it was possible to evaluate not only the current situation but also the potential capability of soil microflora to propagate and to influence the properties of soil. These variants enabled to calculate amount of physiologically available oxygen, stability of organic compounds, amount of easily degradable organic substances, physiological C:N ratio, and factor of impact complex;
- Analytical results were supplemented with data about economical results in the year of sampling and in three preceding years. Yields were converted to cereal units (CU) and the doses of mineral and organic fertilisers to kg.ha^{-1} per year.

Results and Discussion

As far as physical parameters are concerned (Tab. 4), it is possible to say that the bulk volume of soil was one of disturbed values because it was 1.47 g.cm^{-3} in the topsoil; in the subsoil it was 1.54 g.cm^{-3} and both of them were higher than the limit mentioned by Lhotský (1994). The minimum air-filled porosity did not reach the required level of 10 % (its values in topsoil and subsoil were 9.67 % and 7.55 %, respectively). The reduced air-filled capacity resulted, above all in wetter years, in hypoxia, physiological disturbances of cultivated crops, and consequently in reduced yields. However, as compared with data published by Vašků (2008) this was not an exceptional situation because our results concerning porosity of topsoil and subsoil (44.46 % and 42.04 %, respectively) fully corresponded with limits mentioned in his paper, i.e. 37 – 45 % (Tab. 3). Similarly, also our values of water retention capacity (i.e. 31.91 and 31.56 %; Tab. 3), mentioned by the above author as “field water retention capacity”, fully corresponded with literary data (22 – 34 %).

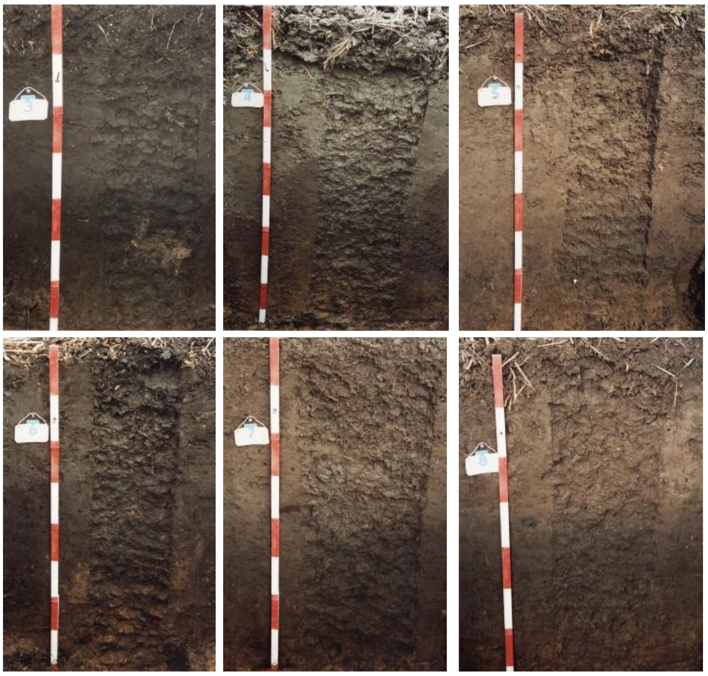

Figure 1: Soil profiles of plots under study

Table 4: Basic physical parameters of topsoil and subsoil (district Kroměříž; 2007, 2008; n=12)

Parameter	Unit	Topsoil		Subsoil	
			Coefficient of variation		Coefficient of variation
Bulk density	*g.cm⁻³*	**1.47**	5.90	**1.59**	4.52
Porosity	*%*	**44.46**	7.35	**42.04**	7.35
Maximum capillary capacity	*%*	**34.79**	3.14	**34.52**	5.12
Water retention capacity	*%*	**31.91**	3.62	**31.56**	4.67
Minimum air-filled porosity	*%*	**9.67**	35.34	**7.55**	43.84
Content of clayey particles	*%*	**37.42**	17.93	**37.67**	13.29

Of chemical parameters (Tab. 5), the quality of humus, measured as the ratio of humic and fulvo acids, was markedly disturbed. The most important, however, were disturbances in saturation of adsorption complex and a decrease in exchange reaction. The value of relative saturation of adsorption complex in topsoil was 73.30 % and this was for chernozem too low although according to all historical data (see Introduction) the adsorption complex in luvic chernozem soils was fully saturated. The calcium reserves should not be lower than 65% (Kutílek 1978) but our results were 63.41 %; similarly, the minimum level of magnesium should be 15 % but our result was 7.50 %. Within a period of approximately 40 years, the originally neutral value of exchange reaction decreased to pH_{KCl} 6.18. Also the total C:N ratio was not balanced: the recorded values (5.11 in topsoil and 5.28 in subsoil) were significantly lower than the recommended value of 10 and indicated a relative surplus of nitrogen.

The observed changes in chemical parameters are so serious that it is necessary to continue with their monitoring and to find out which is the role of the year in this process.

Table 5 Basic chemical parameters of topsoil and subsoil (district Kroměříž; 2007, 2008; n=12)

Parameter	Unit	Topsoil		Subsoil	
			Coefficient of variation		Coefficient of variation
Humus content	*%*	**2.21**	35.20	**1.78**	43.63
Humus quality ($Q_{4/6}$)	*HA:FA*	**0.79**	12.23	**0.82**	11.30
Exchange reaction	pH_{KCl}	**6.18**	11.57	**6.40**	9.15
Actual reaction	pH_{H2O}	**6.98**	8.49	**7.37**	6.3
Cation exchange capacity	$Mmol.kg^{-1}$	**202.58**	16.38	**195.08**	14.47
Relative saturation of SC	*%*	**73.30**	22.25	**77.14**	19.61
Ca saturation	*%*	**63.41**	26.15	**68.69**	23.06
Mg saturation	*%*	**7.50**	17.16	**6.98**	21.99
K saturation	*%*	**2.42**	33.53	**1.46**	42.62
C:N ratio		**5.11**	30.26	**5.28**	38.16

Results of respiration tests (Tab. 6) were compared with data presented by Novák (1969). In our soils under study, the values of basal respiration were reduced both in topsoil and subsoil. Novák (1969) mentioned values of 0.65 and 0.51 mg $CO_2.100g^{-1}$ per hour for topsoil and subsoil, respectively, while our results (2007, 2008) were 0.56 and 0.50 per hour for topsoil and subsoil, respectively. In topsoil and subsoil, the deficit of physiologically available nitrogen (N:B) increased from 1.00 to 1.33 and from 1.06 to 1.32, respectively. The overall evaluation of respiration tests was reflected also in the value of the factor of impact complex [(NG:G):(N:B)]; as compared with data published by Novák (1969), we have observed a marked decrease both in topsoil and subsoil (from 10.54 to 2.72 and from 7.61 to 2.60, respectively). This means that the respiratory (biological) activity of soils under study (and above all of topsoils) could be evaluated as disturbed.

Table 6 Basic biological parameters of topsoil and subsoil (district Kroměříž; 2007, 2008; n=12)

Parameter	*Unit*	**Topsoil**		**Subsoil**	
			Coefficient of variation		**Coefficient of variation**
Basal respiration	*mg CO_2.100g^{-1} per hour*	**0.59**	29.06	**0.50**	30.83
Deficit of physiol. N	*N:B*	**1.33**	15.88	**1.32**	29.30
Deficit of organic subst.	*G:B*	**5.33**	29.10	**4.31**	18.48
Physiological C:N ratio	*G:N*	**4.08**	30.42	**3.49**	32.65
Stability of organic subst.	*NG:B*	**14.88**	55.81	**13.67**	45.79
Factor of impact complex	*(NG:G):(N:B)*	**2.72**	90.34	**2.32**	54.44

The most important relationships (dependences) existing among soil parameters under study, economic results and supply of fertilisers (including organic ones) were determined by means of non-linear regressions (Nosek 1972, Pazourek 1992). Results concerning topsoil were expressed graphically (Figs 2 - 5). As one can see, the increasing doses of supplied nutrients resulted in higher yields (Fig. 2) but the efficiency of dressing decreased. The relationship existing between the amounts of supplied nutrients and humus content is illustrated in Fig. 3. This is a negative relationship – increasing doses of nutrients caused a decrease in the level of organic substances. Although this relationship was significant, it requires a deeper analysis. Namely, it is quite possible that on soils of a relatively lower quality (i.e. with a decreased content of humus) the farmers apply higher doses of nutrients because they want to obtain yields that would be the same as those reached on fields with good reserves of humus. The relationship between the amount of supplied nutrients and the physiological stability of organic substances (Fig. 4), determined in the respiration test as NG:B ratio, is paradoxically positive – the physiological stability of organic substances increased with increasing doses of fertilisers. Basing on these observations it is possible to conclude that the increasing supply of nutrients results in increased mineralisation (i.e. losses of humus) and that the relative content of hardly degradable organic compounds in soil increases as well. This is corroborated by the relationship existing between the content of humus and C:N ratio (Fig. 5). It is generally accepted that for topsoil its optimum value is ~ 10. However, in our study the value of this parameter was only 5.11. This explicitly indicates that there is a deficit of carbon in topsoil of our most fertile soils.

Conclusions

It was found out that in topsoil and subsoil of luvic chernozem in the Kroměříž district:

- bulk density was above the agroecological limit of 1.45g.cm^{-3};
- minimum air-holding capacity was lower than the limit of 10 %;
- humus quality was low (HA:FA ratio was lower than 1),
- the relative saturation of adsorption complex was markedly decreased (from 90 % to 73 %) as compared with historical data
- saturation of adsorption complex was insufficient (63 % instead of required 65 %),
- in topsoil, the level of basal respiration was (0.59 mg CO_2.100g per hour),

- factor of impact complex [(NG:G):(N:B)] was low and indicated disturbances of biological activity both in topsoil and subsoil.

If the system of soil management will not be changed (i.e. insufficient liming and replacement of conventional organic by ploughed-in straw), it can be expected that:

- content of humus (organic substances) in soil will decrease;
- relative physiological stability of organic compounds will increase; and
- C:N ratio will further go down.

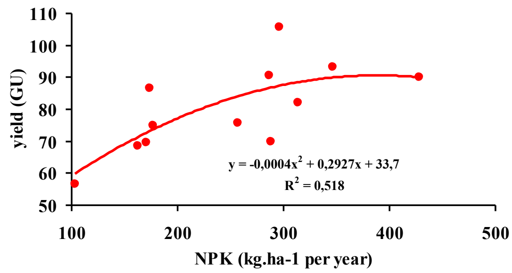

Figure 2: The relationship between the amount of supplied nutrients and yield (n = 12),
BPEJ 3.02.00

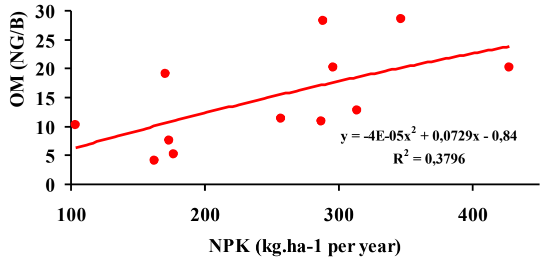

Figure 4: The relationship between the amount of supplied nutrients and the physiological stability of organic substances (n = 12), BPEJ 3.02.00

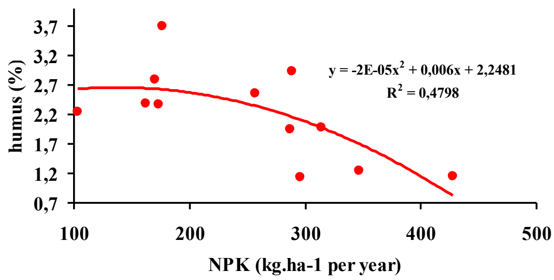

Figure 3: The relationship between the amount of supplied nutrients and humus content (n = 12), BPEJ3.02.00

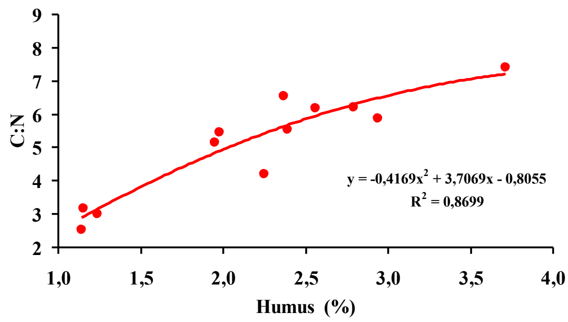

Figure 5: The relationship between the content of humus and C:N ratio (n = 12), BPEJ 3.02.00

Acknowledgement

This paper was written thanks to the financial support of the NAZV research orders MZ270041, QI91C054 and QH72039.

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CONTENT

TERMO-OXIDATIVE STABILITY OF HUMIC SUBSTANCES ORIGINATING FROM DIFFERENT SOURCES

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Abstract
Stable carbon in soil organic matter represented by humic substances is almost unaffected by short-term soil management which is in contrast to the labile fresh fraction and microbial population. It has been demonstrated several times that the nature of humic substances itself, rather than their concentration, is a sensitive indicator of changes in environmental conditions and agricultural management. Humic acids, alkali soluble part of humic substances, were isolated from *Eutric Cambisol, Luvi-haplic Chernozem* and South Moravian lignite. Obtained humic acids were analyzed using thermogravimetry in order to assess their thermo-oxidative behavior. Particularly, the moisture content, temperature of onset degradation and rate of degradation were studied. Results confirmed earlier observations that humic acids isolated from different sources have different thermo-oxidative stability and degradability indicating variability in their chemical composition and physical structure caused by particular genesis ways of their parental materials.
Keywords: humic acids, lignite, TG and DSC analysis

Introduction
Notwithstanding their origin, humic substances are mostly defined based on different solubility and classified into three major groups (= fractions): (1) alkali soluble humic acids (HA), (2) soluble fulvic acids (FA) and (3) insoluble humates. Knowledge of their chemical composition along with their physical structure is currently only a partly solved problem. The available data suggest that HA consists of hydroxyphenols, hydroxybenzoic acids, and other aromatic structures possibly linked by peptidic and ester bridges. An important pool of HA represent also fatty acids (Schnitzer and Khan, 1978).
Although HA originating from various sources are considered to be members of the same group, they can significantly differ in their composition as indicated by results of elemental analysis or other sophisticated methods such as FTIR or NMR spectroscopy. It is quite natural since soil humic acids developed under different conditions than peat or lignite humic substances. The mean residence time in case of soil humic substances is reported hundreds up to thousands years and main development process is humification. In contrast, lignite organic matter developed under partially anaerobic conditions as peat in the first stage and underwent also first stages of coalification. As a result the chemical composition of lignite is represented by mixture of cyclic-aromatic-aliphatic hydrocarbons and their derivatives since lignite represents an intermediate substrate on the transformation way from the parent biomass to the dehydrated, dehydrogenated and deoxidised carbon type complex (Peňa-Mendez et al., 2005; Kučerík et al., 2003).
The aim of this study is to characterize humic acids extracted from different sources using thermogravimetry. The effort is paid to compare their thermo-oxidative stability and degradability with respect to chemical composition and source of isolation.

Material and methods

Humic acids

In order to obtain soil humic acids, standard extraction method was used (Hayes, 1985). Detail information about products is reported in our previous work (Pospisilova et al. 2008 and 2009). Briefly, HA samples were exacted by NaOH, precipitated by HCl, decanted, washed several times, extensively purified by 0.5% mixture of HCl and HF and dialyzed against distilled water until chloride-free, and lyophilised at -50 °C. Soil HA were isolated from *Eutric Cambisol* (= HA - KAm) and *Luvi-haplic Chernozem* (= HA - CEl).

Lignite humic acids (HA – lignite) were isolated from the South Moravian lignite (mine Mikulčice, Czech Republic). Lignite HA were extracted by a procedure derived from the Czech standard for determination of HS in coal (Hubáček et al. 1962). Air-dried lignite was mixed with 0.5 M NaOH and 0.1 M $Na_4P_2O_7$ (60 g lignite: 2000 mL of extraction agents) and shaken for 24 hours in plastic flasks. Humic acids were precipitated from alkaline extract by adding 6M HCl until pH 2. The precipitated part was then treated with 0.5% (v/v) HCl-HF solution for 24 hours, centrifuged and dialyzed (Spectrapore 3, 3500 Mw cutoff) against distilled water until chloride free and finally freeze-dried.

Elemental analysis of obtained humic acids was performed using elemental analyzer PE 2400.

Thermogravimetry

Thermo-oxidative stability of HA samples was studied using TGA Q5000IR (TA Instruments, USA). Approximately 3-5 miligrams of the sample was placed on the Pt pan a and heated under dynamic flow air (25 ml/min from) from 40°C up to either 650 or 900°C. Heating rate was 10°C/min. The experiments were done in triplicates.

Results and discussion

Elemental analysis of studied HA is reported in Table 1 (in atomic %, ash free basis). It can be seen that the highest carbon content contained HA sample isolated from lignite and *Luvi-haplic Chernozem.* Oxygen content was higher in soil humic acids to compare with lignite HA. Nitrogen content was the highest in lignite HA. Hydrogen content was the highest in HA isolated from *Eutric Cabisol* followed by lignite HA. Those results correspond to our previous data (Pospíšilová et al. 2009 and 2010) and literature data reported by Fasurová et al. (2006).

Selected themogravimetry results are given in Figures 1, 2 and 3. It can be seen, that all records showed several mass loss steps (left Y-axes). The right Y-axes reports the differential themogravimetry curve which has the meaning of mass loss rate and its minims and maxims reveal the onsets and endsets of main processes occurring during the heating. The first mass loss which takes place up to approximately 150°C can be attributed to the moisture evaporation; following steps correspond to the humic acids degradation. The latter processes can be divided into two steps, at lower temperatures, typically up to 350 or 400°C correspond to the degradation of labile part and less stable functional groups (mostly containing oxygen and nitrogen). It is worth to note that at this temperature range, part of the material recombines forming stable structures degraded above 400°C. At higher temperatures the rest of the structure and the by-products are decomposed.

Comparison of thermogravimetry results of samples KAm and CE1 clearly shows the differences between samples. First, while the moisture content and onset of degradation were comparable, the mass losses and peak temperatures revealed higher stability of sample CE1.

Lignite HA forming stable structures degraded above 400°C and two main peaks in the temperature region 400 – 500 °C were determined followed by a small step around 550°C which can be attributed to the degradation of heterocyclic (N-containing) condensed structures (Kucerik et al., 2004).

Conclusions

It can be concluded that humic acids isolated from lignite and soils have different composition which results in different stability in low temperature range. Soil humic acids degradation proceeded in two steps and generally at lower temperatures. Humic acids isolated from lignite were showed higher stability in the low temperature range and the degradation started in the high temperature region.

Acknowledgements

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Table. 1. Elemental analysis of studied humic acids (in at. %, ash free basis)

Samples	**%C**	**%H**	**%N**	**%O**
HA – CEl (Praha)	39	38	3.3	19.5
HA – KAm (Vatín)	36	41.7	2.4	19.9
HAK - Lignite	39	39.2	7.0	15.0

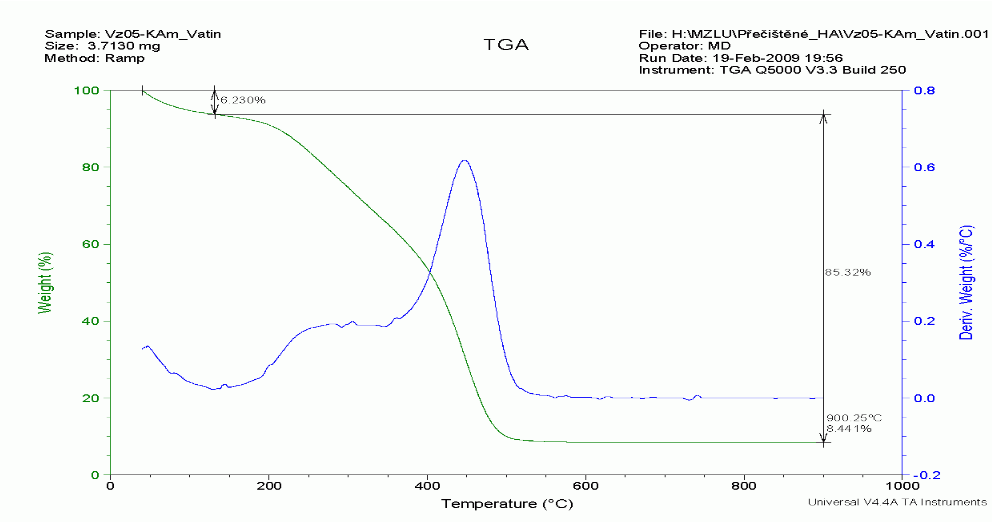

Fig. 1. Thermogravimetry and differential thermogravimetry records of HA isolated from Eutric Cambisol (Vatín)

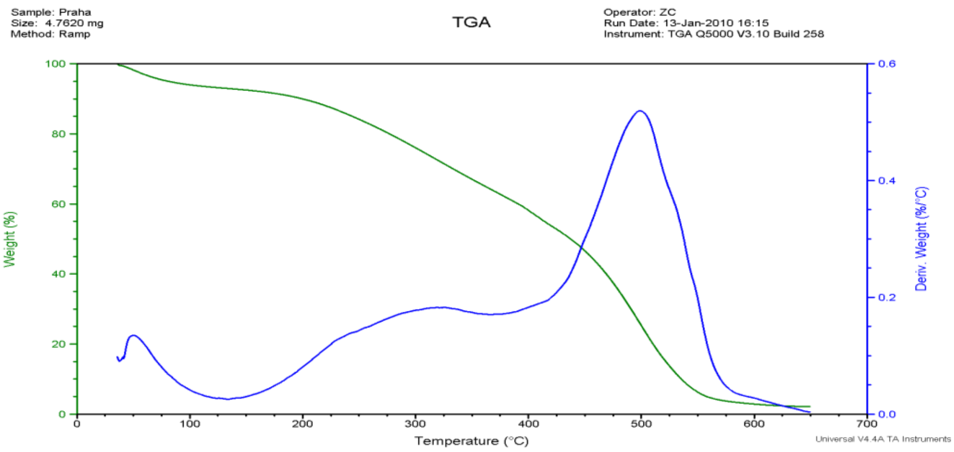

Fig. 2. Thermogravimetry and differential thermogravimetry records of HA isolated from Luvi-haplic Chernozem (Praha)

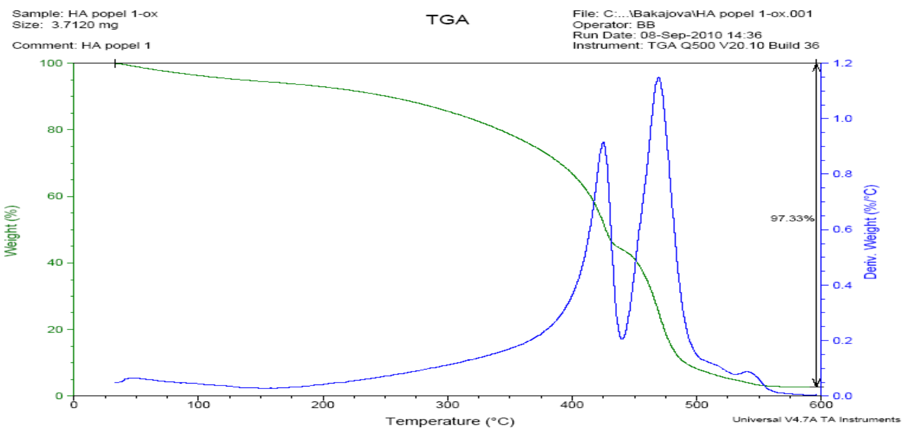

Fig. 3. Thermogravimetry and differential thermogravimetry records of HA isolated from lignite (Mikulčice)

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Characterization of lignohumate by infrared spectroscopy

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Abstract
Intensive agricultural practices caused substantial loss of soil organic carbon. Particularly sandy soils need to apply much more organic material and farmyard for maintaining soil productivity. Natural humic substances are also frequently used for increasing organic matter content and improving soil chemical properties. For this reason quality and chemical properties of commercial lignohumate preparation was studied. SRATR (single reflection attenuated total reflectance) technique and elemental analysis help us to assess the chemical properties of lignohumates. FTIR spectra were measured in the spectral range 550 – 4000 cm^{-1} and spectrometer Shimadzu 8700 was used. Bands indicative of aliphatic groups (C-H at 2925 cm^{-1}); aromatic groups (C=C at 1620 cm^{-1}); phenolic groups (at 1404 – 1419 cm^{-1}); and carboxyl and carbonyl groups (at 1225 – 23 cm^{-1}) were similar to soil humic acids samples. Differences were found in the finger print region 1700 – 1000 cm^{-1}.
Keywords: lignohumate, soil humic acids, FTIR-SRATR spectroscopy

Introduction

Infrared spectroscopy offers wide variety of techniques for evaluation of humic acids chemical composition and structure. Humic acids, the most important fraction of humic substances, are very active in infrared spectral region and we could identify a variety of infrared bands in their molecule (Michel at al. 2009, Inbar et al. 1989). They represent a highly complex and refractory material, which have capacity for diverse chemical and physical interactions in the environment (Senesi 1993, Capriel 1995, 1997). According to Stuart et al. (1996) attenuated total reflectance (ATR) spectroscopy utilises the phenomenon of total internal reflection. The resultant attenuated radiation is measured as a function of the wavelength by the spectrometer and gives rise to the absorption spectral characteristics of the studied samples. The development of an attachment mounted onto FTIR spectrophotometer allowed us to apply the golden gate single reflection attenuated total reflectance (SRATR) technique to obtain differences in the infrared spectral region. The aim of our study was to compare chemical composition of commercial lignohumates and soil humic acids.

Material and methods

Object of our study were commercial lignohumate preparations and soils HA isolated from soils (*Luvi-haplic Chernozem and Haplic Luvisol*). Soils were sampling in the upper layer (0 – 0.20 m). Soil humic acids were isolated according to the International standard method IHSS (Hayes, 2001, Orlov, 1985). Elemental analysis was performed by the standard methods and PE2400 CHNS/O analyser was used. Measurements were done triplicate and average values of each elements were calculated. Infrared spectroscopy was performed by FTIR spectrometer Shimadzu 8700. Golden gate SRATR (Single Reflection Attenuated Total Reflectance) technique was applied. As “single reflection” element IIa diamond was used and spectra were measured in the spectral range 550 – 4000 cm^{-1}. This method has been widely used for complex organic macromolecules characterization and small loads of sample are required. No special sample preparation is necessary and all measurements were done duplicate. Detailed characterization of using analytical methods is given in our previous work Pospíšilová & Tesařová (2009).

Results and discussion

Results showed higher carbon content in the lignohumate sample and in the HA isolated from *Luvi-haplic Chernozem*. Nitrogen content in the lignohumate sample was very low (0.95 %) to compare with soil HA (more than 3 %) - see Tab.1. Both soil HA contained more oxygen to compare with the lignohumate sample. FTIR SRATR spectroscopy showed that all isolated HA samples had similar bands indicative of aliphatic groups (C-H groups at 2925 cm^{-1}); aromatic groups (C=C groups at 1620 cm^{-1}); phenolic groups (at 1404 - 1419 cm^{-1}); and carboxyl and carbonyl groups (at 1225 – 1223 cm^{-1}) – see Fig. 1 and 2. Main differences between soil HA and the lignohumate sample were found in the finger print region 1700 – 1000 cm^{-1}. More intensive were bands indicative for carboxylic groups in the lignohumate sample to compare with soil HA (at 1581 cm^{-1} and 1414 cm^{-1}). Very intensive were bands indicative for $–O–SO_3$ groups (at 1105 cm^{-1}) in the lignohumate sample to compare with soil HA. The last indicated high content of sulphuric groups in the lignohumate. It is also evident that the lignohumate sample had lower content of aliphatic groups (at 2780 – 3000 cm^{-1}) to compare with soil HA. HA isolated from *Haplic Luvisol* contained less aromatic groups (C=C groups at 1620 cm^{-1}) and more aliphatic groups to compare with *L. Chernozem*.

Conclusion

SRATR - FTIR spectroscopy and results of elemental analysis showed the main differences in the finger print region (1700 – 1000 cm^{-1}). All samples had bands indicative of aliphatic groups (C-H at 2925 cm^{-1}); aromatic groups (C=C at 1620 cm^{-1}); phenolic groups (at 1404 - 1419 cm^{-1}); and carboxyl and carbonyl groups (at 1225 – 1223 cm^{-1}). *Haplic Luvisol* contained less aromatic groups and more aliphatic groups to compare with *L. Chernozem*. Lignohumates contained more carboxylic, phenolic and sulphuric groups to compare with soil humic acids.

Acknowledgements

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Tab. 1. Elemental composition (in atomic %, ash free) of lignohumate, soil HA and Elliott soil HA standard 1S02H (IHSS)

HA samples	**%C[a]**	**%H[a]**	**%N[a]**	**%O[a]**
HA – Luvic-haplic Chernozem	38.6	37.9	3.5	19.6
Lignohumate	39	42	0.9	18.5
HA – Haplic Luvisol	33.5	42.5	3.5	19.5
Elliott HA standard 1S02H	44	33.7	2.7	19.4

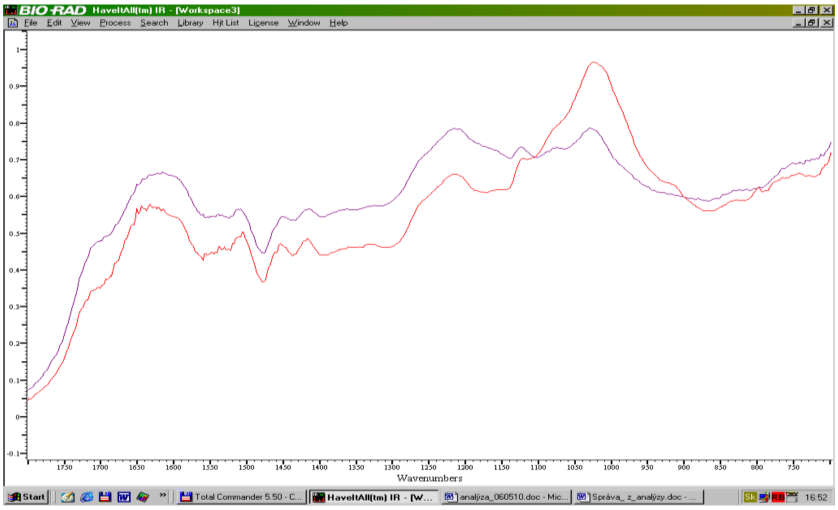

Fig.1. SRATR FTIR spectra of soil HA (red line – HA from *H. Luvisol*, violet line - HA from *L. Chernozem*)

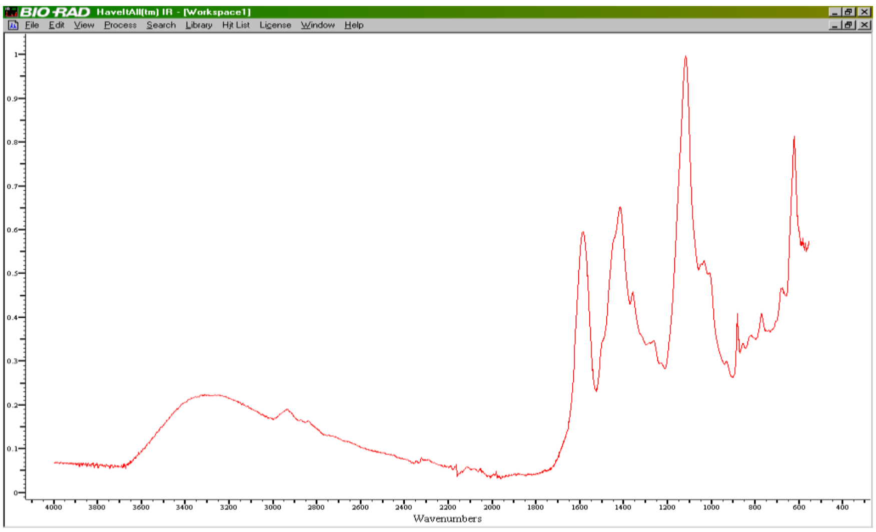

Fig.2. SRATR FTIR spectra of commercial lignohumate sample

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The influence of a meat and bone meal and spraying with effective microorganisms on the aggregate composition of soil

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Abstract
The research covering 5 years and aimed at examining the influence of meat-and-bone meals used independently and in combination with effective microorganisms, as compared to fallow lands, non-fertilized soils, mineral fertilizers or manure, was carried out in atmospheric conditions typical of north-eastern Poland on lumpy structure of lessive soil. Aggregate composition of soil after dry- and wet-sieving generally has not proved any diversification influenced by applied fertilization methods. Water-resistance analysis of soil aggregates has shown the highest water resistance of soil aggregates treated with mineral fertilizers (high share of 3-1 mm fractions). The highest washout level of soil aggregates, down to 0.5-0.25 mm fractions, was noted in non-fertilized soil and on fallow lands. The highest water-resistance of aggregates over 7 mm fertilized with meat-and-bone meal was demonstrated by soil treated with 1.5 t·ha^{-1} meat-and-bone meal combined with effective microorganisms.
Keywords: meat and meal bone, effective microorganims, aggregate fraction

Introduction

Soil structure is one of the basic factors influencing its fertility and constitutes a key indicator of plant crops increase (Kęsik and Błażewicz-Woźniak 2010). Mixing residues of crops and organic fertilizers at shallow depth increases structural stability, prevents against soil crust, facilitates water filtration and makes soils less prone to concentration. Introduction of animal meals is a common phenomenon for soil environment, since organic mass constitutes a basic and most important soil compound. It comprises all dead animal and plant remains as well as organic products of their decomposition (Stevenson 1982). Organic substance and products of its biochemical transformations have crucial impact on the overall soil properties and allow to determine its fertility and productivity. Organic substance delivered to the soil through fertilizers influences its physical qualities, increases biological activity and provides protective and hydrological effect (Konopiński et al. 2001, Kęsik et al. 2007, Łoginow et al. 1991, Jabłoński and Sienkiewicz 1993, Kaniuczak 1994, Krzywy et al. 1996). Introduction of the organic biomass into the soil creates optimum environment for microorganisms development (Dąbek-Szreniawska 2004). Modern agriculture is affected by excessive use of pesticides, high doses of mineral fertilizers and monocultural plant cultivation, which cause that many soils are devoid of useful microorganisms (Sangakkara and Higa 2000). Consequently, application of nutrients from fertilizers proves to be short of effective, triggers constant drop of crops level and makes plant protection expensive and hardly effective. Searching for new remedies, professor Teruo Higa from Ryukyu Universiy in Japan had made a pioneer discovery by producing certain group of microorganisms, referred to as effective microrganisms (EM), which are useful for the purposes of agriculture ecosystems (Higa 1998).

As a part of the comprehensive research, the study sets out to evaluate changes in soil structure influenced by fertilization using meat-and-bone meals and effective microorganisms spraying, in comparison to mineral fertilization, manure, non-fertilized soil or fallow land.

Material and methods

Filed research served as a basic research method aimed at obtaining the pre-defined goal. An exact, static and univariate field experiment was carried out in the years 2005-2009, in the Research Institute located in Bałcyny next to Ostróda. The experiment had been designed as a randomised block arrangement with four replicates. The experiment was conducted in five-year crop rotation of the following plants: spring wheat, ball bean, winter wheat, winter rape, spring wheat. Mineral fertilization (site) with 60 kg·ha^{-1} nitrogen at pre-sowing stage (ammonium nitrate 34%), and 30 kg·ha^{-1} during 1-2 node stage (urea 46%). Phosphorus and potassium were applied at pre-sowing stage, 31 kg·ha^{-1}, P as superphosphate triple (46%) and 83 kg·ha^{-1} K as 60% potassium salt (tab. 1).

Table 1. Experimental design comprised the following fertilization systems

Object	System of fertilization
Without fertilization	control - without fertilization
Black fallow	without cover crop
Mineral fetilization	nitrogen – 90 kg·ha^{-1}, phosphorus – 31 kg·ha^{-1}, potassium – 83 kg·ha^{-1}
FYM	farm yard manure 10 t·ha^{-1}
1.0 MBM	meat and bone meal 1.0 t·ha^{-1}
1.0 MBM + EM-1	meat and bone meal 1.0 t·ha^{-1} and effective microorganisms spraying (EM-1)
1.5 MBM	meat and bone meal 1.5 t·ha^{-1}
1.5 MBM + EM-1	meat and bone meal 1.5 t·ha^{-1} and effective microorganisms spraying (EM-1)
2.0 MBM	meal meat and bone 2.0 t·ha^{-1}
2.0 MBM + EM-1	meat and bone meal 2.0 t·ha^{-1} and effective microorganisms spraying (EM-1)
2.5 MBM	meat and bone meal fertilization 2.5 t·ha^{-1}
2.5 MBM + EM-1	meat and bone meal 2.5 t·ha^{-1} and effective microorganisms spraying (EM-1)

10 t·ha^{-1} manure was applied on annual basis, depending on a given plant belonging to pre-sowing summer-autumn or spring crops. Some parts of sites were fertilized using different doses of meat-and-bone meal with admixture of effective microorganisms (EM-1). This microbiological preparation was used for cultivation of all plants, 5 dm^3·ha^{-1} divided into two doses (first 3 dm^3·ha^{-1} at pre-sowing stage and the second one: 2 dm^3·ha^{-1} prior to first cultivation - harrowing). The preparation contains microorganisms depicted in scientific studies published by Szymański and Peterson (2003) and Valarini et al. (2003) EM-1 preparation was prepared pursuant to the guidelines provided, i.e. microorganisms were activated via incubation with a proper dose of sucrose. Pre-determined amount of nutrients was also injected into the soil together with mineral and natural fertilizers (tab. 2). Surface genetic levels on the examined field show granulometric composition of loamy sand, while elutriation levels indicate prismatic structure of sandy loams. The soil has been classified as arable land of good quality (class IIIa) and as very good for rye (class 4). The experiment was conducted on the overall area of 1320 m^2, which had been divided into 48 plots (12 fertilization methods and 4 replicates). Sowing area of each plot was at the level of 30,0 m^2, while the harvest area equalled 24,75 m^2.

Table 2. Doses of nutrients in kg·ha^{-1}·year^{-1}, with fertilizers

Nutrient	Mineral fertil* kg ha^{-1}	FYM 10 t ha^{-1}	MBM 1.0 t ha^{-1}	MBM 1.5 t ha^{-1}	MBM 2.0 t ha^{-1}	MBM 2.5 t ha^{-1}
Nitrogen	90.0**	51.0	66.5	99.8	133.0	166.3
Phosphorus	31.0	12.1	39.8	59.7	79.6	99.5
Potassium	83.0	49.0	4.1	6.2	8.2	10.3
Calcium	-	34.0	19.0	28.5	38.0	47.5

* for explanation see table 1
** the faba bean in 2006 was not N- mineral fertilized
Objects: without fertilization and black fallow – was not fertilized

Examination of physical soil properties was carried out during high season of plant vegetation - corn at mowing stage (BBCH 51-59), ball bean (BBCH 61-65) and winter rape (BBCH 61-65) at flowering stage. Soil samples were collected from surface levels of plots (at the depth of 0-20 cm) in intact condition and put into boxes (overall weight of approx. 2,0-2,5 kg) in order to determine the soil aggregation composition. Samples used for aggregation examination were dried up in the open air, devoid of dead plant residues and divided into 4 parts which were later sieved through the set of sifters with following diameters: 10.0; 7.0; 5.0; 3.0; 1.0; 0.5; 0.25 mm. Content of aggregates with varied diameters was calculated based on the arithmetic mean taken from 4 independent siftings. Aggregate fractions obtained owing to the above method allowed to collect 25 grams for wet-sieving through a soil aggregates separator, an apparatus designed in the Astrophysics Institute of the Polish Academy of Science in Lublin (Mocek 2000).
Sowing, cultivation processes and plant picking were carried out in compliance with agro-technical requirements typical of given plant species. Only mechanical methods were employed to fight weeds.

Results and discussions
Successful crops and plant growing is, to large extent, dependant on soil clodding and pulverization levels. Excessive share of powdery elements may lead to the soil surface crusting, while cloddy elements and clumps hinder plants sprouting and their steady growth (Wacłowicz and Tendziagolska 2008).
Various fertilizing methods have usually insignificantly influenced aggregate composition of soils (tab. 3). Among the aggregates distinguished after dry-sieving, fractions above 10 mm had the highest average share of all fertilized soils (38.3%), while the share of 0.5-0.25 mm was on the lowest level (5.2%). Soil fertilized with mineral fertilizers proved to be most clumpy, with 43.1% portion of clamps. Least lumpy soil (33.3%) was observed after application of 1.5 t·ha^{-1} meat-and-bone meal in combination with effective microorganisms (MBM 1.5 t·ha^{-1} + EM-1). Mineral fertilization, manure or treatment with meat-and-bone meal in combination with effective microorganisms or without EM-1, as opposed to non-fertilized soil, would insignificantly reduce the level of silty fractions (below 0.25 mm). The smallest share of silty fraction (9.7%), on the other hand, was observed after application of 1.5 t·ha^{-1} meat-and-bone meal together with EM-1 and was similar to levels detected in soil fertilized with mineral fertilizers.

Table 3. Aggregate composition after dry-sieving (%) (mean 2005-2009 years)

Specification*	Aggregate fraction (mm)							
	>10	10-7	7-5	5-3	3-1	1-0.5	0.5-0.25	<0.25
Without fertilization	38.2[a]	6.2[a]	9.1[a]	7.3[a]	13.9[a]	6.4[ab]	5.7[ab]	13.3[a]
Black fallow	36.7[a]	8.3[ab]	8.3[a]	7.2[a]	11.6[a]	9.1[ab]	6.2[ab]	12.7[a]
Mineral fertilization	43.1[a]	8.0[ab]	10.4[a]	7.6[a]	13.1[a]	5.2[a]	2.7[a]	9.9[a]
FYM	36.1[a]	8.1[ab]	11.0[a]	6.7[a]	16.7[a]	5.4[a]	5.4[ab]	10.5[a]
MBM 1.0	40.6[a]	7.7[ab]	8.6[a]	6.6[a]	13.8[a]	6.1[ab]	5.0[a]	11.7[a]
MBM 1.0 + EM-1	36.7[a]	7.7[ab]	7.5[a]	8.4[a]	12.7[a]	9.7[ab]	6.0[ab]	11.2[a]
MBM 1.5	34.5[a]	8.7[ab]	11.0[a]	7.4[a]	14.8[a]	5.4[a]	5.9[ab]	12.4[a]
MBM 1.5 + EM-1	33.3[a]	8.1[ab]	10.5[a]	6.1[a]	14.5[a]	8.7[ab]	9.2[ab]	9.7[a]
MBM 2.0	42.2[a]	7.7[ab]	9.7[a]	7.1[a]	11.3[a]	6.4[a]	4.2[a]	11.5[a]
MBM 2.0 + EM-1	40.3[a]	10.2[ab]	10.1[a]	7.8[a]	12.6[a]	5.3[ab]	3.5[ab]	10.3[a]
MBM 2.5	40.2[a]	9.9[ab]	11.4[a]	6.7[a]	12.1[a]	4.8[a]	4.7[ab]	10.2[a]
MBM 2.5 + EM-1	37.4[a]	8.5[ab]	10.9[a]	7.4[a]	15.2[a]	6.1[a]	4.4[a]	10.1[a]
Mean	38.3	8.3	9.9	7.2	13.5	6.6	5.2	11.1

a,b…homogenous groups
* for explanation see table 1

After five years, analysis of soil aggregates water-resistance carried out based on Bakszajew method (Mocek et al. 2000) proved that soil aggregates treated with mineral fertilizers feature the highest water-resistance level. Only 10.4% of aggregates on the site had been washed out down to the diameter of 0.5-0.25 mm. The highest washout level of soil aggregates, down to 0.5-0.25 mm fraction, was found in non-fertilized soil and on black fallow. Soil covered with mulch products are not subject to compaction and crust formation, as well as bare soil (Nyakatawa et al. 2001). Introduction to soil stabilization plant biomass structure (Schjonning et al. 1994, Pagliai et al. 2004), the reduction rates cloddiness in the arable layer of soil. The obtained results are contrary to studies carried out by Lenart (2008), which demonstrated the smallest water-resistance of aggregates fertilized with mineral fertilizers. According to the own research conducted for soils treated with mineral fertilizers, as much as 66.4% of aggregates has not been washed out and remained on 3-1 mm sifters. Introduction of bone-and-meat meals used independently or in combination with effective microorganisms shown that water-resistance of soil aggregates is ambiguous. The highest water-resistance of aggregates over 7 mm was determined for soil fertilized with 1.5 t·ha-1 meat-and-bone meal in combination with effective microorganisms. Although the smallest share of fractions >10 mm after dry-sieving was noted after application of MBM 1.5 EM-1, researchers noted the highest share of fractions >7 mm in the soil of the site after wet-sieving.

Among the sites with meat-and-bone meal, application of 2.0 $t \cdot ha^{-1}$ of MBM, (without EM-1) had the most beneficial effect on 3-1 mm soil fractions, which constituted almost half (45.6%) of all aggregates.

Table 4. Aggregate composition after wet-sieving (%) (mean 2005-2009 years)

Specification*	Aggregate fraction (mm)					
	>7	7-5	5-3	3-1	1-0.5	05-0.25
Without fertilization	10.8[a]	2.2[ab]	4.5[a]	43.4[a]	1.9[a]	37.2[a]
Black fallow	4.6[ab]	3.5[a]	4.7[a]	47.0[a]	3.1[a]	37.1[a]
Mineral fertilization	16.7[ab]	1.0[ab]	3.8[a]	66.4[a]	1.6[a]	10.4[a]
FYM	13.8[ab]	5.5[ab]	7.1[a]	45.1[a]	3.0[a]	25.6[a]
MBM 1.0	20.8[ab]	6.2[ab]	10.5[a]	18.1[a]	9.1[a]	35.4[a]
MBM 1.0 + EM-1	23.5[ab]	3.5[ab]	4.9[a]	32.0[a]	11.9[a]	24.3[a]
MBM 1.5	26.5[ab]	1.2[ab]	5.5[a]	42.7[a]	4.9[a]	19.1[a]
MBM 1.5 + EM-1	36.1[ab]	3.7[ab]	8.6[a]	25.5[a]	7.8[a]	18.3[a]
MBM 2.0	22.2[ab]	1.2[ab]	3.7[a]	45.6[a]	7.7[a]	19.5[a]
MBM 2.0 + EM-1	28.3[ab]	8.6[ab]	9.2[a]	29.3[a]	7.5[a]	17.2[a]
MBM 2.5	27.0[ab]	6.5[ab]	8.9[a]	20.2[a]	10.5[a]	26.8[a]
MBM 2.5 + EM-1	18.4[ab]	5.2[ab]	6.6[a]	36.9[a]	7.9[a]	25.1[a]
Mean	20.7	4.0	6.5	37.7	6.4	24.7

a,b…homogenous grups
* for explanation see table 1

Conclusions

1. Aggregate composition of soil after dry- and wet-sieving generally has not proved any diversification influenced by applied fertilization methods.
2. Among the aggregates distinguished after dry-sieving, fractions over 10 mm had the mean highest share among all fertilized soils.
3. Soil fertilized using mineral manures proved to be most cloddy, as opposed to the soil fertilized with 1.5 $t \cdot ha^{-1}$ meat-and-bone meal in combination with effective microorganisms.
4. Water-resistance analysis of soil aggregates has shown the highest water resistance of soil aggregates treated with mineral fertilizers (high share of 3-1 mm fractions).
5. The highest washout level of soil aggregates, down to 0.5-0.25 mm fractions, was noted in non-fertilized soil and on black fallow.
6. The highest water-resistance of aggregates over 7 mm fertilized with meat-and-bone meal was demonstrated by soil treated with 1.5 $t \cdot ha^{-1}$ meat-and-bone meal combined with effective microorganisms.
7. Among sites fertilized with meat-and-bone meal, application of 2.0 $t \cdot ha^{-1}$ (without EM-1) had positively influenced 3-1 mm soil fractions, which constituted almost half of all aggregates on the site.

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The effect of different forms of tillage on selected biological and biochemical soil characteristics

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Abstract

In our research, now in its fourth year, we have focused on a comparison of three forms of tillage (ploughing, subsoiling and minimization technique) and their influence on selected biological and biochemical soil characteristics. From evaluation of the results for the third year of analysis in comparison with the start of research it is evident that tillage methods affect activity of most soil enzymes. This is true for cellulase, dehydrogenase, acidic and alkaline phosphatase, nitrate reductase and protease. In 2010 soil respiration was higher in the ploughing variant compared to the other methods, which is due to the greater aeration and lower compaction of the surface layer to 20 cm. This is also evident in the results of soil compaction measurement, which, in the surface layer, is lowest in the ploughing variant and highest in the minimization variant. In the 20 – 40 cm layer such differences were not noted.

Keywords: Soil tillage, enzymes, respirations, soil characteristics

Introduction

The importance of soil for humans and biosphere has often been underestimated in recent years, although human existence is dependent on it and any loss of farmland or detriment to the soil worsens the possibilities for sustainable development. In agricultural use it is the method of agrotechnical management which affects soil properties. When evaluating these influences it is important to choose suitable indicators which are able to sensitively reflect any change in the soil environment. Such indicators include biological and biochemical characteristics of the soil, such as the activity of soil enzymes which are part of biological processes in the soil, e.g. decomposition of organic material, mineralization and release or recycling of nutrients (nitrogen, phosphorus, sulphur or other biogenous elements). In particular, the speed of hydrolytic enzymatic reactions has an immediate influence on the degradation of biopolymers contained in the soil and their transformation into substances which can be exploited by microorganisms or plants. Compared to common chemical processes these reactions have a higher specificity to substrate, they occur at lower temperatures, they are regulated very sensitively, and usually do not give rise to by-products (Šarapatka 2005).

In specialist literature the activity of soil enzymes is considered a sensitive indicator of disturbed biological function of soil e.g. as a result of pollution (Bolton et al. 1985). Besides temperature, soil humidity, pH, quantity and quality of organic matter, nutrient content, biomass of microorganisms, vegetation cover and the presence of activators and inhibitors, this activity is also significantly affected by tillage and fertilization. (Melero et al. 2006).

The process of ammonification has an important position in nitrogen cycle. An ammonification test indicates the ammonifying activity of microflora and the level of biological sorption of organic matter by microorganisms. Various versions of the test enable an assessment of the current content of ammonia nitrogen in a fresh soil sample (Javorský et al. 1987), the potential amount of ammonia nitrogen produced in an incubated soil sample enriched with water and, at the same time, the amount of ammonia nitrogen originally bound in the organic compound.

In biologically active soils ammonia nitrogen undergoes nitrification which is an example of another monitored biological characteristic of the soil. This involves biological oxidation of

ammonia into nitrites, which has 2 phases, i.e. nitritation (ammonia-oxidizing bacteria or AOB) and nitratation (nitrite-oxidizing bacteria or NOB). The process of nitrification depends on a number of conditions (Fecenko, Ložek 2000), especially on soil pH, temperature, humidity, aeration and concentration of nitrogen in the form of NH_4^+ and NH_3^-. The agricultural methods used also have a significant effect on these processes. However, besides processes ensuring and enriching input of plant-available nitrogen, nitrogen loss occurs due to denitrification, volatilization, wash-out and erosion. Nitrogen at depth of 0.8m and deeper in the soil is lost in terms of plant nutrition, only posing a serious danger to the quality of groundwater (Richter, Hlušek 2006).
Within the fields of soil biology and ecology, basal respiration is a quite widespread characteristic for the evaluation of biological activity of soil. We have incorporated this relatively simple assessment in our research in the aim of evaluating biological activity in soil environment in relation to method of management. The hypothesis is based on the fact that respiration of soil microbial communities, like other characteristics, is influenced by working the soil, and in some cases even to a greater extent than the quantity of overall carbon (Campbell 1985). Specialist literature states that classic cultivation of soil with the use of ploughing supports organisms with a short generation period, a wide range of food sources, low C assimilation and high basal respiration (Andrén, Lagerlöf 1983).

In our research we have focused on monitoring the stated biological soil characteristics during various work with the soil and have compared these with commonly used physical and chemical soil characteristics.

Material and Methods

Since the year 2007 we have studied the influence of various agrotechnical processes on soil characteristics in three localities in various types of production and with varying soil and climatic conditions. Agricultural establishments / enterprises in Unčovice, Hrušovany nad Jevišovkou and Lesonice were selected for the research. Unčovice (Olomouc region) is located in a beet producing area at an altitude of 227 metres a.s.l., with an annual rainfall of 536 mm. The area is warm and moderately humid. The soil type is luvic chernozem. Hrušovany nad Jevišovkou (Znojmo region) is within a corn producing area at an altitude of 210 metres a.s.l., with an annual rainfall of 461 mm. The region is warm and dry. The research locality has a modal chernozem soil type. Lesonice (Třebíč region) lies in a potato producing area at a height of 510 metres a.s.l, with an annual rainfall of 567 mm. The region is moderately warm and moderately humid. The soil type under research is modal brown earth.

On all three enterprises trials were conducted with three methods of soil tillage after the same preceding crop. During the monitoring period the same crop rotation was applied to all monitored plots. Soil cultivation in the following variants was chosen:

- classic – ploughing to a depth of 0.22 m,
- minimization with shallow harrowing to a depth of 0.15 m,
- deep subsoiling to a depth of 0.35 – 0.40 m.

For each variant a plot of land ca 30 x 100 m was established depending on the type of machinery used. Fertilization and plant protection were relevant to the needs of individual crops in a given area.
In these semi-operational conditions, in individual variations within the crop rotation, the activity of selected soil characteristics (dehydrogenase, phosphatase, urease, protease, nitrate reductase, cellulase) from the nitrogen cycle (ammonification, nitrification) and soil

respiration are examined. On other worksites further soil characteristics (physical and chemical) are studied, for comparison with our results. For our research soil samples are taken at least twice a year at two depths (to 0.05 and to 0.2 m). Individual characteristics are determined using the following procedures:

- Phosphatase activity is determined using the revised method according to Tabatabai a Bremner (1969) using p-nitrophenylphosphate as substrate.
- Dehydrogenase activity is monitored with the help of a procedure according to Ross (1970) using triphenyltetrazolium chloride as substrate.
- To determine protease activity a method according to Ladd and Butler (1972) is used in which casein is used as substrate.
- Urease activity is analysed using a method according to Tabatabai and Bremner (1972) in which soil samples are incubated with a urea solution.
- To determine activity of nitrate reductase, soil samples are incubated according to a method by AbdelMagid and Tabatabai (1987) using KNO_3 as substrate.
- To determine cellulase activity a method is used according to Schiner and von Mersi (1990) using CM-cellulose.
- Ammonification is determined using a method according to Pokorná, Novák (1981). Various versions of the ammonification test (A_A,K_A,Pep_A) enable assessment of the current ammonia nitrogen content in a fresh soil sample (A_A), the potential amount of ammonia nitrogen produced in an incubated soil sample enriched with water H_2O (K_A) and the amount of ammonia nitrogen originally bound in the organic compounds. The difference (K_A-A_A) represents the ammonification itself, while the difference (Pep_A-A_A) represents the carbon mineralization.
- Nitrification is also determined using a method according to Pokorná, Novák (1981); oxidability of nitrogenous substances is determined with the help of a nitrification test organized in three parallel results from one sample. This means the current content of $N.NO_3$ (mg/kg) in a fresh sample (variant: A_n), content of $N.NO_3$ (mg/kg) after 7 days of incubation at 28°C with added H_2O (variant: K_n) and content of $N.NO_3$ (mg/kg) after 7 days of incubation at 28°C with added ammonia nitrogen in the form of ammonia sulphate $(NH_4)_2SO_4$ (variant: R_N).
- Measurement of respiration activity is based on monitoring the amount of CO_2–C released (usually in grams) within a certain time period in relation to one gram of dry soil (Šantrůčková 1993). The possibilities and methods of measuring respiration have been described in ISO/DIS 16072-2001. Microbial respiration of soil is monitored during a 14-30 day period of aerobic incubation. The results of microbial respiration measurements are then expressed as the average daily production of CO_2–C in mg of CO_2-C. per kg_{dry}.
- To measure soil resistance an Eijkelkamp penetrometer is used, soil humidity and conductivity is monitored in situ with the help of a HH2 Moisture Meter DELTA-T DEVICES and a WET Sensor probe, WET-2 type.
- Other stated characteristics (physical and chemical) utilize methods commonly used in pedological laboratories and published in procedures by Zbíral et al. (1995 – 1997).

For statistical evaluation, correlations between individual soil characteristics were studied as well as the difference between individual variants of working the soil with the help of Kruskal-Wallis tests using STATISTICA software.

Results and discussion

From statistical evaluation in the first years of the research project significant differences appear between the majority of soil characteristics and the locality, mainly due to different soil types in each research area. However, in terms of soil characteristics depending on the variants of the research, the differences are much less statistically remarkable. Evaluation of the results for Lesonice plots is a good example as the difference between the variants can be proven in 2009 for pH, Mg content, activity of acidic and alkaline phosphatase and conductivity, mostly between the ploughing and minimizing variants. The results of evaluation using the Kruskal-Wallis test are shown on an example of alkaline phosphatise in Tab. 1 and Fig. 1.

Tab. 1 Results of Kruskal-Wallis test in alkaline phosphatase evaluating the difference between various methods of working the soil (ploughing, subsoiling, minimum tillage)

Dependent phosphatase	Multiple comparison of p-values (bilateral); phosphatase (Degr89a) Independent (grouping) variable: variant Kruskal-Wallis test: H (2, N= 12) = 7.538462 p =.0231 Sum of condition: Locality = "L"		
	P R:2.5000	S R:8.0000	M R:8.0000
Ploughing (P)		0.0930	**0.0324**
Subsoiling (S)	0.0930		1.0000
Minimum tillage (M)	**0.0324**	1.0000	

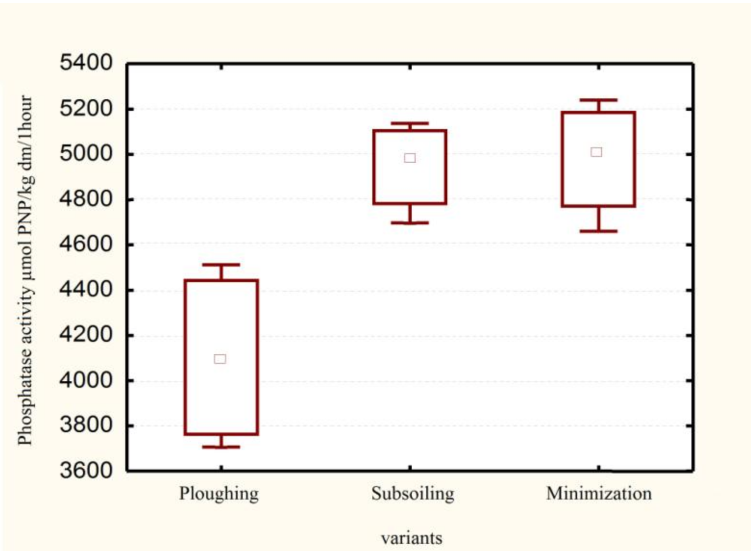

Fig. 1 Activity of alkaline phosphatase in various forms of tillage (ploughing, subsoiling and minimum tillage)

Nevertheless, from the evaluation of results of the third year of research, i.e. 2010 it appears that working the soil without turning the topsoil (variants of subsoiling and minimum tillage) showed a higher activity of most soil enzymes. This statement correlates with specialist literature (e.g. Roldan et al. 2003). This applies for cellulase, dehydrogenase, both acidic and alkaline phosphatase, nitrate reductase and protease (Fig. 2) Such an increase can be related to a higher content of organic matter in the top soil layer in these variants (Slepetiene, Slepetys

2005; Roldan et al. 2003), while the method of working the soil can have a greater effect on the content of various C forms than crop rotation (Soon et al. 2007).

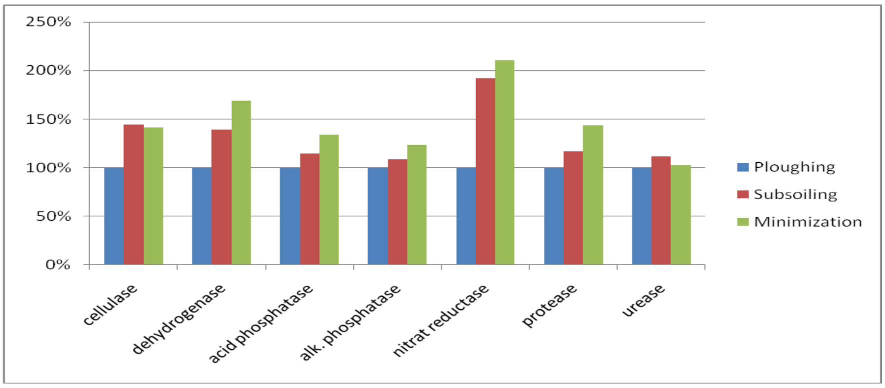

Fig. 2 Activity of selected soil enzymes affected by various forms of tillage in 2010

In 2010 soil respiration was higher on ploughed plots compared to other forms of tillage which is the result of better aeration and less compaction of topsoil (to 20 cm). This also shows in the results of soil compaction measurement (in 0 – 20 cm layer) which is lowest in the ploughing variant and highest in the minimum tillage variant. The results also correspond with data already published, e.g. Fabrizzi et al. (2005). In the 20 – 40 cm layer these differences were not registered (Fig. 3). Statistically significant differences were not found - after three years of monitoring – in ammonification and nitrification. Results from other co-partners in the project indicate the first statistical differences between the monitored variants in other soil characteristics – e.g. in physical soil properties (Badalíková, Bartlová 2010; Bartlová, Badalíková 2010).

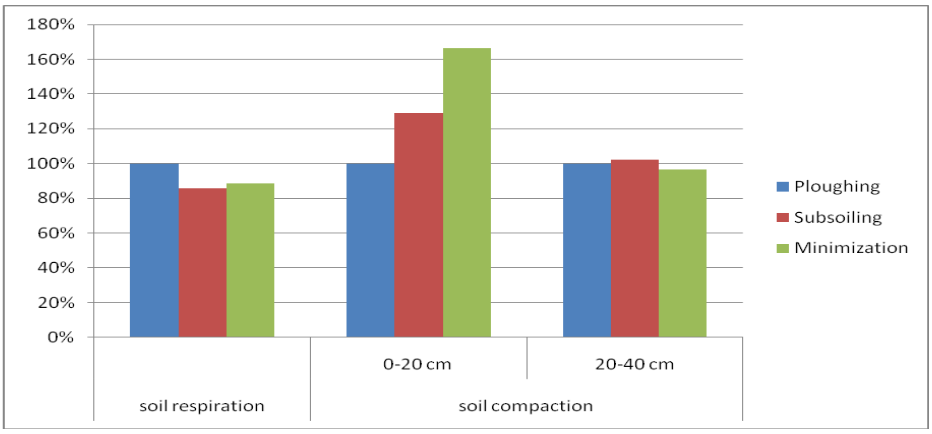

Fig. 3 Respiration and compaction of studied layers in various forms of soil tillage in 2010

Conclusion

In the following decades crop production will have to be able to supply a denser population from more limited land area, will have to strive for minimization of negative impact on individual elements of the environment and, at the same time, greater efficiency will become necessary. This will demand different approaches to agricultural practice, where the recent trend in many agricultural systems is towards minimum possible working of the soil. These methods have attracted considerable attention worldwide and we, in the Czech Republic, have also focused on this issue in Czech conditions. The first results presented in this article show an increase in biological activity expressed by the activity of soil enzymes under minimum tillage management compared to traditional working of the soil. Similar first results are evident in other research partner worksites, relating to physical and chemical soil characteristics. In the following period, after completing analysis of the fourth year of monitoring, summary analysis will be carried out as well as evaluation of the results and recommendations for practitioners will be issued in the form of procedures.

Acknowledgements
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CONTENT

Microbial activities related to the soil nitrogen transformation in humid mediterranean conditions

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Abstract
This study was carried out in the soil under oak forest (*Quercus suber* L.) in humid Mediterranean condition in the Sierra del Hacho situated in the Spanish province Malaga with the aim to estimate the effect of understory vegetation cover on soil microbial transformation of nitrogen (vs. bare soil). Soil samples were taken representatively twice in consecutive years (July 2008 and February 2009, representing wet and dry part of the year, respectively) from the upper soil horizons to the depth of 0,1m. To quantify net rates of N mineralization and net nitrification (and/or immobilization) we have evaluated the net changes in ammonia- and nitrate-nitrogen contents extracted from homogenized soil samples during the laboratory incubation. The significant differences were found out between the individual times of soil sampling (wet vs. dry part of the year) indicating the different soil conditions for mineral nitrogen immobilization, mainly sources of available soil carbon in the corresponding part of the year. However the differences between net nitrogen mineralization in soil samples collected beneath vegetation cover and from bare soil without the vegetation cover were not so evident. Our results indicate the importance of temporal and spatial heterogenity of key soil conditions, which may ultimately determine rates of nutrient turnover in this humid Mediterranean ecosystem.
Keywords: humid Mediterranean climate, soil, nitrogen, net mineralization, net nitrification

Introduction

Soil nutrient availability is an important factor affecting nutrient status and fertility of the soil. The readily available nutrients occur in the rhizospheric soil in soil solutions and can be taken up by plants directly. Nevertheless the potentially available nutrients (N, P, S) which are tightly bound into different organic heteropolymers in soil organic matter can only be taken up by roots after being transformed to the more simple compounds, at the best way into inorganic ones. Soil organic matter can provide mineral nutrients for plants and micro-organisms through the mineralization process (Marinari et al., 2010) coupled with the release of energy for microbial activities. To obtain as much as possible specific information on microorganisms is permanent need. Some people, scientists including often assume, that microbes are passively reacting to abiotic and biotic stimuli rather than controlling soil processes explicitly. However, there is increasing evidence that the structure of microbial communities alters soil processes (Smithwick, 2005). In particular, nitrogen (N) is a limiting nutrient in many ecosystems (Carnol and Ineson, 1999). It is well known that important ecosystem processes such as nutrient cycling, nutrient mineralization, soil organic matter accumulation and soil biological activity, among others, are also related to soil nitrogen availability (Sánchez et al., 1997). Results show that the mechanism of the movement of different nitrogen forms towards roots is different: nitrate N mainly moves by mass flow and therefore its enrichment is found around roots whereas ammonium by diffusion, resulting in depletion around roots (Song and Li, 2006). Microbial transformations of soil nitrogen are largely dependent on environmental conditions (Carnol and Ineson, 1999). Nitrogen limitation to plant productivity is relatively common in semi-arid ecosystems. The N cycle in dry

ecosystems is characterized by slow production of available N in reduced forms (mainly NH_4^+) during the dry period because of slow mineralization and decomposition processes. On the other hand rapid recycling and uptake of reduced N is occuring at the wet season (Gelfand and Yakir, 2008). The influence of water on nitrification in soils is also closely linked to oxygen availability, as autotrophic nitrifers are obligate aerobes. Water content has been reported to stimulate nitrification up to an optimum, where oxygen diffusion becomes limiting (Carnol and Ineson, 1999).
In this study, we investigated changes in two parts of nitrogen cycle, in soil nitrogen mineralization and nitrification between soil samples collected directly beneath vegetation cover and from the neighbouring bare soil.

Material and methods
Experimental plots were established in the neighbourhood of the municipality Gaucín situated in the Sierra del Hacho in the Spanish Malaga province. The main characteristics of the study area are shown in Tab. 1.

Tab. 1 General characteristics of the study area

Mediterranean climate	Humid
Rainfall (mm.year^{-1})	1100
Slope gradient (°)	22
Slope length (m)	110
Geology	Phyllites
Vegetal cover (%)	90
Main vegetal species	*Quercus suber, Quercus faginea, Quercus ilex* *Cistus salvifolius, Erica arborea, Cistus albidus* *Phlomis purpurea, Pistacia tentiscus, Ononis reuteris* *Calicotome villosa, Daphne gnidium*
Bulk density (g.cm^{-3})	1,08
Sand (%) (2-0.125 mm)	18,8
Very fine sand (%) (0,125-0,063 mm)	8,6
Silt (%) (0,063-0,002 mm)	48,7
Clay (%) (<0,002 mm)	23,9
Texture	Loam
Electrical conductivity (mS/m^{-1})	2,48
Organic matter (%)	10,1
Soil organic carbon (t.ha^{-1})	35
Aggregate stability (%)	76,5
Factor K (USLE)	0,09
Cation exchange capacity (meq 100 g^{-1})	33,5
Saturated hydraulic conductivity (cm.h^{-1})	21,8

In order to determine net nitrogen mineralization and net nitrification the soil sampling was performed in different parts of the growing season in two subsequent years (July 2008 and February 2009). Representative soil samples were taken either directly beneath vegetation cover or pairwise from the neighbouring bare soil. The depth of sampling was always 0,1 m. The obtained soil samples were homogenised, sifted through a sieve with the mesh size of 2

mm, and placed into plastic bags. Prior to analyses, the soil samples were stored at the temperature of 4 °C.
The water holding capacity (WHC) of soil was estimated in the laboratory using the method described by Dykyjová et al., (1989). The dry matter (DM) content of samples was determined after drying the soil samples at the temperature of 105 °C till the stable weight was achieved. One week prior to incubation, the stored samples were pre-incubated to restore and stabilise their microbial activity. Before the analysis, these samples were saturated to 60% of WHC either with distilled water (basal activities) or with a solution of glucose (potential activities). The glucose solutions were used in the variant of potential microbial activities for supporting microorganisms with extra added carbon as a source of easily degradable organic material. Soils samples (70 g of DM), collected in July 2008, and were incubated in laboratory for 37 days. The same experiment was repeated one year later using soil samples collected in February 2009. Values of net ammonization and net nitrification and/or net immobilization were estimated according to Hart et al. (1994). To know more about the possible fate of released mineral forms of nitrogen we used a simulation of rain event. After 15 days of incubation were soil samples carefully washed out using 120 ml distilled water in order to obtained percolates for the estimation of mineral N. After it, the original soil moisture were reestablished and maintained for the rest of incubation. Contents of NH_4^+-N a NO_3^--N extracted either from soil samples or from percolates was estimated by means of a distillation-titration method (Peoples et al., 1989). Values of net mineralization, net nitrification were calculated by means of subtraction the original amounts of ammonia- and nitrate-nitrogen in soil samples at the beginning of incubation from those obtained at the end of incubation together with the amounts of NH_4^+-N a NO_3^--N in percolates. Negative values indicate net immobilization. Results were expressed as mg of NH_4^+-N and NO_3^- -N in 1 kg of DM.

Statistics
Data on soil nitrogen, nitrification and nitrogen mineralization rates were analyzed using one way analysis of variance (ANOVA). Least significant difference (LSD) values at the 5% levels of significance ($p<0.05$) and Tukey test values were calculated.

Results and discussions
López et al. (2003) found that the reduction of NO_3^- suggests that the autotrophic ammonia oxidation is the dominant path for nitrate production in ecosystem. The bare-soil microenvironment had the lowest ammonium-N concentration and high nitrate-N/ammonium-N ratio. The relatively high soil NH_4^+-N under the understory vegetation may have caused a reduction in the efficiency of the inhibition of autotrophic nitrification (López et al., 2003). The highest soil NH_4^+-N concentrations were generally found in the soils beneath vegetation cover. The spatial pattern in extractable NO_3^--N concentrations showed a similar trend with the highest concentrations beneath the vegetation cover. With the exception of NH_4^+-N ions extracted in basal variants, no statistically significant differences were found out in contents of NO_3^--N ions extracted within the whole incubation period from soil samples taken either directly below vegetation cover or from the soil without the vegetation cover and no statistically significant differences were found out in contents of NH_4^+-N and NO_3^--N extracted from soils stimulated by glucose. As compared with basal variant, contents of NH_4^+-N and NO_3^--N extracted during the whole period of incubation were lower in soils stimulated by a glucose solution in both years. Although this was more clear in the case of NO_3^--N in 2008, the calculated differences were statistically significant in both years. It can be concluded that the soil microbial activities are in this soils limited by the readily available carbon and that the presence of plant roots with a corresponding amount of rhizodeposition particularly exudates can effectively stimulate immobilization and prevent loss of nitrogen in

mineral forms. In percolates collected in the middle of the experimental period, the contents of NO_3^--N in non-stimulated soils were in average higher by 91% than in samples taken up to the end of the laboratory incubation in 2008. These facts demonstrate the high mobility of nitrate nitrogen against ammonium nitrogen, movement of which in soils is controlled by different mechanisms.

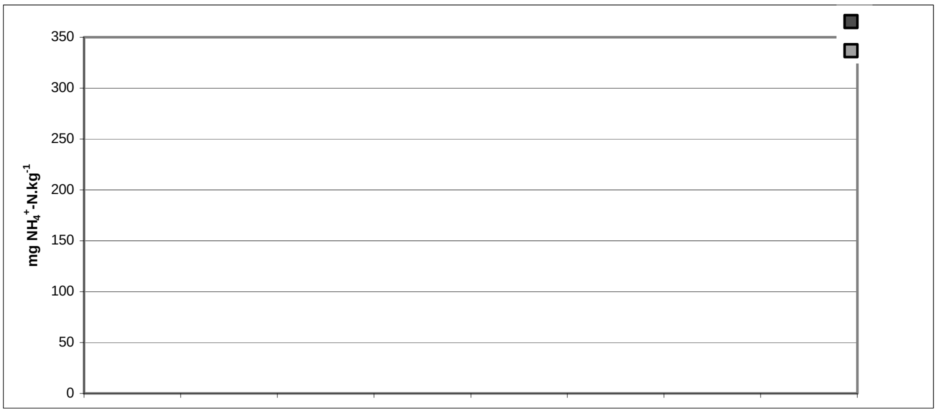

Fig. 1 Contents of NH_4^+-N in soil percolates and in final extracts of soil samples

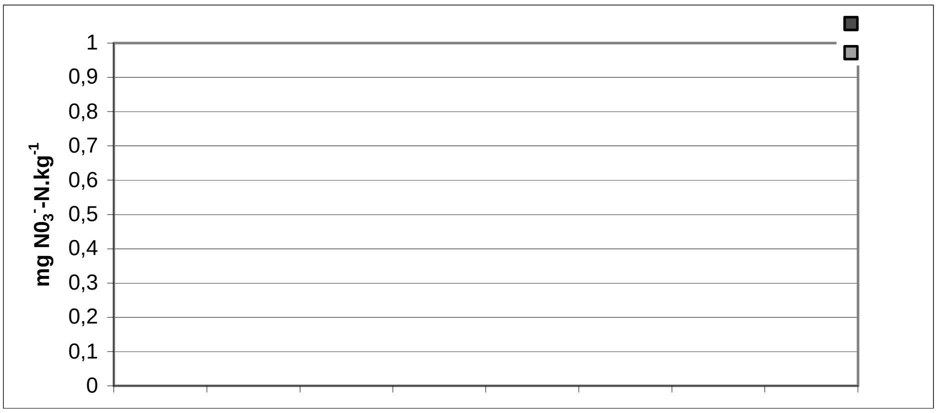

Fig. 2 Contents of NO_3^--N in soil percolates and in final extracts of soil samples.

Nitrogen mineralization is an essential function of the soil microbial system (Ellenberg, 1971). Pathak and Rao (1998) reported that added organic matter has a favourable effect on nitrogen mineralization rate in saline and alkaline soils under laboratory conditions. Garten (1993) found that higher NH_4^+ concentrations were related to higher rates of net N mineralization and nitrification. Owen et al. (2003) indicated that the net N mineralization and nitrification rates are often positively related to temperature and N availability. Steenwert and Belina (2008) concluded that the cover crops enhanced the soil's capacity for supporting greater microbiological functions of nitrification and denitrification. The lack of strong temporal change in NO_3^- -N and the mild increase in NH_4^+-N when soil water content increased (i.e., in spring) may partly be attributed to its potential rapid consumption by microbial immobilization (Steenwerth, 2008).

Net nitrogen mineralization was maximal in 2008 in soil samples collected beneath the vegetation cover (307.04 mg kg^{-1} soil per 37 days) and minimal in 2009 in bare soil (37.3 mg kg^{-1} soil per 37 days). Net N immobilization in general, as indicated by negative values, was evident mainly in the 2008 year independently if the soil samples were collected beneath the vegetation cover or not. The reason for this phenomenon is the individual time of soil sampling (wet vs. dry part of the year) indicating the different soil conditions for mineral nitrogen immobilization, mainly sources of available soil carbon in the corresponding part of the year (Fig. 3). The addition of readily available carbon in glucose solution decreased rates of the net soil N mineralization and net nitrification especially in the case of soil microflora in the soil samples collected in year 2008. This indicates limitation of soil microorganisms by the readily available carbon sources. Net nitrogen mineralization and nitrification were higher below vegetation cover in all experimental years. The significant differences between net nitrogen mineralization in soil samples collected beneath vegetation cover and from bare soil without the vegetation would rather support the hypothesis of incomparable soil conditions for microbial activity. There were significant variations in nitrogen mineralization due to vegetation cover, variant and year ($p<0.05$).

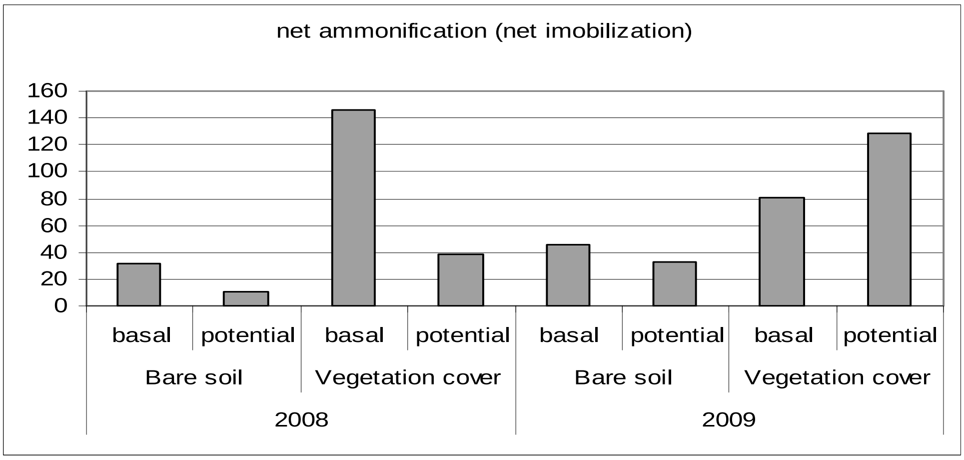

Fig. 3 Net mineralization and immobilisation (negative values)

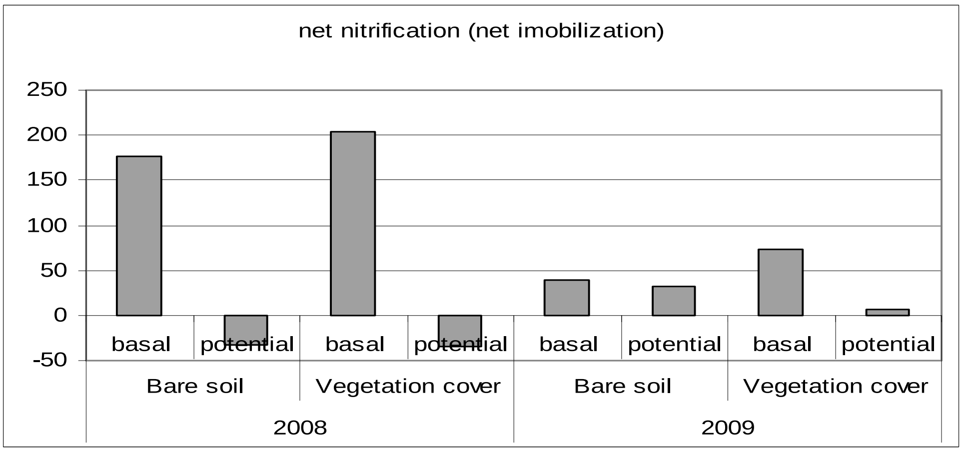

Fig. 4 Net nitrification and immobilisation (negative values)

Conclusions

The highest soil NH_4^+ concentrations were generally found in the soils beneath vegetation cover. As compared with basal microbial activities, contents of NH_4^+-N and NO_3^--N extracted during the whole period of incubation were lower in soils stimulated by a glucose solution in both years under study. This was more evident in the year 2008. Thus it can be concluded that the soil microbial activities are in this soils limited by the readily available carbon and that this limitation is temporally and spatially different. There were significant differences between net nitrogen mineralization in soil samples collected beneath vegetation cover and from bare soil without the vegetation. These results indicate the importance of spatial heterogeneity, which may ultimately determine rates of nutrient turnover in this humid Mediterranean ecosystem.

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CONTENT

MINERAL COMPOSITION OF AGRICULTURAL SOILS DEVELOPED ON LOESS

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Abstract

The study is focused on the comparison of mineral composition of different soil types formed on loess. The soil types were classified according to the World reference base for soil resources. Samples were collected from individual soil horizons. Basic soil properties such as the particle-size distribution, pH values, $CaCO_3$ contents, base saturation, cation exchange capacity, soil organic carbon and nitrogen were analysed using routine pedological methods. Mineral composition was evaluated on the basis of XRD analyses of the fraction < 0.001 mm. Semiquantitative mineral composition was calculated from the areas of basal peaks. The studied soils were found to be dominated by quartz, kaolinite and illite. Semiquantitative analyses of mineral composition of the Greyic Phaeozem, Haplic Chernozem and Haplic Luvisol revealed differences in the association and proportion of individual minerals

Keywords: loess, mineralogy, Haplic Chernozem, Haplic Luvisol, Greyic Phaeozem

Introduction

Knowledge about mineral composition of soils uses to be the key to solving specific environmental problems. Completeness of environmental record in soils is related to the type of parent material. Recent soils and paleosols formed on loess are commonly found in different territories. The most characteristic soil types for this parent material in the Czech Republic are Greyic Phaeozem, Haplic Chernozem and Haplic Luvisol. Mineral composition of loess-paleosol sequence were characterized for example by Bronger (2003), Dodonov et al. (2006), Kalm et al. (1996), Perederij (2001) and Žigová and Šťastný (2006). To the soil profile distribution of minerals in the individual soil types in the Czech territories has been paid only limited attention. Sirový (1966) described some aspects of mineral composition of the clay fractions in soils. Žigová et al. (2007) reported about mineralogy of Prague soils cover in conditions of anthropogenic influence. The purpose of this study is to compare mineral composition of different soil types developed on loess.

Material and methods

The study was conducted on different soil types formed on loess. A five year rotation system with conventional tillage was used at all locations. Winter barley was planted in all areas. Basic information about soil profiles are presented in Table 1. Morphological description and horizon designation of soil profiles were documented by Jahn et al. (2006). All samples were collected from soil horizons in soil pits. Soil types were classified according to the World reference base for soil resources (IUSS Working Group WRB, 2007). The leading soil forming process of Greyic Phaezems is clay illuviation and humification. The genesis of Haplic Luvisol is connected with clay illuviation process. Humification is characteristic for Haplic Chernozem.

The pH of soil was potentiometrically measured an electrode SenTix 21 in the supernatant suspension of a 1:2.5 soil liquid mixture. The liquid was distilled water (pH_{H2O}) with 1 M KCl (pH_{KCl}). $CaCO_3$ content (volumetric method), organic carbon, nitrogen content (Kjeldhal method), base saturation, cation exchange capacity (Mehlich method) as well as particle-size distribution were determined by the Research Institute for Soil and Water Conservation in Prague.

Samples of fractions <0.001 mm for XRD analyses were separated by sedimentation from a dense suspension in distilled water and mounted oriented slides (Jackson, 1979). The samples were studied in natural state and then saturated in ethylene glycol at 80°C for four hours and finally heated in a muffle furnance at 550°C for four hours. X-ray diffraction spectra were obtained on a diffractometer Philips X'Pert PW 3020 under the following working condition: CoKα radiation, 40 kV, goniometric shift 1°. min^{-1} . Semiquantitative values were calculated from individual basal peaks.

Tab. 1 Basic information about studied localities

Locality	Altitude m	N	E	Soil type	Horizon	Depth cm
Čáslav	276	$49^0$53,544´	$15^0$23,547´	gzPH	Ap	0-23
					Bth	23-37
					BthCk	37-44
					Ck	44-125
Hněvčeves	272	$50^0$18,772´	$15^0$43,011´	haLV	Ap_1	0-29
					Ap_2	29-40
					Bt_1	40-75
					Bt_2	75-102
					Bt_2C	102-120
					Ck	120-145
Ivanovice na Hané	233	$49^0$18,644´	$17^0$05,821´	haCH	Ap	0-20
					Ah	20-51
					Ahk	51-74
					Ck	74-88

gzPH - Greyic Phaeozem, haLV - Haplic Luvisol, haCH - Haplic Cherrnozem

Results and discussions

Soil chemical properties and soil organic matter

These data are summarized in Table 2. The pH values were assessed by scale of Baize (1993). Greyic Phaeozem has a neutral reaction in horizons Ap and Bth and a basic one in horizons Bth and Ck. The same pH values are characteristic for Haplic Chernozem which means Ap and Ah horizons show a neutral reaction and a basic one in horizons Ahk and Ck. By contrast, the values pH of Haplic Luvisol are weakly acid in horizons Ap_1 and Ap_2 and basic in Bt_1, Bt_2, Bt_2C and Ck horizons. The content of $CaCO_3$ corresponds to the parent material character and type of pedogenesis. The lowest content of $CaCO_3$ has Ck horizon of Haplic Luvisol. Cation exchange capacity is relatively higher in the upper parts of soil profiles and decreases with depth. Haplic Chernozem has the highest value of cation exchange capacity. On the other hand, lower values of cation exchange capacity were obtained by the Haplic Luvisol and Greyic Phaeozem.

The values of base saturation are similar in the Ap and Ck horizons of all soil types. Lower values of base saturation are related to occurence of Ap_2, Bt and Bth horizons. This can be primaly explained by clay illuviation process. This process is usually related to present horizons E, Bt and Bth. The character of pedogenic processes has been most probably

affected by anthropogenic factor, thus E horizon in consequence of tillage turned up to the horizon Ap in Greyic Phaeozems and Ap_2 in Haplic Luvisol.
C_{ox} and N_t contents are highest in Ap horizon in all soil types but the values and distribution in soil profiles differ. Haplic Chernozem has the highest content of soil organic matter which decreases gradually according to soil profile. A relatively high content of soil organic matter is typical for Ap and Bth horizons of Greyic Phaezozem. The lowest content of soil organic matter has been found in Haplic Luvisol. Ouantitative parametr of soil organic matter as a C/N ratio indicated differences among Greyic Phaezozem, Haplic Luvisol and Haplic Chernozem. Greyic Phaezozem and Haplic Luvisol have practically the same C/N ratio in Ap horizon.

Tab. 2 Soil chemical properties and soil organic matter

Locality	Depth cm	pH_{H2O}	pH_{KCl}	$CaCO_3$ %	BS %	CEC mmol/100g	C_{ox} %	N_t %	C/N
Čáslav	0-23	7.34	6.85	0.3	86	21.13	1.19	0.14	8.50
	23-37	7.44	6.72	0.1	92	23.92	0.57	0.05	11.40
	37-44	7.55	6.97	1.2	100	21.35	0.50	0.08	6.25
	44-125	7.95	7.37	12.5	100	14.55	0.26	0.05	5.20
Hněvčeves	0-29	6.31	5.57		83	17.27	1.01	0.14	7.21
	29-40	6.44	5.74		46	18.42	0.86	0.10	8.60
	40-75	6.61	5.73		87	23.69	0.51	0.06	8.50
	75-102	6.87	6.04		91	21.39	0.35	0.05	7.00
	102-120	7.12	6.26		86	22.04	0.28	0.05	5.60
	120-145	7.44	7.11	7.2	100	18.28	0.20	0.05	4.00
Ivanovice na Hané	0-20	7.16	7.04	0.2	93	28.30	1.64	0.22	7.39
	20-51	7.35	7.02	0.2	92	26.05	1.71	0.18	9.50
	51-74	7.76	7.18	1.0	100	21.19	0.44	0.07	6.28
	74-88	7.89	7.47	13.0	100	15.96	0.40	0.05	8.00

BS - base saturation, CEC - cation exchange capacity

Particle-size distribution

The results of of particle-size distribution are shown in Table 3. The particle-size distribution is a function of parent material and pedogenic process. 0.01-0.05 mm fraction dominate in all localities which is characteristic for soils developed on loess. Content of fraction 0.05-0.25 mm and 0.25-2.00 mm is small. The results particle-size analysis showed some different distribution of clay particles. Elevated portion of particles <0.001 mm in the Bt and Bth horizons indicates clay illuviation process in soils as Haplic Luvisols and Greyic Phaezems. Haplic Luvisol has a higher ratio of texture differntiation by particles <0.001 mm than Greyic Phaeozems. This method allowed to qualitatively confirm the clay illuviation process which was documented by macromorphological description of soil profiles during field work.

Tab. 3 Particle-size distribution

Locality	Depth cm	<0.001 mm %	<0.01 mm %	0.01-0.05 mm %	0.05-0.25 mm %	0.25-2.00 mm %
Čáslav	0-23	25.9	41.1	48.8	8.7	1.5
	23-37	31.6	46.1	46.2	7.5	0.2
	37-44	27.7	41.2	48.2	10.5	0.2
	44-125	20.4	35.4	52.6	11.9	0.1
Hněvčeves	0-29	17.3	31.0	54.8	12.9	1.2
	29-40	19.5	33.2	50.0	15.5	1.3
	40-75	29.3	41.3	48.1	9.9	0.7
	75-102	27.1	40.7	46.7	12.3	0.3
	102-120	25.3	37.8	49.2	12.4	0.6
	120-145	21.1	33.6	51.4	14.5	0.5
Ivanovice na Hané	0-20	21.4	39.3	40.2	19.4	1.0
	20-51	23.8	40.9	47.6	10.7	0.8
	51-74	25.5	41.6	47.7	10.1	0.6
	74-88	20.9	37.6	48.8	12.8	0.8

Mineralogical composition

Results of mineralogical composition of fractions <0.001 mm are presented in Table 4.

Tab. 4 Mineralogical composition of the fraction <0.001 mm

Locality	Depth cm	A %	Ch %	F %	Gy %	I %	K %	Q %	Plg %	Sm %
Čáslav	0-23	0	2	6	0	15	10	60	5	1
	23-37	0	3	7	0	10	11	58	5	6
	37-44	0	5	5	0	12	15	49	6	7
	44-125	0	4	4	0	11	14	54	6	7
Hněvčeves	0-29	1	1	5	0	11	7	68	6	1
	29-40	0	3	5	0	12	6	67	6	0
	40-75	0	2	5	0	6	10	70	4	2
	75-102	0	1	7	0	6	7	69	11	1
	102-120	0	1	4	0	6	5	77	5	1
	120-145	1	2	3	0	7	10	67	4	6
Ivanovice na Hané	0-20	0	3	5	1	19	7	61	5	0
	20-51	0	4	5	0	12	6	69	5	0
	51-74	1	3	5	0	8	5	66	8	5
	74-88	0	7	5	0	10	8	61	5	5

A - amphibole, Ch - chlorite, Gy - gypsum, I - illite, K - kaolinite, F - feldspar, Plg - plagioclase, Q - quartz, Sm - smectite

Mineralogical composition of Greyic Phaeozem is relatively stable in soil profile. The content of quartz varies from 49 to 60%. Illite and kaolinite are the most represented among clay minerals. Increased content of smectite probably relates to precipitation quantity which

accelerates its formation. Quartz, illite and kaolinte are the dominant components of Haplic Luvisol. Distribution of illite and kaolnite changes in lower parts of soil profile. A higher content of smectite was indicated only in Ck horizon. Haplic Chernozem contains from 61 to 69% quartz. This soil has a higher content of illite than kaolinite. Smectite is present only in AhCk and Ck horizons.
All studied profiles are developed on loess. These soils show some similarity in mineralogical composition such as dominant occurence of quartz, illite and kaolinite. Other minerals including feldspare, plagioclase and chlorite are represented in minor amounts. Amphibol was detected only in some horizons in Haplic Luvisol and Haplic Chernozem. Gypsum was identified only in Ap horizon of Haplic Chernozems.

Conclusions
The different processes of soil development on loess are connected with climatic conditions. The process of clay illuviation can be documented only in localities with higher precipitation. The mineralogical composition of <0.001 mm fractions soils developed on loess has a polymineral character. Semiquantitative analyses of mineral composition of the Greyic Phaeozem, Haplic Chernozem and Haplic Luvisol revealed differences in association and proportion of respective minerals. These differences are due to the type of pedogenesis. The Greyic Phaeozem has practically the same amount of illitte and kaolinite and a relatively high content of smectite. Haplic Luvisol show as good as the same occurence of illitte and kaolinite with a small portion of smectite. Haplic Chermozem contain more illite than kaolinite. Smectite was identified only in the lowest parts of those soils.

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Section II

Evaluation of biodiversity in the Czech Republic

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Abstract
The paper presents the importance and principles of sustainability assessment methods and provides an overview of the basic indicators used for assessing the biodiversity (diversity of grown field crops, diversity of field size, the length of land borders, the proportion of area without the chemical crop protection, intensity of fertilization, frequency of mowing and tillage, the number of crossing the land). Knowledge and practical experience in using indicators to assess biodiversity at farm level in the country are presented.
Keywords: biodiversity, sustainability, indicator

Introduction

Biodiversity is known as a measure of the variation of living organisms in the ecosystem. The level of biodiversity shows the health of ecosystems. Relationship between the farmed landscape and biodiversity is very complex (Assmann, 2010). Agriculture is largely dependent on a functioning ecosystem with fertile soil, clean water and clean air. The diversity of animals and grown crops is entirely in the hands of farmers and their work has great potential to affect the biological diversity of the environment, as well as wild animals and plants. Assessment of performed arrangements (agricultural activities) effect on biodiversity is very difficult. Not all the links and connections between substance and energy flows in nature are known and therefore it is difficult to set limits, in which our influence on different components of biodiversity begins to negatively affect the functioning of the system.
Payraudeau and van der Werf (2005) stated that from an environmental viewpoint, agricultural activity is sustainable, if the produced polluting emissions and range and way of exploitation of natural resources may be in the long term ensured by the natural environment.
Professional agricultural public is aware of the importance and significance of biodiversity in relation to sustainable development and the need of development of appropriate methods of assessment (Büchs, 2003).
The evaluation of agricultural biodiversity is usually seen as part of an overall evaluation in terms of sustainability. Despite all the imperfections, there are several ways to evaluate biodiversity. There are many evaluation models in the world.
The most attention is focused on several areas, which include diversity of crops species and varieties, size and shape variability of fields, diversity of working methods and dates of operations, land use of agricultural land (conventional farming, organic farming, as well as arable land, grassland etc.), proportion of land not used directly for agricultural activities (hedgerows, hedges) and the intensity of external inputs (pesticides, fertilizers).
The aim of this paper is an overview of characteristics and indicators used for assessing biodiversity at farm level.

Overview of methods for agricultural diversity assessment

Methods for assessing sustainability are being developed since the 1990s (Rosnoblet et al., 2006). The assessment is mostly done using indicators that provide clear description of the complex phenomena. Bockstaller and Girardin (2003) define providing information (often simplified) about the complete system (e.g. agroecosystem), or about measurable criteria (e.g.

biodiversity, sustainability, etc.) as the main indicator function. The indicator also serves as a decision support, helping to achieve the desired objectives, such as the sustainability of the farming system. For the evaluation of biodiversity indicators of pressure and state according to OECD classification (1999) are practically used.

Number of authors highlights a determination of end-users and their practical aims according to their requirements (Girardin et al. 1999; Bockstaller, Girardin, 2003; Bockstaller et al., 2008). Users can be divided into two main groups. Administration and policy requires documentation of indicators for their political and administrative decision making. Farmers and agricultural advisors can use information provided by indicators for decision-making in their everyday practice, where indicators can provide information to identify weaknesses in management, but also the potential for improvement. These results can be used also for farms eco-auditing (Meyer-Aurich, 2003).

The value of the indicator is given in the main unit or the result can be translates into a relative number, a sort of mark or score points. It can be a value that reflects:

1) risk or impact in the range from 0 to 1 (Hülsbergen, 2003), 1 to 10 (Eckert et al., 2000) etc.,
2) effect on the environment in the range 0–10 (Bockstaller et al., 1997),
3) range between negative and positive values, such as –3 to +3 (Rigby et al., 2001), expressing the negative and positive effects.

Selection of scale, evaluating the transfer function and the range of values is subjective, depends on practical considerations and can be discussed. It is important for communication. Anyway, this choice should be clear and transparent (Bockstaller et al., 2008).

Evaluation of biodiversity is related to a specific spatial unit for a set period of time. The most common measure of time is one year. The spatial aspect is evaluated as a whole farm unit or region. Land holding of companies is often fragmented in the Czech Republic, which distorts the evaluation.

The diversity of the agricultural system is regarded from several perspectives. It may be a variety of groups or types of crops grown in a given year, the diversity of field size (Eckert et al., 2000), or the proportion of ecologically valuable areas in the farm area (Eckert et al. 2000; Häni et al., 2003). The concept may be understood more broadly as variability of economic systems in terms of frequency and timing of working operations, the diversity of ways of tillage, harvesting methods etc. (Zapf et al., 2009). Thenail et al. (2009) and Leteinturier et al. (2006) evaluated the crop rotation or crop sequence, which affects both the stability of agrosystem, enabling the reduction of inputs for plant protection products and the diversity of the landscape.

Frequently this area is seen from the perspective of non-productive diversity of wildlife. It's actually the original viewpoint. For example Manhoudt et al. (2005) distinguishes biodiversity directly in the stand of crops, in the lateral strips around fields and in forests in linear landscape elements.

Experience in the Czech Republic

An evaluation model designed for an overall assessment of sustainability of agricultural enterprises called SAGROS is in the implementation phase in the Czech Republic. It works on farm level. Results of individual indicators (in appropriate units) are transferred for the dimensionless value from 0 to 1, where 0 means the undesirable (unsustainable) state and a state of optimal value of 1 to the boundary value are considered as sustainable. This threshold is set as 0.75. Calculation is performed for the time period of one year, but for the evaluation results for at least the last 3 years are needed. There are following indicators included in the area of biodiversity:

Diversity of land use and cultivation
To analyze the diversity of agro-systems the fair value of individual indicators (the diversity of agricultural land use, diversity of crop groups, diversity of plant species and varieties) are used. After the calculation of partial diversity indexes follows the determination of the total value (diversity of land use and diversity of cultivation), individual values of diversity are summarized and averaged.

Fields structure
Indicators of the spatial structure diversity evaluate the field's size, the length of their land borders and coefficient of variation of field acreage. Partial indicators are calculated as the arithmetic average of single field values.

Share of agricultural land without application of crop protection products
Area of agricultural land without use of pesticides is counted and its share in the UAA is calculated.

The overall index of treatment
It evaluates consumption of pesticides on the farm according to the amount of active substances in comparison with the average consumption in the Czech Republic. It takes into account the maximum doses and use of unregistered or expired preparations.

Intensity of fertilization
Changes in nutrient management and efficiency of their use can be estimated based on the amount of applied mineral and organic fertilizers. For the analysis of partial indicator of fertilization intensity the total N fertilizer supply on individual fields is determined. Total supply of nitrogen in mineral fertilizers is included. The final value is determined as a weighted average of the individual plots values.

Diversity of agro-technical treatments on arable land (tillage, harvest and mowing frequency)
The evaluation function is based on the fact that the increasing share of cultivated area in a short period of time is shrinking supply of niches and habitats. From this point of view the worst valuation gets the farm, which manages all field areas at one time and thereby reduces the range of planted soil niches (habitats). Mowing frequency indicator is related to the grassland and includes succession of grassland and providing habitat for organisms.

The frequency of crossing the land
Course of evaluation function monitors the increasing risk of soil compaction with increasing frequency of crossing of the land.

Conclusions
The need for biodiversity assessment and subsequently the assessment of sustainability management is now required not only by society but also by experts. In western countries, the evaluation models are established and are used mostly on a voluntary basis. The benefit for farmers is the possibility to present the sustainability of their performance to the public, which can be a competitive advantage. On the other hand this type of evaluation can help farmers to find weaknesses in their management.
The initial experience with the introduction of the presented indicators into practice shows that the greatest weakness of the evaluation system is inadequate quantity and quality of input data. The reason is the lack of records on the farms. Farms have a sufficient level of those records, which are required by law (fertilizers and pesticides). Greater range of input data

from agronomic records and especially accurate records of activities undertaken on agricultural land are needed for assessment.

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CONTENT

WEED SPECTRUM CHANGES UNDER DIFFERENT CROPPING SYSTEMS

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Abstract

The effects of soil tillage and crop rotation on weed infestation were studied in long-term trials. Both factors are influencing quality and quantity of weed seed bank and actual weed infestation. The interaction between soil tillage and crop rotation (or with other agronomic factors) can be important as well. The recognition of the rhythm of a soil seed bank and actual weed infestation increasing and decreasing in a given time period, all of which happens without the direct influence of the farmer, is the contribution to understanding the specific characteristics and agro-phytocoenosis changes.

Keywords: weed seed bank, actual weed infestation, crop rotation, soil tillage

Introduction

There are many agronomic factors, which influence weed occurrence in arable fields. Tillage systems affect weed emergence, management and seed production. Changes in tillage practices consequently change the composition, vertical distribution and density of weed seed banks in agricultural soils (Buhler, 1995). Many authors (Triplett and Lytle, 1972; Froud-Williams *et al*., 1981; Knab and Hurle, 1986; Moyer *et al.*, 1994) have reported changes in weed communities connected with less intensive tillage. Most research has indicated that less intensive tillage favours perennial species, species disseminated by wind, annual grasses and volunteer crops. However, in some cases, tillage has no selective effect on weed flora (Swanton *et al.*, 1993).

Crop rotations have many benefits that can influence the success of crop production enterprises. Crop rotation is an essential practice in sustainable agriculture, because of its many positive effects like increasing soil fertility and reducing crop competitiveness. A well-planned crop rotation system can help producers avoid many of the problems associated with weeds, particularly perennial weeds (Daspehov, 1967, Liebman and Elizabeth, 1993, Tabachnik and Fidell, 1996). In fact crop rotation is an effective practice for controlling serious weeds because it affects weed growth and reproduction negatively and as a result reduces weed density (Derksen *et al.*, 1993; Blackshaw *et al.*, 1994).

Results of a literature survey (234 references) indicate that weed population density and biomass production may be markedly reduced using crop rotation (temporal diversification) and intercropping (spatial diversification) strategies. Crop rotation resulted in emerged weed densities in test crops that was lower in 21 cases, higher in 1 case, and equivalent in 5 cases in comparison to continuous crop systems. Growers experience has shown that changing tillage practices without increasing crop diversity within rotations has generally led to increased weed problems, especially in sole cropping systems (Liebman and Robichaux, 1990).

Material and methods

The effects of soil tillage and crop rotation on weed infestation were studied in long-term trials. The long-term field trial with a monoculture of spring barley was established in 1970 in Žabčice. There are two variants of primary soil tillage, first one with ploughing to depth of 0.22 m and second one with shallow loosening to depth of 0.12 m. Numeric method was used for evaluation of weed infestation (actual weed infestation).

Between the years 1967 and 1985, weed seed bank in the soil of arable land was examined in a small-plot stationary long-term field experiment at Basic Agrotechnical Research Institute, Hrušovany u Brna. Two types of seeds were defined: “entire seeds” that, during visual observation, seemed unharmed, and “healthy seeds,” which had undisturbed seed content (most likely viable seeds). The effect of crop sequence in three separate five-year series was examined (winter wheat and spring barley represented 60–80%, 40–60%, 40%). Other variants were monocultures of grain maize and winter wheat. The presented options were not treated with herbicides. The effect of herbicides was observed in the same variants (except for the maize monoculture). Postemergent herbicides against dicotyledonous weeds and *Avena fatua* were applied to winter wheat and spring barley.

Results and discussions

The long-term use of minimum soil tillage causes both a decrease of number of species and a decrease in weed specimens. The minimum tillage showed in particular occurrence *Avena fatua, Convolvulus arvensis, Fallopia convolvulus* and *Sonchus arvensis.* In the variant with conventional tillage it was the species of *Persicaria lapathifolia* and *Veronica polita*. Weed infestation was also significantly affected by the way of straw management. Here it turned out that straw burning decreased overall weed infestation, as opposed to variants which are commonly used in practice.

The soil’s bank of weed seeds comprised of 50 species in differing numbers. The shares of important species on the soil’s total weed infestation increased during the course of the experimental period. The soil’s weed infestation was dramatically affected by observed aspects. The resulting weed infestation of entire seeds in untreated plots over a 19-year period increased by 55 to 106% in different crop rotations, in the grain maize monoculture by 325%, and in the winter wheat monoculture by 373% (Figure 1 and 2). Variants treated with herbicides in different crop rotations had lower numbers of weed seeds than in the initial year; the winter wheat monoculture weed infestation increased by 136% over the course of the entire period of observing the field’s weed infestation.

Although there were several years that passed between sample taking (during the years 1967, 1971, and 1975, there were 4-year intervals; during the years 1975, 1980, and 1985, there were 5-year intervals), there is an apparent continuity in the recorded data from the soil’s bank of weed seeds.

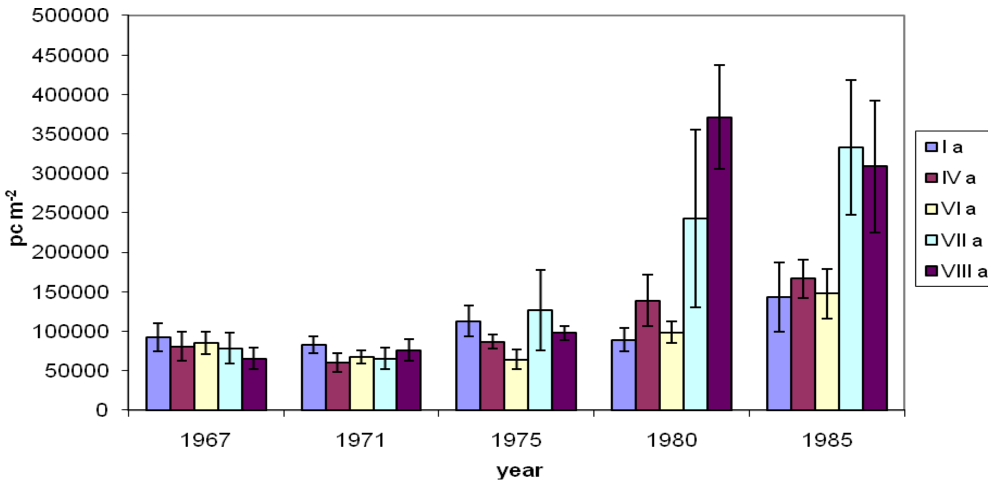

Fig. 1 Number of entire weed seeds (herbicide untreated variants

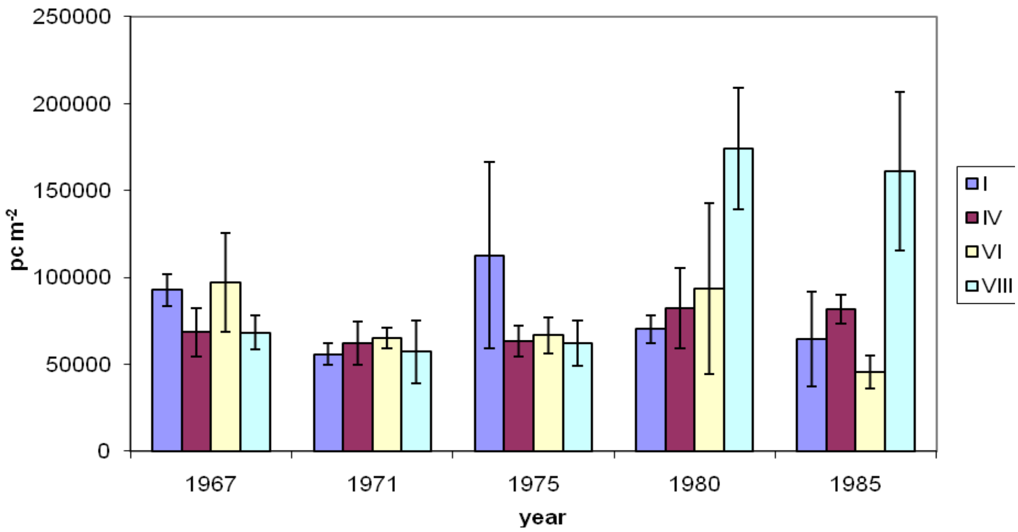

Fig. 2 Number of entire weed seeds (herbicide treated variants)

<u>Legend:</u>
I and I a = crop rotation with 60 % ratio of cereals (changed during course of trial)
IV and IV a = crop rotation with 40 % or 60 % ratio of cereals (changed during course of trial)
VI and VI a = crop rotation with 40 % ratio of cereals
VII = grain maize monoculture
VIII and VIII a = winter wheat monoculture

The changes to the soil seed bank without the effect of herbicides applied compensation of those retreating weeds that, under the given conditions, multiplied. Among these receding species belong *Sinapis arvensis, Fallopia convolvulus, Silene noctiflora,* and *Stellaria media.* Decreases that were not as significant, especially in healthy seeds, were seen in *Anagallis arvensis*. Evident, even surprising, decreases in the number of seeds of the given species in time shows that changes in crop stands, which occurred during the course of the experiment, were not favourable for these weeds. Growth was seen in *Consolida regalis, Descurainia sophia, Papaver rhoeas,* and *Amaranthus retroflexus.* Significant variability in weed infestation development, between times and options, were observed at the *Avena fatua*. The soil seed bank of *Polygonum aviculare* grew severalfold only in the winter wheat monoculture. The occurrence of *Veronica hederifolia* was low and quite balanced. Relative stability in the soil weed seed bank and an inconclusive effect of crop rotation were found in case of *Chenopodium album* and *Stachys annua.*

Weed infestation of arable land of important weed species in a large measure was affected by the application of herbicides in cereals. The following species were among the weeds that had the most sensitive reactions: *Descurainia sophia*, *Consolida regalis,* and *Papaver rhoeas.* In semi-sensitive types, i.e. *Sinapis arvensis*, *Fallopia convolvulus,* and *Silene noctiflora,* the decrease was regular, but on a lower level. Decreases in the soil's weed infestation on treated variants were directly correlated to the concentration of treated cereals in crop rotations.

In many cases, increases in the soil's weed infestation were recorded by entire and healthy seeds after the application of herbicides. In the case of *Anagallis arvensis* and *Stellaria media,* this was the most frequent occurrence. The reason can be a lower herbicide effect of the applied herbicides, but also an effect of the structural change in crop stand after chemical treatment. Both specified species are of smaller growth and are usually covered by larger weeds. A significant portion of these larger weed species is effectively killed by the used herbicides. The improved light conditions could have allowed for a higher seeding reproduction of *Anagallis arvensis* and *Stellaria media*; therefore, leading to an increase in the soil seed bank.

Herbicides were applied only in cereals (wheat and barley), where *Echinochloa crus-galli* and *Amaranthus retroflexus* are not regular components of the actual weed infestation. They were, therefore, not affected directly by the herbicide application. The seed bank of *Amaranthus retroflexus,* especially healthy seeds, was higher in treated areas. In these areas the competition of other weeds was most likely decreased, namely in plants where herbicides were not directly applied.

The effect of chemical weed control on the weed seed bank in the soil is primarily direct. Herbicides limit seed reproduction. What is important is also the indirect effect, whereby the lowering of competition in some weed species gives rise to weed infestation of the soil with the seeds of the unaffected weeds. These can be species that the given herbicide kills. According to the resulting findings, herbicides did not completely eliminate the effect of crop rotations. At a lower intensity of chemical control on the balanced seeding series, there were larger decreases in the soil's weed infestation than at a higher intensity of chemical weed control, but during an inappropriate crop rotation. The results also show that after terminating chemical weed control, weed infestation would return within a short period of time to a level of untreated variants.

It is evident from the comparison of the actual weed infestation of winter wheat and spring barley that spring barley offered better conditions for the activation of potential weed infestation.

The data collected during the period of the experiment allowed for the evaluation of mutual relationships between potential and actual weed infestation in cereals in areas untreated by herbicides. What follows from the average values of weed infestation in winter wheat and spring barley is that spring barley offered more suitable conditions for weed seed growth. The numbers of healthy seeds in the soil were much higher than numbers of weed plants in crop stands. Although these differences exist, they were usually congruent in the trends of change. In regularly- and abundantly-occurring species, the changes of their occurrence were evaluated (Figure 3 – 5). These changes, in most cases, had an identical course in individual options. In the case of *Sinapis arvensis* and *Stellaria media,* there was a systematic decrease in potential and actual weed infestation during the experimental period. On the other hand, an increase was recorded with *Papaver rhoeas*. Special attention should be paid to weed species that had alternating decreases and increases within relatively short time periods. This kind of periodicity was evident in *Consolida regalis, Descurainia sophia* and *Avena fatua*. For the changes of these trends the deciding factors was most likely the concentration of plants of the given weeds on the surface. In the case of *Chenopodium album*, the changes of potential and actual weed infestation were not concurrent and were usually not statistically significant.

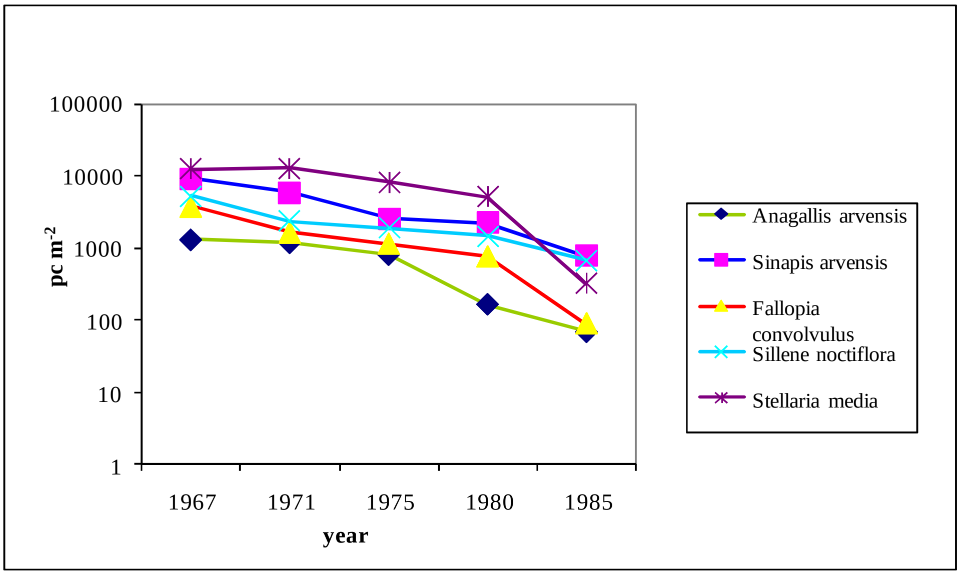

Fig. 3 Occurrence of weeds - decreasing trend

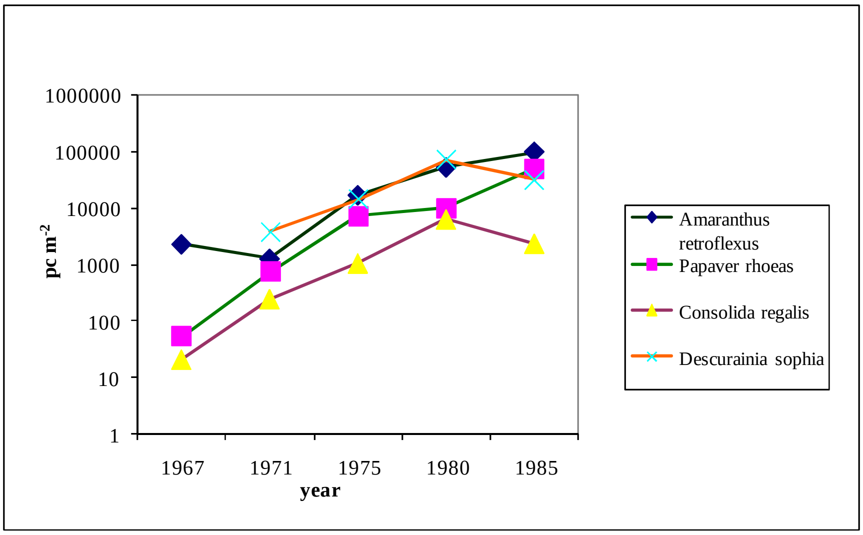

Fig. 4 Occurrence of weeds – increasing trend

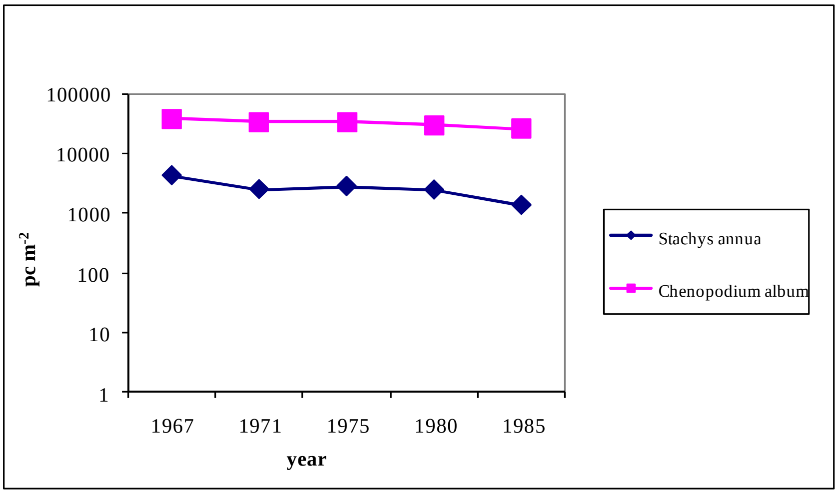

Fig. 5 Occurrence of weeds – stagnation trend

Conclusions

The results from long-term trials showed how soil tillage and crop rotation influence the weed seed bank and weed infestation of crop stands. Often, these factors are acting together or with other agronomic factors. The recognition of the rhythm of a soil seed bank and actual weed infestation increasing and decreasing in a given time period, all of which happens without the direct influence of the farmer, is the contribution to understanding the specific characteristics and agro-phytocoenosis changes.

Acknowledgements

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The long-term effect of different tillage methods on weeds in the monoculture of spring barley

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Abstract
Weed growth in the long-term monoculture of spring barley was observed at the field experiment station in Žabčice (South Moravia Region, Czech Republic). Weed growth among spring barley was evaluated over a course of six years, from 2005 to 2010. Two methods of tillage were used during the experiment: *conventional tillage* and *minimum tillage*. The average number of weeds observed during this period under the conventional tillage method was 4.44 types.m^{-2} and 14.78 individuals.m^{-2}. For minimum tillage, it was 3.54 types.m^{-2} and 17.36 individuals.m^{-2}. The minimum tillage option predominantly gave way to the following types: *Avena fatua*, *Convolvulus arvensis*, *Galium aparine* and *Sonchus arvensis*. Under the *conventional tillage* method, the major types were *Silene noctiflora* and *Veronica polita*. Long-term use of the minimum tillage option causes a decrease in weed type diversity, but there is an increase in the number of types that are difficult to eliminate.
Keywords: weeds, monoculture, spring barley, tillage

Introduction
The long-term influence of a given factor can change the conditions for weed lifecycles; therefore, influencing weed growth intensity and the spectrum of weed types. Different depths of tillage, in the conditions of the monoculture of spring barley, significantly affect weed growth.

Material and methods
Observing weed growth in spring barley was carried out at the experimental station in Žabčice (South Moravia Region, Czech Republic), which is located in the corn-producing area and belongs to a very warm and dry climatic region. The long-term average of total precipitation is 481 mm and the long-term temperature average is 9.2 °C. Data about precipitation and temperature were taken from the meteorological station at the experimental station in Žabčice (MENDELU).

Weed growth was observed in spring barley, which is grown in a long-term monoculture (founded in 1971). There are two types of tilling used. The fist is a traditional type of tillage (*conventional tillage* CT), with ploughing 0.22 m deep (where soil layer is inverted). The second option is *minimum tillage* (MT) with disc equipment penetrating into a depth of approximately 0.12m (Krejčíř, 1996).

Weed growth among spring barley was evaluated over a period of six years – always in the spring, before herbicides were applied. The amount of weeds was investigated on a $1m^2$ plot, every year, with 75 repetitions. The dates of evaluation were 13 May, 2005; 22 May, 2006; 28 April, 2007; 24 April, 2008; 4 May, 2009; and 2 May, 2010. Weeds were named in Latin as per Kubát (2002).

To investigate the influence of tillage on individual weed types that grew in the spring, a multidimensional ecological data analysis was used. The choice of an optimal analysis was directed by the length of the gradient, ascertained by the Detrended Correspondence Analysis (DCA). The Canonical Correspondence Analysis (CCA) was also used. While testing the evidence using the Monte-Carlo test, 499 permutations were counted. Data was processed using Canoco 4.0. computer software (Ter Braak, 1998).

Results and discussions

Over the course of the six-year observation period, 34 types of weeds were found. The most common types were: *Galium aparine, Stellaria media, Silene noctiflora* and *Cirsium arvense*.

Table 1 has data showing the average number of individual weed types under the conventional tillage option, all observed from 2005 to 2010. The average number of individual weeds and the average number of weed types in each year are also stated in this table.

Table 2 has data showing the average number of individual weed types under the minimum tillage option, all observed from 2005 to 2010. The average number of individual weeds and the average number of weed types are also stated.

The results of weed growth from the six-year observation period were processed by the DCA, which determined the length of the gradient to be 3.883. The length of the gradient was below 3.5 – the CCA was used for further evaluation. The CCA results are noteworthy – a significance level of α = 0,002 for all canonical axes.

Based on the data regarding the frequency of occurrence of individual weed types and options of tillage, the CCA establishes the spatial organization of individual weed types. This concept is graphically presented with the help of an ordination diagram (Fig. 1).

Table 1 Average number of weeds under conventional tillage in the long-term monoculture of spring barley

Weed types	Individual observed years under the conventional tillage option (pcs.m^{-2})					
	2005	2006	2007	2008	2009	2010
Amaranthus sp.	0.01	1.31	0.24		0.23	
Anagallis arvensis	0.05			0.09		
Avena fatua					0.03	0.04
Cirsium arvense	0.43	5.23	2.27	0.01	0.03	
Convolvulus arvensis			0.03			0.01
Echinochloa crus-galli		1.44	0.01			0.01
Euphorbia helioscopia			0.01		0.01	
Fallopia convolvulus	0.97	0.16	0.39	2.36	0.83	0.51
Fumaria officinalis						0.01
Galium aparine	4.07	1.81	3.08	4.28	1.27	3.01
Hyoscyomus niger		0.03				
Chenopodium album	0.01	0,07	0.03	0.01		0.01
Lactuca serriola	0.01					
Lamium amplexicaule	0.68	0.61	1.65	1.69	0.11	1.19
Lamium purpureum		1.40		0.08	0.11	
Malva neglecta						
Microrrhinum minus	0.56	0.49	0.20	0.63	0.99	0.41
Papaver rhoeas			0.01			
Persicaria lapathifolia	0.63	0.84	0.28	0.56	0.43	0.81
Polygonum aviculare	0.01			0.09		0.01

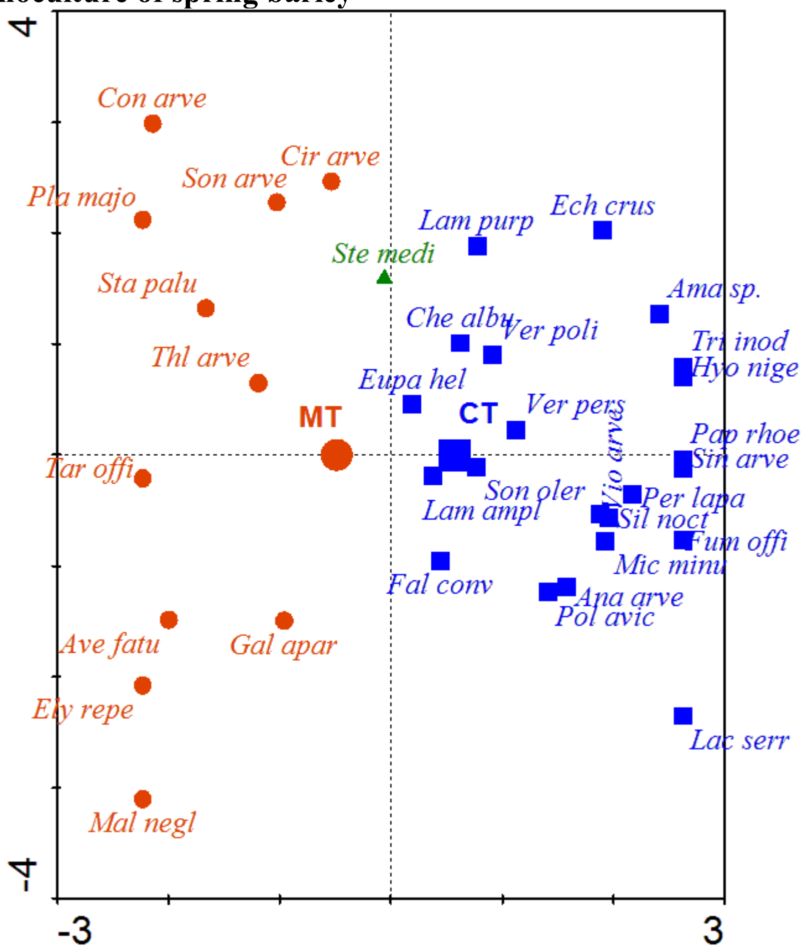
Silene noctiflora	3.36	2.04	2.05	5.05	2.57	5.11
Sinapis arvensis	0.01	0.01				
Sonchus arvensis		0.32	0.17			
Sonchus oleraceus	0.05	0.05	0.08			0.09
Stachys palustris	0,03	0.03	0.05	0.07		
Stellaria media	2.67	4.35	2.11	1.27	0.07	1.88
Thlaspi arvense	0.01		0.01	0.01		
Tripleurospermum inodorum	0.01	0.01				
Veronica persica			0.25	0.11		
Veronica polita	1.47	2.60	0.21	0.49	0.07	0.51
Viola arvensis	0.07	0.04	0.08	0.28	0.03	0.03
Number of types	4.63	5.36	4.68	4.99	2.87	4.11
Number of individuals	15.12	22.84	13.23	17.09	6.75	13.65

Table 2 Average number of weeds under minimum tillage in the long-term monoculture of spring barley

Weed types	Individual observed years under the minimum tillage option ($pcs.m^{-2}$)					
	2005	2006	2007	2008	2009	2010
Amaranthus sp.	0.03	0.05				
Anagallis arvensis	0.01			0.01		0.01
Avena fatua	0.35			0.88	0.09	
Cirsium arvense	0.77	7.45	6.25	0.33		0.01
Convolvulus arvensis	0.07	0.57	0.45		0.91	0.09
Echinochloa crus-galli		0.19	0.07			
Elytrigia repens	0.01					
Euphorbia helioscopia	0.01					0.01
Fallopia convolvulus	1.00	0.17	0.21	2.03	0.35	0.49
Fumaria officinalis						
Galium aparine	2.48	2.52	1.69	11.35	4.57	26.73
Hyoscyomus niger						
Chenopodium album	0.03	0.03	0.04			
Lamium amplexicaule	1.12	0.15	1.00	1.83	0.19	0.83
Lamium purpureum		0.92			0.05	
Malva neglecta					0.01	0.01
Microrrhinum minus	0.11		0.08	0.31	0.03	0.03
Persicaria lapathifolia	0.12	0.08	0.04	0.05	0.01	0.05
Plantago major		0.03				

Polygonum aviculare	0.01			0.01		0.01
Silene noctiflora	0.84	0.41	0.29	1.13	0.25	0.27
Sinapis arvensis						
Sonchus arvensis	0.27	0.64	0.41	0.15	0.03	
Sonchus oleraceus		0.05	0.03	0.04		0.05
Stachys palustris	0.15	0.32	0.44	0.24	0.16	
Stellaria media	2.53	8.69	3.00	0.39		0.61
Taraxacum officinale		0.01		0.03		
Thlaspi arvense			0.07	0.08		
Veronica persica			0.08	0.04		0.04
Veronica polita	0.68	1.41	0.43	0.25	0.03	0.11
Viola arvensis	0.04		0.01	0.04		
Number of types	4.27	4.20	3.88	4.19	1.88	2.83
Number of individuals	10.63	23.71	14.60	19.19	6.68	29.37

Fig. 1 Ordination diagram showing the long-term effect of tillage on weeds in the monoculture of spring barley



Ordination diagram legend: ■ **CT** – conventional tillage option, ● **MT** – minimum tillage option.

Abbreviations: *Ama sp. – Amaranthus* sp., *Ana arve – Anagallis arvensis, Ave fatu – Avena fatua, Cir arve – Cirsium arvense, Con arve – Convolvulus arvensis, Ech crus – Echinochloa crus-galli, Ely repe – Elytrigia repens, Eupa heli – Euphorbia helioscopia, Fal conv – Fallopia convolvulus, Fum offi – Fumaria officinalis, Gal apar – Galium aparine, Hyo nige – Hyoscyomus niger, Che albu – Chenopodium album, Lac serr – Lactuca serriola, Lam ampl – Lamium amplexicaule, Lam purp – Lamium purpureum, Mal negl – Malva neglecta, Mic minu – Microrrhinum minus, Pap rhoe – Papaver rhoeas, Per lapa – Persicaria lapathifolia, Pla majo – Plantago major, Pol avicu – Polygonum aviculare, Sil noct – Silene noctiflora, Sin arve – Sinapis arvensis, Son arve – Sonchus arvensis, Son oler – Sonchus oleraceus, Sta palu – Stachys palustris, Ste medi – Stellaria media, Tar offi – Taraxacum officinale, Thl arve – Thlaspi arvense, Tri inod – Tripleurospermum inodorum, Ver pers – Veronica persica, Ver poli – Veronica polita, Vio arve – Viola arvensis.*

The ordination diagram (Fig. 1) clearly shows that conventional tillage commonly gave way to the following types: *Amaranthus* sp., *Anagallis arvensis, Echinochloa crus-galli, Fallopia convolvulus, Fumaria officinalis, Hyoscyomus niger, Chenopodium album, Lactuca serriola, Lamium amplexicaule, Lamium purpureum, Microrrhinum minus, Papaver rhoeas, Persicaria lapathifolia, Polygonum aviculare, Silene noctiflora, Sinapis arvensis, Sonchus oleraceus, Tripleurospermum inodorum, Veronica persica, Veronica polita* and *Viola arvensis.*

The minimum tillage option, according to the ordination diagram, commonly gave way to the following types: *Avena fatua, Cirsium arvense, Convolvulus arvensis, Elytrigia repens, Galium aparine, Malva neglecta, Plantago major, Sonchus arvensis, Stachys palustris, Taraxacum officinale, Thlaspi arvense.*

The *Stellaria media* type was probably affected by another factor that is not included in the analysis; that is why its symbol is in the middle of the ordination diagram.

The minimum tillage option predominantly gave way to types that obviously prefer the accumulation of seeds in the upper tilled layer of soil. These types are mostly annuals (*Avena fatua, Galium aparine, Thlaspi arvense*). Shallow tillage slightly damages the root system of perennial weeds; therefore, allowing greater development. Higher representations of the *Convolvulus arvensis* type with respect to minimal or no tillage options were also investigated by Bilalis, Efthimiadis and Sidirias (2001).

Conventional tillage ensured a higher occurrence of types with seeds, which probably have a longer persistence in the soil bank. This is the place where they can live until the time when, by tillage, they are brought into the layer where they germinate (*Fallopia convolvulus, Chenopodium album, Amaranthus* sp., *Persicaria lapathifolia, Silene noctiflora, Veronica polita*).

Nielsen and Pinnerup (1982) investigated a higher occurrence with reduced tillage in the *Veronica arvensis* type. Thus, we can assume the same reaction in the *V. polita* type, which is evident from the results of our observations.

In the case of minimum tillage, there is a decrease of the number of individual weeds as well as a decrease of type diversity. A similar conclusion was found by Ball and Davies (1996) in the area of the soil's seed bank. SOANE AND BALL (1998) state that weed growth among the monoculture of spring barley has greatly changed over the course of 25 years and has mostly been affected by chemical regulation.

Conclusions

Long-term use of minimum tillage causes a decrease in weed type diversity, but there is an increase in the number of types that are difficult to destroy. During the observation period, the average number of weeds under the conventional tillage option was 4.44 types.m^{-2} and 14.78 individuals.m^{-2}. The minimum tillage option gave way to 3.54 types.m^{-2} and 17.36 individuals.m^{-2}. *Avena fatua, Convolvulus arvensis, Galium aparine* and *Sonchus arvensis* occur mostly under the minimum tillage option. Under the conventional tillage, it was the *Silene noctiflora* and *Veronica polita* types.

It is necessary to note that the way soil is tilled affects the weed types as only one out of many factors, but also that it works as a polyfunctional factor, which is dependent on many other factors.

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THE IMPACT OF VARIOUS SOIL TILLAGE AND STRAW MANAGEMENT ON WEED INFESTATION IN SPRING BARLEY

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Abstract
The impacts of various soil tillage and straw management on weed infestation was assessed in spring barley cropped after maize. Chopped straw of fore-crop was treated with four liquid fertilizers (variants A-D) which increase microbial activity and improve straw decomposition. The individual variants were as follows: variant A involved the application of Beta-liq liquid fertilizer, variant B the application of DAM 390 and variant C the fertilizer Unifert. All doses of fertilizers mentioned above corresponded to 30 kg of nitrogen ha^{-1}. The last variant, D, was used as a check, without any fertilizer. Two variants of soil tillage – conventional and minimum tillage were used as well. In total, 31 weed species occurred during observation. The most frequent weed species were: *Galium aparine, Veronica polita, Fallopia convolvulus, Silene noctiflora, Chenopodium album.* Average numbers of weed specimens during three years of observation were 6.58 pc m^{-2} in variant with conventional tillage and 6.19 pc m^{-2} in variant with minimum tillage. Differences in weed infestation were found out in variants with different straw management: variant A 4.49 pc m^{-2}, variant B 5.35 pc m^{-2}, variant C 6.78 pc m^{-2} and D 6.91 pc m^{-2}.
Keywords: weeds, straw management, soil tillage, spring barley

Introduction

Transformation of the Czech agriculture was associated with a number of changes in methods of arable farming. Numbers of farm animals, above all of cattle, were reduced and at present more and more farms operate fully without animal husbandry and instead of it use straw (Procházková et al. 1999).

Usually more than a half of the required supply of organic matter into the soil originates from post-harvest crop residues. The remainder (i.e. 40-50 % of the total requirement) must be supplied in the form of organic fertilizers. At the same time, however, the percentages of cereals and other straw-producing crops have increased. To maintain and/or even to increase soil fertility, the importance of straw management and its incorporation into the soil after the harvest has markedly increased. This means that especially within the minimum tillage system, the different methods of straw management and incorporation are very important (Kubát 1998).

These changes in straw management as well as different forms of applied nitrogen can, in combination with various methods of minimum tillage, influence the weed infestation of cereals.

Material and methods

The effects of application of various fertilizers on straw and of different methods of tillage on the weed infestation in spring barley were studied in a field experiment established in the experimental station of the Mendel University in Brno (Czech Republic) situated in the altitude of 184 m above sea level. The long-term averages of annual sum of precipitation and of temperatures were 481 mm and 9.2 °C, respectively.

This field experiment was established in 2004. The size of individual plots was 410 m^2 (21.0 x 19.5 m) and each variant had four replications. The experimental crop rotation was as follows: grain maize, spring barley, safflower, winter wheat and winter wheat.

Each crop was grown using two different variants of tillage: conventional tillage (CT), when after harvest of fore-crop, stubble breaking (disking) to the depth of 0.10 m was the first operation after harvest. Thereafter the field was ploughed to the depth of 0.20 – 0.24 m. Pre-sowing tillage and sowing itself were performed together using a drilling machine. In the second variant the method of minimum tillage (MT) was used. In this case the stubble breaking to the depth of 0.10 m was performed immediately after the harvest. In this variant, ploughing was replaced by a shallow loosening of soil (disking) to the depth of 0.15 m and the pre-sowing tillage and sowing itself were performed also together using a sowing combination.

After the harvest, straw remaining on plots was chopped and treated with fertilizers. To balance the C:N ratio, three various fertilizers were applied on straw in the total dose of 30 kg N per hectare. In the first variant, the preparation Beta-liq was applied in the dose of 1 t ha^{-1} (A); a liquid molasses-based organic-mineral fertiliser containing 3% of N and 5% of K_2O. In the second variant, the liquid fertilizer DAM 390 was applied in the dose of 100 kg ha^{-1} (B); a nitrogen fertilizer solution composed of urea and ammonium nitrate, containing 30% N. In the third variant the liquid fertilizer Unifert was applied in the dose of 230 kg ha^{-1} (C); liquid organic-mineral fertilizer on the base of alimentary waste products, containing 13% of N and 3% of K_2O. The fourth variant was used as a check, i.e. without fertilizers (D).

Weed infestation was assessed in spring barley crop stand before herbicide application. Dates of evaluation were 23.4. 2008, 4.5. 2009 and 2.5. 2010. The assessed plot has 1 m^2 and 16 replications were done in each variant.

The weed infestation was evaluated using the method of multi-dimensional analysis of ecological data. The choice of the optimum analysis was performed on the base of the length of gradient, which was estimated by means of Detrended Correspondence Analysis (DCA). The obtained results were processed using the method of Canonical Correspondence Analysis (CCA). When testing the significance of results by means of the Monte-Carlo test, in total 499 permutations were calculated. These data were processed using the program Canoco 4.0 (Ter Braak 1998).

Results and discussions

During observation 31 weed species was occurred. The most frequent weed species were: *Galium aparine, Veronica polita, Fallopia convolvulus, Silene noctiflora, Chenopodium album*.

Bellow mentioned tables show average number of weed species and weed in variants of soil tillage and straw management (table 1 for year 2008, table 2 – year 2009 and table 3 – year 2010).

Tab. 1 Average number of weeds in variant soil tillage and straw management (year 2008)

	Variants of soil tillage and straw management (pc m^{-2})							
	CT				MT			
Weed species	A	B	C	D	A	B	C	D
Amaranthus sp.				0.06				
Carthamus tinctorius	0.06	0.19	0.25	0.06				
Cirsium arvense				0.06	0.06	0.25	0.13	0.38
Consolida orientalis	0.50	0.44	0.63	0.56	0.06			0.06

Euphorbia helioscopia		0.06					0.06	
Fallopia convolvulus	2.19	3.38	1.63	5.69	1.63	1.19	1.13	1.13
Fumaria officinalis	0.81	0.88	0.56	0.75	0.06	0.06	0.06	
Galium aparine	0.13	0.13	1.19	4.06	0.69	0.69	2.69	7.75
Chenopodium album	1.38	2.50	2.25	0.69	0.88	1.13	1.88	0.25
Lactuca serriola								0.06
Lamium amplexicaule	0.13	0.06	0.38	0.06	0.06	0.25	0.19	0.44
Microrrhinum minus		0.06	0.19					
Persicaria lapathifolia		0.06						
Polygonum aviculare			0.06		0.06			
Silene noctiflora	3.25	1.69	2.13	1.31	0.44	0.81		
Sinapis arvensis			0.06					
Sonchus oleraceus				0.06		0.13		
Stellaria media							0.25	
Taraxacum officinale		0.06						
Thlaspi arvense	0.06	0.25	0.25			0.06		0.06
Tripleurospermum					0.06			
Veronica persica					0.13		0.19	
Veronica polita	0.75	1.63	0.94	0.69	1.00	2.19	2.44	2.63
Viola arvensis		0.06	0.06	0.06		0.19	0.19	0.06
Number of species	4.13	4.25	4.25	3.63	3.06	3.44	3.25	3.19
Number of specimens	9.25	11.44	10.56	14.13	5.13	6.94	9.19	12.81

Tab. 2 Average number of weeds in variant soil tillage and straw management (year 2009)

Weed species	***Variants of soil tillage and straw management (pc m^{-2})***							
	CT				MT			
	A	B	C	D	A	B	C	D
Amaranthus sp.		0.31	0.38	0.19			0.19	0.31
Cirsium arvense	0.25							
Consolida orientalis				0.06				0.44
Convolvulus arvensis					0.31		1.31	0.19
Fallopia convolvulus	1.38	0.50	0.56	0.38	0.25		0.19	0.13
Fumaria officinalis			0,06					
Galium aparine	0.06	0.06	0.31	0.56	1.25	1.19	1.00	2.56
Chenopodium album	0.06	0.81	0.44	0.44	0.25	0.19		0.06
Lamium purpureum							0.19	
Silene noctiflora	1.31	0.88	0.94	0.19				

Sinapis arvensis				0.13				
Sonchus oleraceus		0.06						
Thlaspi arvense			0.13					
Tripleurospermum inodorum							0.06	
Veronica polita			0.13	0.44			0.13	0.44
Number of species	1.81	2.00	1.81	1.75	1.13	1.13	1.50	2.06
Number of specimens	3.06	2.63	2.94	2.38	2.06	1.38	3.06	4.13

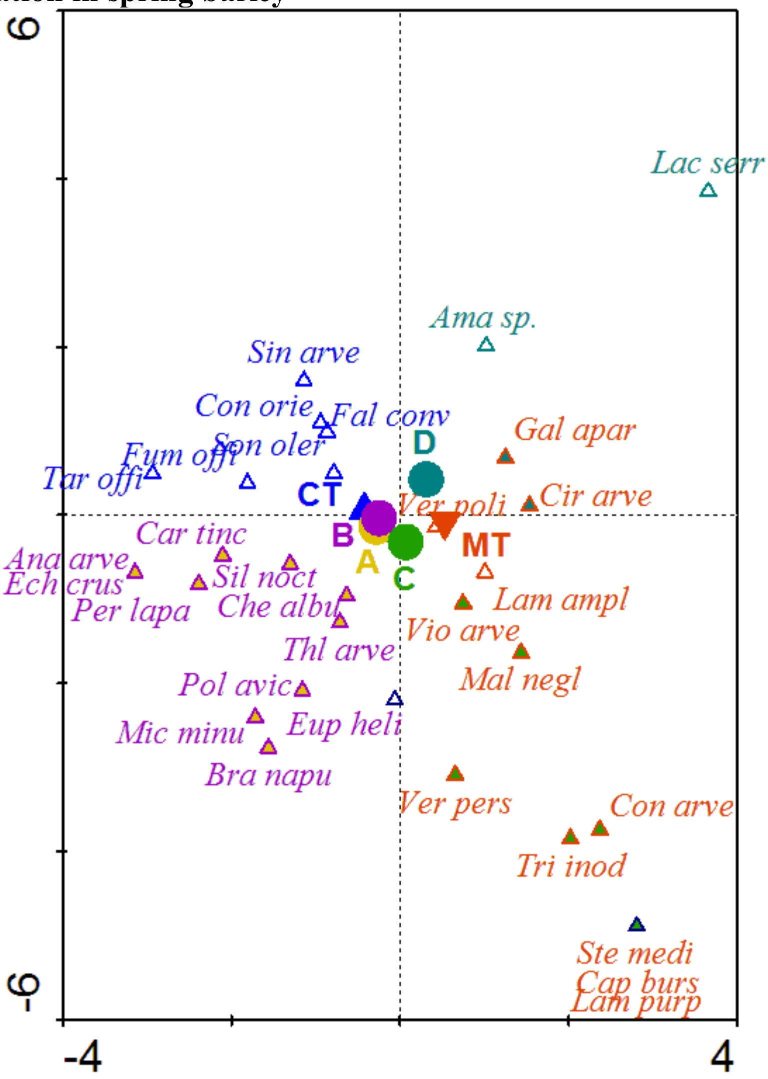
Three-year average number of weed specimens was 6.58 pc m^{-2} in CT and 6.19 pc m^{-2} in MT. The results in variant with different straw management were: 4.49 pc m^{-2} (variant A), 5.35 pc m^{-2} (variant B), 6.78 pc m^{-2} (variant C) and 6.91 (variant D).
Based on data of frequency occurrence of particular weeds in variants of soil tillage, CCA determines three-dimension ordering of weed species (ordinary diagram, figure 1).
From figure1 is visible, that CT creates conditions for higher occurrence of *Fallopia convolvulus, Fumaria officinalis, Consolida orientalis, Sonchus oleraceus, Sinapis arvensis* and *Taraxacum officinale*. Contrary, variants with minimum tillage (MT) had higher occurrence of *Galium aparine, Veronica polita, Convolvulus arvensis, Cirsium arvense, Lamium amplexicaule, Viola arvensis, Veronica persica, Capsella bursa-pastoris, Stellaria media, Lamium purpureum, Tripleurospermum inodorum* and *Malva neglecta.*

Tab. 3 Average number of weeds in variant soil tillage and straw management (year 2010)

Weed species	***Variants of soil tillage and straw management (pc m^{-2})***							
	CT				MT			
	A	B	C	D	A	B	C	D
Amaranthus sp.				0.19				0.69
Anagallis arvensis	0.06							
Brassica napus subsp. napus			0.06					
Capsella bursa-pastoris							0.25	
Cirsium arvense		0.125			0.63	0.38		0.56
Consolida orientalis	0.06		0.125					
Convolvulus arvensis					0.69		0.75	
Echinochloa crus-galli	0.06							
Fallopia convolvulus	0.13	0.19	0.25	0.31		0.06		0.06
Fumaria officinalis			0.13		0.13			
Galium aparine	0.69	1.38	2.75	1.25	0.88	2.13	1.50	0.13
Chenopodium album	0.25	1.63	0.31	0.19	0.44	0.31	0.81	0.38
Lamium amplexicaule							0.13	
Malva neglecta						0.06		
Microrrhinum minus			0.31					
Persicaria lapathifolia		0.13	0.13					

Polygonum aviculare	0.06							
Silene noctiflora	0.44	0.88	2.81	1.06	0.50	0.94	1.25	0.50
Sinapis arvensis			0.06					
Sonchus oleraceus	0.06							
Thlaspi arvense	0.13		0.13		0.25	0.13		0.06
Veronica persica	0.13							
Veronica polita	1.44	0.75	2.63	1.25	0.44	0.63	0.56	1.38
Viola arvensis		0.06						
Number of species	2.69	2.94	3.63	2.63	2.69	2.19	2.63	1.94
Number of specimens	3.50	5.13	9.69	4.25	3.94	4.63	5.25	3.75

Figure 1 Ordinary diagram – the impact of soil tillage and straw management on weed infestation in spring barley



Legend to ordinary diagram:
Variants of tillage, ▲ **CT** – conventional tillage, ▼**MT** – minimum tillage,
Variants of straw management ● **A** – application of Beta-liq fertiliser; ● **B** – application of DAM 390 fertilizer; ● **C** – application of Unifert fertilizer; ● **D** – check, without any fertilizer.
Abbreviations of weed species: *Ama sp.* – *Amaranthus* sp., *Ana arve* – *Anagallis arvensis, Bra napu* – *Brassica napus subsp. napus, Cap burs* – *Capsella bursa-pastoris, Car tinc* – *Carthamus tinctorius, Cir arve* – *Cirsium arvense, Con orie* – *Consolida orientalis, Con arve* – *Convolvulus arvensis, Ech crus* – *Echinochloa crus-galli, Eup heli* – *Euphorbia helioscopia, Fal conv* – *Fallopia convolvulus, Fum offi* – *Fumaria officinalis, Gal apar* – *Galium aparine, Che albu* – *Chenopodium album, Lac serr* – *Lactuca serriola, Lam ampl* – *Lamium amplexicaule, Lam purp* – *Lamium purpureum, Mal negl* – *Malva neglecta, Mic minu* – *Microrrhinum minus, Per lapa* – *Persicaria lapathifolia, Pol avic* – *Polygonum aviculare, Sil noct* – *Silene noctiflora, Sin arve* – *Sinapis arvensis, Son oler* – *Sonchus oleraceus, Ste medi* – *Stellaria media, Tar offi* – *Taraxacum officinale, Thl arve* – *Thlaspi arvense, Tri inod* – *Tripleurospermum inodorum, Ver pers* – *Veronica persica, Ver poli* – *Veronica polita, Vio arve* – *Viola arvensis.*

The most frequent weeds in variant of straw management A and B were: *Silene noctiflora, Chenopodium album, Thlaspi arvense, Carthamus tinctorius, Microrrhinum minus, Persicaria lapathifolia, Polygonum aviculare, Euphorbia helioscopia, Anagallis arvensis, Brassica napus subsp. napus* and *Echinochloa crus-galli.*
Variant C had the highest occurrence of: *Convolvulus arvensis, Viola arvensis, Veronica persica, Capsella bursa-pastoris, Stellaria media, Lamium purpureum, Tripleurospermum inodorum* and *Malva neglecta.*
Conditions in variant D increase number of weed species *Galium aparine, Cirsium arvense, Amaranthus* sp. and *Lactuca serriola.*
After comparison of particular variants we can conclude, that variant A (where Beta-liq was applied) had the lowest weed infestation. It could be connected with residual amount of sugar in this fertilizer which improves activity of soil microorganisms and has direct effect on weed seeds. There was positive effect in some cases, it means that the number of weed specimens increased (e.g. *Chenopodium album*, *Fallopia convolvulus*, *Silene noctiflora*). On the other hand abundance of some species decreased (*Galium aparine*). The highest weed infestation was in variant D (check, without nitrogen application). This variant is characterized by nitrogen depression, what can reduce competitiveness of spring barley in comparison with competitive strong weed species (e.g. *Galium aparine* and *Cirsium arvense*).
Minimum tillage reduced weed infestation, but occurrence of worse controllable weed species as *Galium aparine, Convolvulus arvensis* and *Cirsium arvense* increased.

Conclusions

The results showed, that straw management and soil tillage are factors, which can influence weed infestation in spring barley. Application of various nitrogen fertilizers and different soil tillage systems change conditions in soil or directly affect weeds. Competitive very strong weeds e.g. *Galium aparine* and *Cirsium arvense*, are able to be dominant also in conditions of nitrogen depression. Fertilizer Beta-liq, containing residual sugar, probably improves activity of soil microorganisms or directly affects weed seeds in the soil. There was positive effect in some cases, it means that the number of weed specimens was increased (e.g. *Chenopodium album*, *Fallopia convolvulus*, *Silene noctiflora*).
In general, these mechanisms can influence weed spectrum in spring barley.

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Section III

Effect of different methods of tillage on yields and economy of growing maize for grain

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Abstract

In the experimental part, authors evaluate results of studies on different methods of tillage on yields and economy of maize grown for grain. Experiments were performed within the period of 2007 – 2009 using the method of exact field experiments established on plots with clayey-loamy and gleyed Fluvisol in the Experimental Station of Mendel University in Žabčice situated in the sugar-beet-growing region. Maize for grain followed after winter wheat. Evaluated were two experimental variants, viz. Variant 1 with conventional ploughing and Variant 2 with shallow soil loosening (minimum tillage). As far as the method of tillage was concerned, better results were obtained in Variant 1 with the conventional method of ploughing.

Keywords: soil processing, maize for grain, grain yield, economic evaluation

Introduction

In recent years, growing of maize for grain has passed through a period of an unprecedented boom. Today, this crop is grown not only in the warmest regions but also – thanks to great advances in genetics and breeding – also in higher and colder altitudes. Besides its use as a fodder crop and various edible products, it is more and more important also in other and various industrial branches, especially as a raw material for bioethanole making and or for processing in biogas stations *(Hůla, Abrham, Bauer et al., 1997).*

Earlier, only conventional methods of cultivation (i. e. tillage and sowing) were used. Traditional methods and cycles of working operations were used without greater modifications nearly in all regions of the Czech Republic. Also the methods of tillage and technological lines were very uniform and the machinery used for soil processing did not differ too much, regardless to various soil and climatic conditions. Today, conventional technologies are more and more combined with minimisation methods and ploughing is left out on a large scale *(Zimolka et al., 2008*).

Material and methods

Effects of different methods of soil processing on yields and economy of growing maize for grain were investigated within the period of 2007 – 2009 using the method of exact field experiments established on fields of the Experimental Station of Mendel University in Žabčice, which is situated in the sugar-beet-growing region.

Characteristics of the experimental site

The Experimental Station Žabčice is situated in the maize-growing region and the main site parameters were as follows: altitude 177 m, clayey-loamy and gleyed Fluvisol with humus content 2.5 %, good contents of phosphorus, potassium and magnesium, and pH 6.7. The average annual temperature and annual sum of precipitation are 9.2 ^{o} C and 480 mm, respectively.

Experimental variants

The experimental crop turnover was as follows: maize for grain, spring barley, safflower, winter wheat, and again winter wheat.

Variants of soil tillage on plots with maize fro grain:

Variant 1 - conventional methods of tillage with ploughing
Stubble ploughing with the KVERNELAND plough to the depth of ca 0.10 m, performed as soon as possible after the harvest and followed by normal ploughing to a medium depth (0.24 m). Sowing – using the combination KVERNELAND ACCORD.
The soil surface was treated with the sowing combination KVERNELAND ACCORD (without sowing) with the depth of soil loosening to the depth of sowing (i.e. ca 0.08 m); maize sowing was performed with a 4-row single grain sowing machine KLEINE MULTICORN

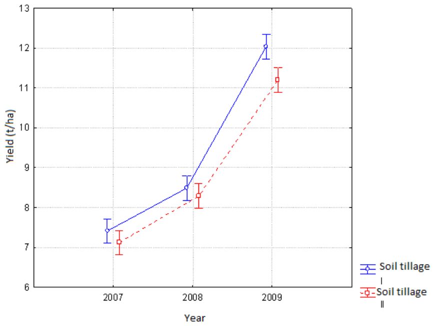
Variant 2 – minimum tillage

Stubble ploughing performed after the harvest, shallow soil loosening (0.15 m) prior to sowing followed by pre-sowing soil loosening to the depth of sowing, and maize sowing with a 4-row single grain sowing machine KLEINE MULTICORN
Maize cultivar and seeding dose:
Cv. Thermo, 80,000 plants per hectare

Results and discussion

Table 1 Effect of tillage methods on maize yields (t.ha^{-1})

Variant	**Average yield**	**Significance**
I.	9.31	A
II.	8.87	B



Economic evaluation of both technologies used when growing maize for grain

Table 2 Economic evaluation of conventional and minimisation technology

Method of tillage	**Yield**	**Revenues**	**Costs**	**Gross profit**
	t.ha^{-1}	**CZK.ha^{-1}**	**CZK.ha^{-1}**	**CZK.ha^{-1}**
I Conventional ploughing	9.31	26,534	16,487	**10,047**
II Minimum tillage	8.87	25,280	15,874	**9,406**

The method of conventional tillage with ploughing was more demanding as far as the consumption of labour and energy were concerned. Stubble ploughing was performed after the harvest and followed by ploughing to the depth of 0.22 m. Post-harvest residues, germinated rubbed off grains and weeds were incorporated into the soil by ploughing. Because after the ploughing a relatively high proportions of lumps remained on the soil surface, it was necessary to use a suitable method of soil processing in the next spring. This operation was performed at the moment when approximately three quarters of the field surface (furrows) were sufficiently dry. The pre-sowing soil preparation was performed immediately before sowing in such a way that seeds were incorporated into an optimum depth of the sowing bed. Mineral fertilisers were applied simultaneously with sowing. When using the conventional methods of tillage with ploughing, the surface soil layer was loose and for that reason it was necessary to reduce the pressure on the drill sowing apparatus because it there was a risk that seed would be placed too deep.

The advantage of the conventional method of soil processing consist in the fact that the ploughed toplayer is well prepared and enables an easy application of the pre-emergent herbicide.

In Variant 1 with ploughing, the average yield was 9.31 $t.ha^{-1}$; this was higher by 0.44 $t.ha^{-1}$ than in Variant 2 with minimum tillage. within the period of 2007 – 2009, the average yield was 8.87 $t.ha^{-1}$.

When using the **method of minimum tillage,** the stand establishment was easy and without problems. A shallow tillage performed in the autumn after the harvest resulted in a partial incorporation of plant residues into the soil and their mixing with the topsoil.

Seed material was applied into the optimum depth and also the efficiency of pre-emergent herbicides was also good (obviously due to a good preparation of the sowing bed).

From the economic point of view, Variant 2 was less advantageous. In Variant 1, a higher subsidy was received (10,047 $CZK.ha^{-1}$) than in Variant 2 (9,406 $CZK.ha^{-1}$).

The highest number of long-term experiments focused on evaluation of minimisation technologies is performed in the US. In general, it was reported that in the majority of cases, technologies with a shallow processing of topsoil gave higher yields than the conventional methods with ploughing. Lower yields obtained when using methods of minimum tillage were usually accredited to an insufficient protection of crops against weeds. In spite of this, however, the minimisation technologies are continuously developed and improved (e.g. the problem of lower maize yields in marginal regions are solved by means of ridge tillage (i.e. sowing of maize into ridges) and loosening of topsoil to different depths and without turning *(Hůla, Procházková et al., 2008).*

Conclusions

Maize for grain was cultivated after winter wheat and the following two variants of soil processing were used: Variant 1 – conventional method with ploughing to the depth of 0.22 m and Variant 2 – minimum tillage with loosening of topsoil to the depth of 0.15 m.

Basing on obtained results, it was possible to draw the following conclusions:

- The highest yield was recorded in 2009 (12.,04 $t.ha^{-1}$); in this year, there were the most favourable weather conditions (above all due to higher sums of precipitations in June and July). On the other hand, the lowest yield (7.12 $t.ha^{-1}$) was recorded in 2007 when the weather conditions were less favourable. Also in this year a higher average yield was obtained in Variant 1 (9.32 $t.ha^{-1}$) than in Variant 2 (8.87 $t.ha^{-1}$).
- In Variant 2, conditions for sowing were relatively good. The advantage of this method consisted in the fact that the soil surface was more resistant to water and wind erosion and also that the minimum tillage showed a positive effect on soil texture.
- In Variant 2, the number of working operations on the field was high. However, a more intensive processing of soil created optimum conditions for incorporation of seed into the soil and the efficiency of pre-emergent herbicides was higher. The main disadvantage of this method consisted in an increased risk of the occurrence of water and wind erosion.
- From the economic point of view, the conventional method of tillage (Variant 1) gave better results than Variant 2: the total revenues and costs were 26,534 $CZK.ha^{-1}$ and 16,487 $CZK.ha^{-1}$, respectively so that the gross profit and the labour consumption per hectare were 10,047 $CZK.ha^{-1}$ and 6.32 hours, respectively. In Variant 2, the corresponding values were 25,280 and 15,874 $CZK.ha^{-1}$, respectively, so that the gross profit was only 9,406 $CZK.ha^{-1}$; however, the consumption of labour was slightly lower (5,97 h). The difference between gross profits was 641 $CZK.ha^{-1}$. Another influencing factor is represented by the fact that the

machinery used for the minimum tillage is more universal than that used for conventional methods of soil processing. When using a skiver it is possible to carry out shallow post-harvest ploughing, soil preparation for sowing and also loosening of topsoil to greater depths and all these operations represent an advantage as compared with conventional methods of tillage. When considering the application of minimisation technologies, it should be kept in mind that these methods protect soil against water and wind erosion and that they also improve the texture of the topsoil.

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Effect of different tillage intensity on yields of winter wheat

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Abstract

Effects of different tillage intensity on yields of winter wheat cultivated after alfalfa on Chernozem soil in the sugar-beet-growing region were followed within the period of 1989 – 2010. Evaluated were the following four variants of soil processing: Variant 1 – ploughing to the depth of 0.22 m; Variant 2 – ploughing to the depth of 0.15 m; Variant 3) – sowing to non tilled soil and Variant 4 – shallow soil loosing to the depth of 0.10 m. The highest and the lowest yields of winter wheat were obtained in 1994 and 1993, respectively. The highest average yield was obtained in Variant 2; thereafter followed Variant 1, Variant 4 and Variant 3. Statistically significant were only differences between Variants 1 and 3 and Variants 12 and 3. Difference between other variants were statistically insignificant. The obtained results indicate that the minimization technology can be applied under the existing pedological and climatic conditions.

Keywords: tillage,winter wheat, yield

Introduction

When growing field crops, soil processing represents one of the fundamental measures, which contribute to creation of stable and high yields. It is also one of important tools enabling to kill weeds and to control the occurrence of various pests an diseases. First of all, tillage changes the physical condition of soil and, thus, its aerial, water, biological and thermal regime. Tillage should increase soil fertility and create suitable conditions for growth and development of plants. Opinions about, concepts of and approaches to good methods of tillage pass through a process of permanent development. From the viewpoint of agrotechnical measures, soil processing represents the most demanding and energy consuming measures. When using conventional methods of tillage based on ploughing, weigh approximately 35 % of total fuel consumption in crop production (Šimon and Lhotský 1989). Systems of tillage and crop establishment belong to important parts of production technologies of cereals. As far as the growing of winter wheat is concerned, there is a wide assortment of soil processing technologies available at present. It is quite clear that the choice of methods of tillage and crop establishment should be done with regard to concrete growing and environmental conditions, local situation, soil quality, position of winter wheat in the crop turnover, and management of post-harvest residues of preceding crops (Hůla, Procházková et al., 2008, Arshad, 2001, Hemmat and Eskandari, 2006, Hrubý and Procházková, 2008).

Material and methods

Experiments were performed in the sugar-beet-growing region (agroclimatic region T2 – warm and semiarid) on plots of Research Institute of Crop Production in Ivanovice na Hané, Czech Republic within the period of 1989 – 2010. The soil was characterised as typical loamy Chernozem. The altitude of the experimental site and the depth of humus horizon were was 225 m., and 0.40 – 0.50 m, respectively. Soil reaction was neutral. Content of humus was 2.6 % and reserves of P, K, Ca and Mg were classified as good. The average annual temperature and sum of precipitations were 9.13 °C and 539.91 mm, respectively (20-year average).

CONTENT

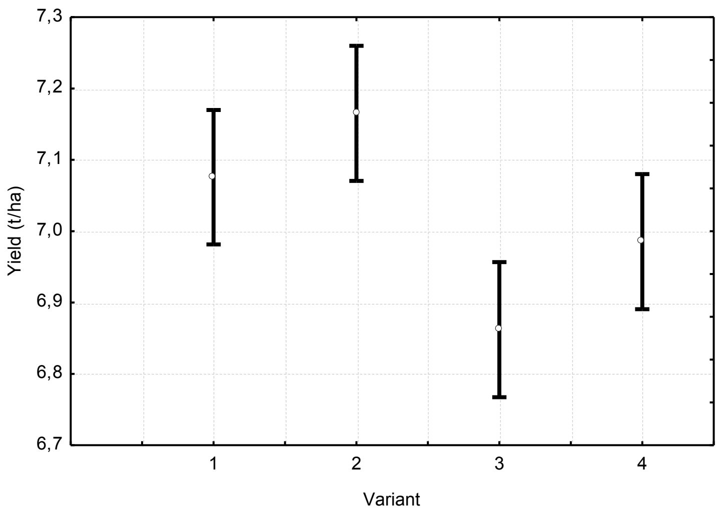
The experiment was established in four variants and replications. The total area of individual harvested plots was 22 m^2 .
Within the framework of crop rotation system (crop turnover), winter wheat followed after alfalfa **.**

Table 1: Variants of tillage for winter wheat

Variant	**Method of tillage**
1	Ploughing (0.22 m)
2	Ploughing (0.15 m)
3	Direct sowing without tillage (zero tillage)
4	Shallow disk tillage (0.10 m)

Results and discussion

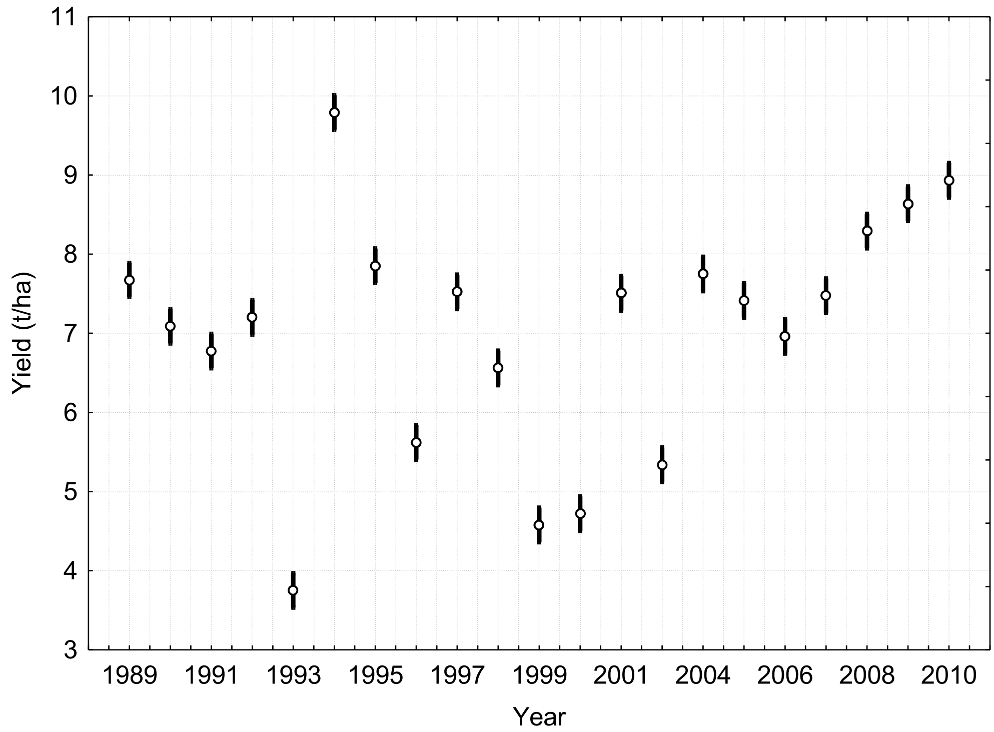
Figure 1: Effect of different tillage intensity on yields of winter wheat grown after alfalfa



The highest yield was recorded in Variant 2 (i.e. ploughing to the depth of 0.15 m). This highest yield was obtained because of a good incorporation of alfalfa post harvest residues into the soil and also due to a relatively slight water evaporation and drying of toplayer. The lowest yield was obtained in Variant 3 (i.e. sowing without tillage). Differences between individual experimental variants were statistically significant. A decrease, recorded in Variant 3 was most probably caused by a low quality of established crop (the amount of post-harvest residues on the soil surface was too high).

In Variant 1, the yield was slightly higher than the average and its difference from Variant 3 was statistically significant. A shallow disk tillage (Variant 4) enabled a good establishment of winter wheat crop and the obtained yield was higher than in Variant 3. However, the difference between these two variants was statistically insignificant.

Figure 2: Average yields of winter wheat grown after alfalfa (1989 - 2010)



When comparing 20-year results of experiments with a various intensity of tillage, the best results were recorded in Variant 2. In this case, the average yield was 7.16 t/ha. This resulted from a good incorporation of alfalfa post-harvest residues into the soil and, thus, good sowing and germination of winter wheat plants. A slightly lower yield (7.08 t/ha) was recorded in Variant 4 .

Conclusions

These experimental results demonstrated that the effect of various intensity of soil processing on yields of winter wheat grown on Chernozem in the sugar-beet-growing region was significant only in between Variants 1 and 3 (i.e. ploughing to the depth of 0.15 m and zero tillage, respectively) and Variants 2 and 3 (i.e. ploughing to the depth of 0.15 m and zero tillage, respectively). In all other cases the observed differences were statistically insignificant. Possibilities of application of minimised methods of tillage are determined by local pedo-climatic conditions and year. It can be concluded that under given conditions of the experimental locality reduced methods of tillage for crops of winter wheat can be applied.

Acknowledgement

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The influence of controlled traffic on field on soil compaction parameters

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Abstract
In the field experiment there were all the work stages assured by machine sets in the system of permanent driving tracks at the module of working width 6 metres. The total area of tracks on the plot represented 32 % of plot area, which constitutes a significant reduction in comparison with conventional method of driving along the plots, when a share of track area represents 75 up to 100 % of total plot area. In the paper there are evaluated soil physical properties at four variants of tracks. The results confirm an advantage, which represents concentration of passages into tracks aimed at protection of most part of a plot from soil compaction. Another advantage of mentioned concentration of passages into tracks is an increase of soil tillage quality on the area outside of track.
Keywords: controlled traffic farming; soil compaction; soil physical properties

Introduction

The processes of undesirable soil compaction have been studied intensively in recent years (Håkansson 1992 and 1995, Unger 1996). In the prevention of soil compaction it is important that a certain load of soil may induce a different response in the soil at one site during the year. Measures preventing soil compaction have been developed that include both preventive and remedial ones (Lhotský 2000). Matthews (1982) stated that the energy requirement for soil tillage would decrease by 50% if the influence of wheel traffic of farm machines on the production part of fields were eliminated by means of wheel traffic restriction to permanent traffic lanes; the energy requirement for soil tillage could further decrease significantly if minimum soil tillage and absence of wheel traffic were combined.

Currently, a possibility of confining the wheel traffic across fields to defined traffic lanes becomes increasingly important in order to conserve a major part of the production area of fields without negative influence of wheel ruts (Chamen et al., 2003, Tullberg 2001, Lamour et Lotz 2007). The system of controlled traffic farming (CTF) in fields is also promising because satellite navigation systems are available that make it possible to reach a necessary accuracy for the performance of field operations including sowing.

The objective of a pilot field trial was to evaluate the influence of the restriction of wheel traffic to traffic lanes during field operations on physical properties of soil and on parameters of soil tillage quality.

Material and methods

In spring 2010 in a beet-growing region a pilot field trial was established in a 10-ha field that was aimed at the restriction of wheel traffic on the soil to permanent traffic lanes.

Soil conditions: 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 2009 after winter wheat harvest 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. After this medium-deep cultivation of soil the field remained without wheel traffic until spring 2010, when wheel traffic was organised within the CTF system using OutTrac (Chamen 2009) – Fig. 1. It is typical of this wheel traffic system that the wheel ruts of a harvester-thresher that has a wider wheel track than tractors are on the outer side of common permanent traffic lanes.

Tab. 1 lists farm machines used for field operations in the field concerned. 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.

To evaluate the influence of wheel traffic of farm machines on the soil in a system of restricted wheel traffic four variants of traffic lanes were defined:

1. Traffic lanes of tractors during sowing, application of chemicals for plant protection, application of mineral fertilisers and during stubble breaking
2. Traffic lanes of dual wheels of tractor during sowing, lanes of a harvester-thresher and lanes of tractor during stubble breaking
3. Outside the traffic lanes
4. Traffic lanes on a part of the field with uncontrolled wheel traffic in direction of travel (area of 3 ha).

In the particular variants of wheel traffic basic physical properties of soil were evaluated after the collection of undisturbed soil samples with an Eijkelkamp sampling set (twice per growing season). Measurements were done with a registration penetrometer and the proportions of size fractions of clods after soil tillage were determined.

A GPS satellite system with the correction signal of RTK VRS was used for the navigation of farm machines during sowing, soil tillage, application of chemicals for plant protection and during harvest. An assisted steering system AgGPS EZ-STEER (Trimble) was used. The vehicles for grain transport during the operation of a harvester-thresher did not pass across the field, the grain tank of a harvester-thresher was emptied to a tractor semi-trailer on the edge of the field near the road.

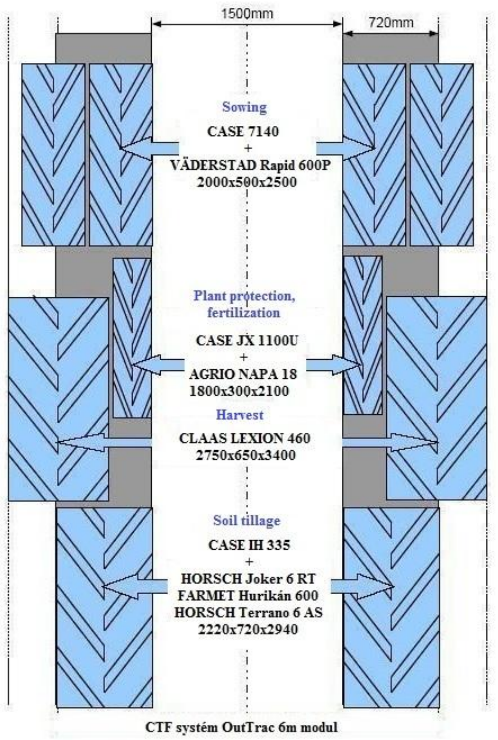

Fig. 1 Wheel ruts of tractors and harvester-thresher after their restriction to permanent traffic lanes – the area of lanes is enlarged by the wheel track of harvester thresher that is larger than that of tractors and by dual wheels of tractor during sowing

CONTENT

Tab. 1 Field operations in 2010 and data on farm machines

Field operation	Time	Machines	Working width [m]	Distance of tracks [mm]	Tire width [mm]
Herbicide application	7.4.	CASE JX 1100U + AGRIO NAPA 18	18	1800	320x2
Pea sowing	8.4.	CASE 7140 + VÄDERSTAD Rapid 600P	6	2000	500x4
Herbicide application	27.4.	CASE JX 1100U + AGRIO NAPA 18	18	1800	320x2
Herbicide application	17.6.	CASE JX 1100U + AGRIO NAPA 18	18	1800	320x2
Pea harvest	28.7.	CLAAS Lexion 460	6	2750	650x2
Shallow loosening (depth 60-80 mm)	30.7.	CASE IH 335 + HORSCH Joker 6 RT	6	2220	720x2
Shallow loosening (depth 80-100 mm)	12.9.	CASE IH 335 + FARMET Hurikán 600	6	2220	720x2
Loosening (depth 120-150 mm)	18.9.	CASE IH 335 + HORSCH Terrano 6 AS	6	2220	720x2
Sowing of winter wheat	12.10.	CASE 7140 + VÄDERSTAD Rapid 600P	6	2000	500x2

Results and discussions

Tab. 2 shows the average values of basic physical properties of soil in the summer season, after pea harvest by a pea harvester and after stubble breaking (soil samples were taken on 19 Aug. 2010). A comparison of determined values with critical values of compaction (Lhotský 2000) demonstrates differences among the experimental variants. It is a partial argument in favour of the restriction of wheel traffic to defined traffic lanes.

Tab. 2 Average values of basic physical properties of soil (19 Aug. 2010)

Variant	Depth [mm]	Bulk density [$g.cm^{-3}$]	Moisture [% vol.]	Porosity [% vol.]
1	50-100	1,55	31,1	38,7
1	150-200	1,55	30,3	38,7
1	250-300	1,56	28,8	38,1
1	350-400	1,50	30,4	40,7
2	50-100	1,45	34,1	42,6
2	150-200	1,50	32,5	40,6
2	250-300	1,58	30,3	37,7
2	350-400	1,52	30,4	40,0
3	50-100	1,39	33,6	45,2
3	150-200	1,47	31,2	41,9
3	250-300	1,53	30,7	39,6
3	350-400	1,53	28,8	39,7
4	50-100	1,23	21,5	51,4
4	150-200	1,58	23,0	37,6
4	250-300	1,66	26,2	34,2
4	350-400	1,56	26,2	38,4
Indicator of harmful compaction – loam soil (Lhotský 2000)		over 1,45	-	under 45,0

Box diagrams in Figs. 2 to 4 illustrate the values of bulk density (soil samples were taken on 19 Aug. 2010). At a depth of 150-200 mm (Fig. 2) the lowest bulk density was determined in variant No. 3 (no wheel traffic) but differences among the variants were below the level of statistical significance at this depth. At a depth of 250-300 mm (Fig. 3) a statistically significant difference in the values of bulk density of soil was found out between variants No. 3 and No. 4. At a sampling depth of 350-400 mm (subsoil layer, Fig. 4) differences in bulk density of soil among the variants were statistically insignificant.
Fig. 5 documents the values of penetration resistance of soil in October 2010. The values of penetration resistance of soil were influenced by higher soil moisture at the time of measurement, but differences in this parameter among the experimental variants were below the level of statistical significance.

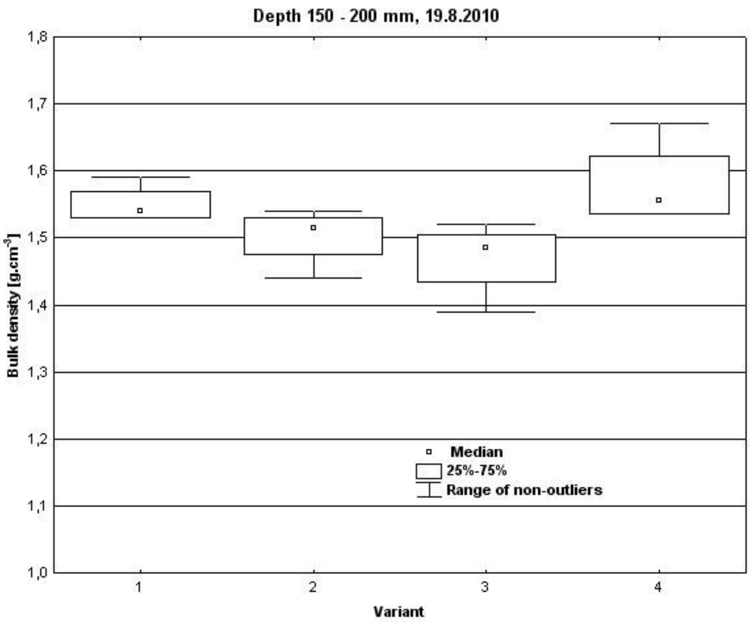

Fig. 2 Bulk density at a depth of 150-200 mm (19 Aug. 2010)

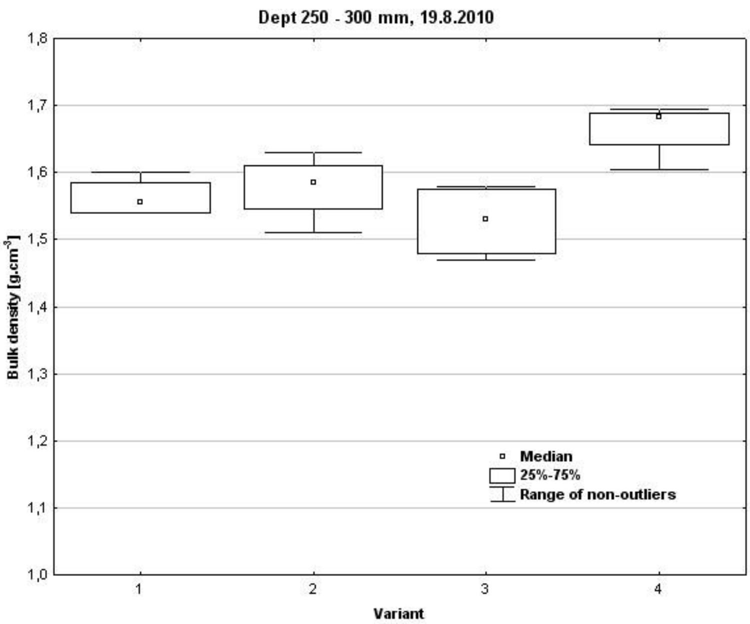

Fig. 3 Bulk density at a depth of 250-300 mm (19 Aug. 2010)

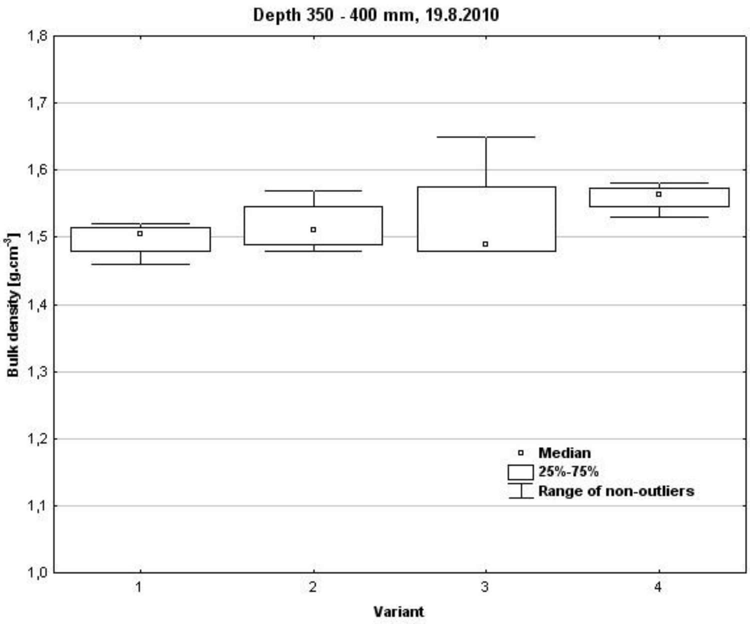

Fig. 4 Bulk density at a depth of 350-400 mm (19 Aug. 2010)

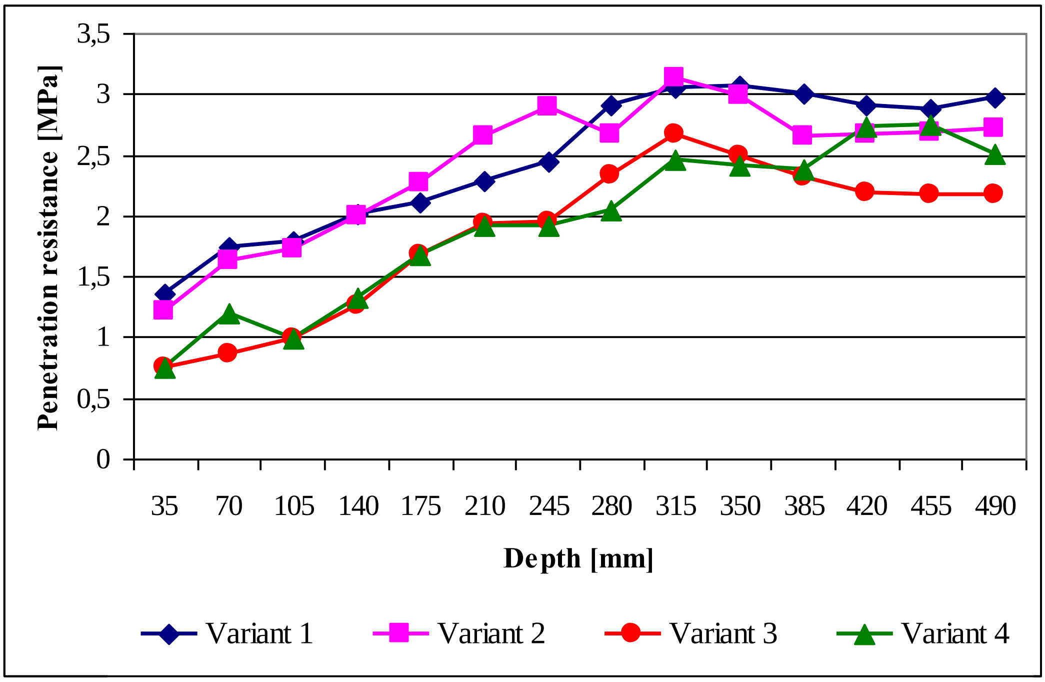

Fig. 5 Penetration resistance of soil in October 2010

After pea harvest the soil was worked by a sweep cultivator to a depth of 60 to 80 mm (pea harvest on 28 July 2010, stubble breaking on 30 July 2010). Repeated shallow loosening of soil aimed at a suppression of emerged wasted pea seeds was performed on 12 Sept. 2010. Cloddiness of the tilled topsoil layer was evaluated in order to assess the influence of different load of soil caused by the wheel traffic of farm machines on parameters of soil tillage quality and on the creation of conditions for the sowing of subsequent crop. Agricultural requirements for the quality of seedbed preparation imply that seedbed layer and surface layer of soil should not contain any clods larger than 50 mm in diameter. This requirement was met only in variant No. 3 (variant without influence of wheel traffic on the soil). Obviously, the permanent separation of traffic lanes from the production area of the field appeared beneficial from the aspect of soil tillage quality.

The system of controlled traffic farming, practised in a 10-ha field using the module of the 6-metre working width of farm machines, allowed to consistently separate the area designed for restricted traffic lanes of farm machines from the production area of the field. A relatively favourable situation was created when the total area of traffic lanes in the field (with the exception of headland) accounted for 32% of the total field area at the 6-m module of working width. At an 8-m module of the working width of farm machines it is realistic to reduce the area of traffic lanes to 20 – 25% of the field area. It is a significant reduction in the trafficked area of the field – Chamen (2009) reported that under conventional wheel traffic across fields the trafficked area accounted for 75 to 100% of the field area. Kroulík et al. (2009) stated that the wheel traffic in winter cereals covered 86% of the field area.

The total width of wheel ruts was influenced by the unequal wheel track of tractors and harvester-thresher and by the use of dual wheels of tractor during sowing. The proportion of traffic lanes in the total field area can be reduced by using narrower wheels of large diameter and by unification of the wheel track of tractors and harvesters – but it is a costly method. The chosen CTF system in an experimental field was based on a possible choice of combinations of heavy-duty farm machines in an agricultural enterprise for a pilot testing of the controlled traffic system.

Conclusions

Findings from the pilot field trial document that the system of controlled traffic farming is realisable in conditions of an agricultural enterprise. It is conditioned by the use of a precise navigation satellite system with the correction signal and assisted or automatic steering of tractors and harvester thresher.

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CONTENT

A DECREASE OF WATER INFILTRATION IN WHEEL RUTS OF FARM MACHINES

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Abstract

Physical properties of soil and infiltration rate of water in crop stand and in wheel ruts of farm machines were evaluated in fields with registered wheel traffic of farm machines in wheel rows. A comparison of the rate of water infiltration under rainfall simulation at the constant intensity of rainfall 87 $mm \cdot h^{-1}$ confirmed a negative influence of soil compaction in wheel ruts of machines. In the loam-sandy soil surface water runoff started 5 times sooner in wheel ruts than in crop stand. Light soils were able to infiltrate a fifteen-minute torrential rain at places outside wheel ruts. Only 30 to 40% of precipitation water was infiltrated at the same time in wheel ruts and the content of soil in runoff water was 4.9 times higher than in crop stand. On the heavy-textured sandy-clay soil cumulative surface water runoff after 60 minutes was 30% of the precipitation amount at places of wheel ruts, which was a fourfold value compared to surface water runoff at places outside wheel ruts.

Keywords: water infiltration; rainfall simulation; wheel ruts

Introduction

Currently, such a soil management system is considered perspective that leads to a reduction in soil compaction by consistent separation of wheel ruts of farm machines from the area not compacted by wheel traffic (Chamen 2009; Lamour et Lotz 2007).

The benefits of controlled traffic farming (CTF) can be assumed also in the water regime of soils. Li et al. (2004) reported that water runoff from fields where the system of permanent wheel ruts was applied was lower by 36% compared to a field with standard traffic. Water runoff from a field with direct drilling and permanent wheel ruts was reduced by 47.2% compared to the results of water runoff from a cultivated field with conventional management. The orientation of wheel ruts and respect of land slope are important (Tullberg 2001).

Material and methods

Two fields with controlled traffic farming were chosen to compare surface water runoff in wheel rows and in crop stand. No-tillage technology without ploughing has been used in both fields for a long time. Shallow cultivation of soil with tillers to a depth of 150 – 200 mm is regularly followed by deep loosening with chisel ploughs.

The first field in the Brodce nad Jizerou cadastre has a light loam-sandy soil. Three repeated measurements of surface water runoff evoked by a rainfall simulator were done on 30th March 2010 in winter wheat stand and in wheel ruts after two passes of farm machine combinations: after spraying to control winter weeds on 30th October 2009 with a MAZZOTTI self-propelled sprayer (weight 7.2 t) and after spring supplemental fertilisation with ammonium saltpet on 18 March 2010 using a BOGBALLE spreader mounted on a STEYER 4100 PROFI tractor (weight of the machine combination 7.3 t).

In the second field with medium-textured soil and increased viscosity (Tab. 1) in the Předměřice n. L. cadastre winter wheat was planted as forecrop. After stubble breaking deep loosening to a depth of 300 mm was carried out at the end of September and ridges at a spacing of 750 mm were made at the same time. In spring on 21st April 2009 maize for grain was planted into ridges by a pneumatic sowing machine HORSCH MAISTRO 24RC with

520/85 R42 tyres and of total weight 7.6 t that was aggregated to a JD 8400T caterpillar tractor with tracks 430 mm in width and of total weight 12.4 t.

Tab. 1 Soil texture on experimental plots

Group	Size of particles [mm]	Site Brodce n. J.		Site Předměřice n.L.	
		Class distribution [% weight]	Quality of soil	Class distribution [% weight]	Quality of soil
I.	<0.01	8.58	Loam-sandy soil	44.94	Sandy-clay loam as clay-loam soil, medium-textured soil with increased viscosity
II.	0.01-0.05	7.26		19.15	
III.	0.05-0.20	37.42		24.10	
IV.	0.20-2.00	46.75		11.80	

Surface water runoff was measured under simulated sprinkling on a measurement area of 0.5 m^2 in size and at rainfall intensity of 87.8 $mm \cdot h^{-1}$, in three replications for each treatment. Infiltration rate is determined from the defined rainfall intensity that is constant for the time of measurement and from surface runoff of water from the measurement area (Kovaříček et al. 2008). Intercepted water from surface runoff is filtered, filtered off soil is dried up and from the dry weight of washed soil the unit loss of soil ($g \cdot m^{-2} \cdot h^{-1}$) caused by water erosion is determined. Before sprinkling soil moisture content and porosity were determined in undisturbed soil samples taken from topsoil for the compared treatments of the experiment. The soil surface was described by average gradient, surface roughness in the direction of the slope line and by vegetation cover. At Předměřice n. L. site maize plants growing on the measurement area were clipped off just above the soil surface.

Results and discussions

Rainfall simulation on the light sandy soil in Brodce n. J. cadastre was carried out 12 days after spring supplemental fertilisation. The physical condition of soil in the evaluated treatments before simulated sprinkling is described by the average values of reduced bulk density (RBD), soil moisture, porosity and maximum air capacity in Tab. 2. In the regularly cultivated topsoil layer to a depth of 150 mm there are significant differences in all parameters between the treatments of crop stand and compacted wheel rows. The soil compacted by wheel traffic has by 5% lower porosity in the surface soil layer.

Tab. 2 Physical properties of light sandy soil in crop stand and in wheel row after wheel traffic - Brodce n.J.

Variant	Depth [mm]	Bulk density [g.cm^{-3}]	Soil moisture [% volume]	Soil moisture [% weight]	Total porosity [%]	Minimum air capacity [%]
Stand outsider track	100	1.49	27.5	18.5	43.7	10.5
	150	1.57	26.5	16.9	40.5	10.9
	200	1.61	22.8	14.2	39.2	12.1
	250	1.60	21.9	13.7	39.5	13.3
Tracked line	100	1.62	29.9	18.5	38.6	8.9
	150	1.73	25.8	14.9	34.5	7.6
	200	1.61	22.9	14.2	38.9	13.2
	250	1.64	22.2	13.6	38.0	13.3

CONTENT

A decrease in porosity and macropores (expressed by minimum air capacity MAC) in the wheel row to the critical level of harmful compaction was reflected in the earlier onset of surface water runoff (Tab. 3) and increased soil wash-off. Runoff started three and five times sooner on compacted soil compared to the treatments in crop stand while soil wash-off was three to five times higher. After 15-minute sprinkling surface water runoff was 6% of the precipitation amount in the treatments in wheel rows (Fig. 1) while in wheat stand all water was infiltrated at that time. After 30 minutes of sprinkling 14.6 mm of water ran off in the wheel row, i.e. 30% of the precipitation amount, and after 60 minutes it was already 45%. In crop stand outside the wheel ruts only 3 mm of water ran off along the surface in 30 minutes and it was 16 mm of the precipitation amount 87.8 mm in 60 minutes, i.e. 18%. At a long intensive rainfall on the compacted sandy soil the surface water runoff amounted up to a half of the precipitation amount whereas it was only 1/5 in crop stand.

Tab. 3 Basic characteristics of the measurement sites and the results obtained at the measurement (rainfall simulation) - Brodce n. J., light sandy soil

Variant	Site	Inclination rate [°]	Surface roughness [mm]	Soil moisture [% weight]	Total porosity [%]	Sheet wash soil [g.m^{-2}.h^{-1}]	Beginning surface runoff [min]
Stand outsider track	1	2.1	19.0	14.9	37.5	12.4	12.4
	2	1.3	19.9	14.9	47.0	18.5	19.9
	Mean	1.7	19.5	14.9	42.3	15.5	11.2
Tracked line	1	2.0	17.6	12.1	12.1	64.8	1.9
	2	1.8	18.9	14.8	12.3	63.8	5.9
	Mean	1.9	19.8	13.5	12.2	64.3	3.9

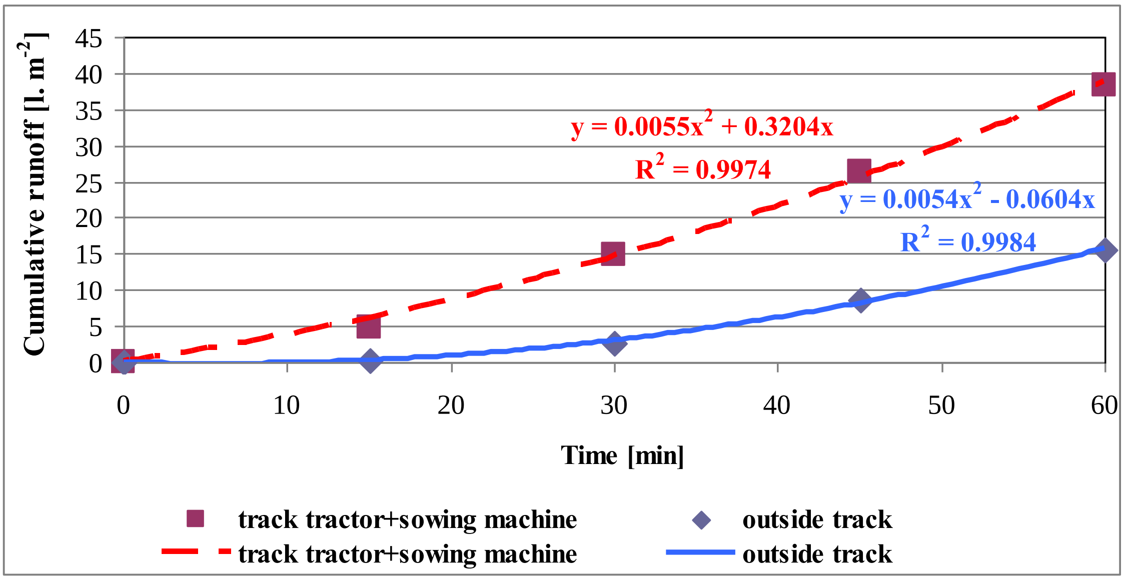


Fig. 1 Cumulative water runoff during heavy rain (87,8 mm.h^{-1}) on sandy soil (Brodce n. J.)

On the second plot with heavy-textured soil in Předměřice n. L. cadastre surface water runoff at intensive rainfall was evaluated in maize stand (6 leaves, height of 400-450 mm) on 18th June 2009, i.e. in the period of an increased threat of the occurrence of torrential rain and water erosion. Maize was planted by a caterpillar tractor drawn seed broadcaster (18 m) on 20th April, when moisture conditions were optimal. Surface water runoff from measurement areas located in rows with wheel ruts of the tractor and broadcaster combination was compared with areas in maize rows outside the ruts. After the evaluation of undisturbed soil samples the values of the studied parameters demonstrated the friendliness of the broadcaster and tractor combination in relation to soil (Tab. 4). In wheel ruts the critical values of harmful compaction were not exceeded (Lhotský 2000).

Tab. 4 Physical properties of medium-textured sandy clay loam soil in crop stand and in wheel row (Předměřice n.L.)

Variant	**Depth [mm]**	**Bulk density [g.cm^{-3}]**	**Moisture [% volume]**	**Moisture [% weight]**	**Total porosity [%]**	**Minimum air capacity [%]**
Stand outsider track	100	1.06	33.1	31.3	58.9	23.8
	200	1.18	33.2	28.3	54.3	18.2
	300	1.41	35.8	25.4	45.2	8.0
Track of tractor set+sowing machine[1)]	100	1.30	37.2	28.6	49.4	10.9
	200	1.37	35.8	26.1	46.6	9.6
	300	1.42	38.1	27.0	44.9	5.7

1) tractor JD 8400T, + sowing machine HORSCH MAISTRO 24RC

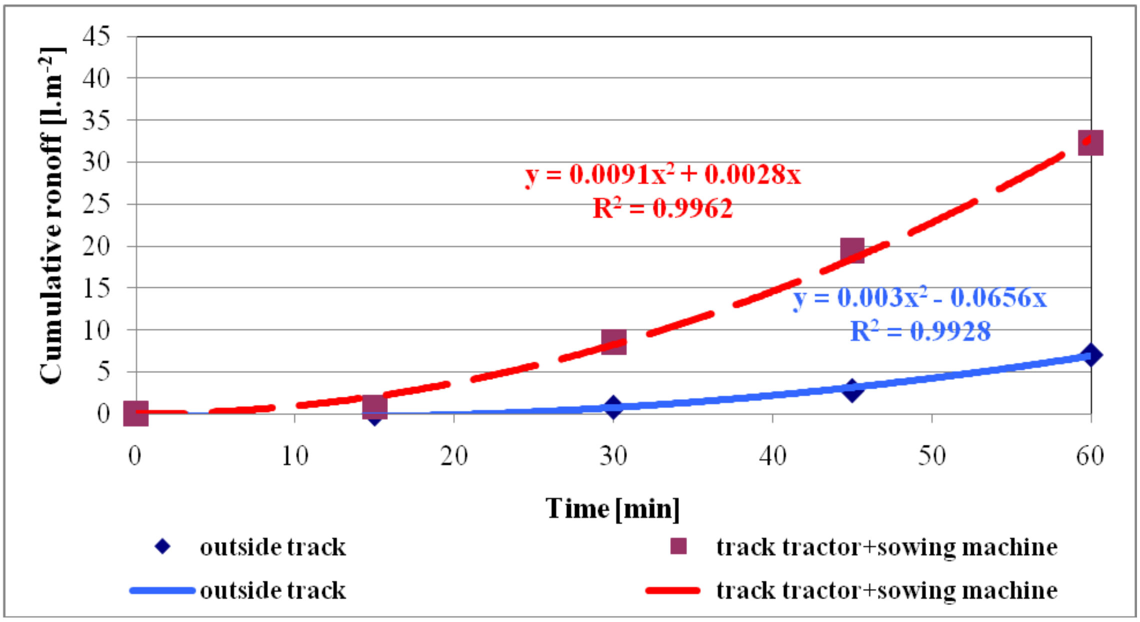
Soil roughness in wheel ruts was significantly higher than in rows outside the ruts. A high tread of the tractor rubber track was a dominant factor for the creation of transverse depressions that were pronounced also after the subsequent pass of the broadcaster tyre. The time of the onset of surface water runoff at simulated sprinkling was similar in both compared treatments (Tab. 5).

Cumulative surface runoff in wheel ruts was 9 mm after 30 minutes of rainfall of the intensity 87.8 mm·h^{-1} while it was minimal outside ruts (Fig. 2). However, this parameter continually increased until the end of measurement. After 60 minutes it increased to 30% in ruts and to 7% of the precipitation amount outside ruts. The soil wash-off in water from surface runoff was moderately increased in wheel ruts.

CONTENT

Tab. 5 Basic characteristics of sites and the results of measurements of surface water runoff under simulated sprinkling

Variant	Site	Inclination rate [°]	Surface roughness [mm]	Soil moisture [% weight]	Total porosity [%]	Sheet wash soil [g.m^{-2}.h^{-1}]	Beginning surface runoff [min]
Stand outsider track	1	2.9	17.8	15.3	4.0	2.3	28.6
	2	3.3	18.3	16.5	8.3	17.1	15.5
	Mean	3.1	18.1	15.9	6.2	9.7	22.1
Track of tractor set+sowing machine	1	1.5	27.4	17.3	1.5	14.6	14.8
	2	1.5	21.9	17.1	1.5	52.5	13.7
	Mean	1.5	24.7	17.2	1.5	33.6	14.3



Obr. 2 Cumulative water runoff during heavy rain (87,8 mm.h^{-1}) on medium-textured sandy clay loam (Předměřice n.L.)

Conclusions

On the loam-sandy soil at the chosen rainfall intensity of 87.8 mm·h^{-1} surface water runoff started five times sooner in wheel ruts than in crop stand. Light soils in crop stand were able to infiltrate a 15-minute torrential rain. In wheel ruts only 30 to 40% of precipitation water was infiltrated at the same time and the content of soil in runoff water was 4.9 times higher than in crop stand.

On the heavy-textured sandy-clay soil at the identical rainfall intensity the total amount of precipitation water was infiltrated for 15 minutes both in crop stand and in wheel ruts. Cumulative surface water runoff over 60 minutes was 30% of the precipitation amount in wheel ruts, which was a fourfold value of surface water runoff compared to places outside wheel ruts.

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Soil tillage methods and their effect on soil parameters

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Abstract

In years 2007-2010, two variants of soil tillage technologies, viz. shallow loosening to the depth of 0.12 m (Variant 1) and conventional technology of ploughing to the depth of 0.22 m (Variant 2) were compared with the aim to determine their impact on selected soil physical properties. In both variants of soil tillage the same crops were grown: winter wheat, spring barley, pea, safflower and maize for grain. Spring wheat was used as a subsequent crop. In all experimental years, the following physical parameters were followed and determined: bulk density, porosity, structural coefficient and stability of soil aggregates. The obtained results confirmed a positive effect of ploughing on soil structure and porosity. In contrast, in Variant 1 the soil aggregates showed a higher spreading resistance. However the results of field experiments suggested that methods of soil processing did not show a significant effect on soil parameters under study.

Keywords: physical properties, shallow loosening, conventional technology

Introduction

The past research and studies on long term effects of tillage on physical properties of soil have yielded many apparently contradictory results (Lal *et al.*, 1989). Recent literary data comparing conventional tillage (CT) and no-till (NT) in temperate agroecosystems with varying soil textures and climates was reviewed for the purpose to assess rates of change in the magnitude and stratigraphy of bulk density, porosity, pore size classes, organic matter content, and organic matter fractions (Kay, 2002). Recently, ploughless tillage has become increasingly popular, mainly to reduce the cost of tillage. Ploughless tillage may improve the soil structure compared with mouldboard ploughed soil, for example by increasing the organic matter content close to the soil surface, thereby reducing the risk of slaking (Arvidsson, 1998). So *et al.* (2009) studied the impact of 14 years of conventional and no-till cultivation on the physical properties and crop yields of a loam soil at Grafton NSW, Australia. During the earlier years of the trial, soil porosity and crop yields were not greatly affected by the different tillage techniques. During later years and at the end of the trial, however, soil porosity and structural stability were greater under NT.

On marginal and degraded soils, tillage may be required to prepare suitable seedbed or to release adequate nitrogen through mineralization but in the longer term, tillage reduces soil organic matter content, increases soil erodibility and supports emissions of greenhouse gases. The loss of organic matter often results in an increased bulk density of the surface soil because organic matter stabilizes soil aggregates against slaking, dispersion and collapse (So, 2009). In contrast, the prolonged use of continuous no-till (NT) has been shown to gradually improve the stability, macroporosity, and crop yields of loamy soils over time (Hamblin, 1984; Unger and Fulton, 1990).

Material and methods

Experiments were performed in years 2007 and 2010 in the cadastre of the municipality Troubsko, which is situated in the sugar beet growing region. The altitude of the experimental plot was 270 m above sea level and the average precipitations and temperature were 547 mm and 8.4 °C, respectively. The soil was classified as a loamy, degraded chernozem with neutral pH, 2 % of humus content, satisfactory content of phosphorus, and good reserves of magnesium and potassium. After the harvest of the foregoing crop (i.e. spring wheat), the whole stubble was ploughed and thereafter processed as follows: one half of the field was shallowly loosened to the depth of 0.12 m (Variant 1) while the other was ploughed to the depth of 0.22 m (Variant 2). The following crops were rotated in both variants of this experiment: spring wheat and winter wheat, spring barley, pea, maize, and safflower. Methods of fertilizing and crop protection were the same in both variants. Doses of nutrients applied to individual crops are presented in Tab. 1.

Table 1 Doses of nutrients (kg.ha^{-1})

Crop	**N**	**P_2O_5**	**K_2O**
Winter wheat	120	90	140
Spring barley	50	90	140
Pea	20	90	140
Safflower	60	90	140
Maize for grain	170	90	140
Spring wheat	120	90	140

Samples for the estimation of some physical properties of soil were collected after the harvest of each crop. The reduced bulk density was estimated in intact, to a constant weight dried samples by means of a standard gravimetric method. Physical condition of soil was evaluated using the method of soil columns sampled in Kopecký's stainless physical cylinders (Kopecký, 1961). Percentages of soil porosity were calculated using numeric values of bulk density of 1 cm^3 as an entry value (Valla *et al.*, 2000). Water stability of soil aggregates was evaluated using the wet sieving method (Kandeler, 1996). Soil structure was estimated by means of dry soil sieving on sieves with the mesh size of 0.25; 0.5; 1; 5; 10; 20 mm. Samples were taken from two depths, viz. 0 – 0.15 and 0.15 – 0.30 m. Each structural fraction was separately weighed and converted to percentages. For the *per se* evaluation, the coefficient of structurality was calculated; this coefficient expresses the relationship between agronomic valuable (0.25-10 mm) and less valuable structural elements (>10 and <0.25 mm). The dry matter (DM) content in the sample was estimated after drying of soil samples at the temperature of 105 °C to a constant weight and a subsequent application of gravimetric method of DM estimation (according to the standard ČSN 721110, 1959). Drying of samples to a constant weight enable to eliminate non-crystalline water from the sample without any changes in organic matter contained in the sample. Statistical evaluation was performed by means variance analysis (ANOVA P>0.05) and the Tukey's HSD procedure was used as a multiple range tests.

Results and discussions

Values of bulk density are an important indicator of the degree of pedocompaction, which represents a great negative factor. Optimal and critical limits of soil bulk density for crop growth depend upon soil texture, mineralogy, particle shape, and organic matter, which affect soil structure and, thus, water, air and mechanical resistance of the soil. Crops and cultivars respond differently to soil compaction depending on their root system (Guimaraes *et al.*, 2002). The best, or at least the simplest estimate, is to relate the field bulk density to a reference bulk density which is named the *degree of compactness* (DC). For no-till soils a reasonable assumption is that optimal DC-values are similar to those for annually loosened soils, but there is some evidence that high DC-values are less detrimental. Among the equations established to estimate the critical bulk density the critical values when considering the least limiting water range is actually lower than the critical values which restrict crop growth (Reichert, 2009).

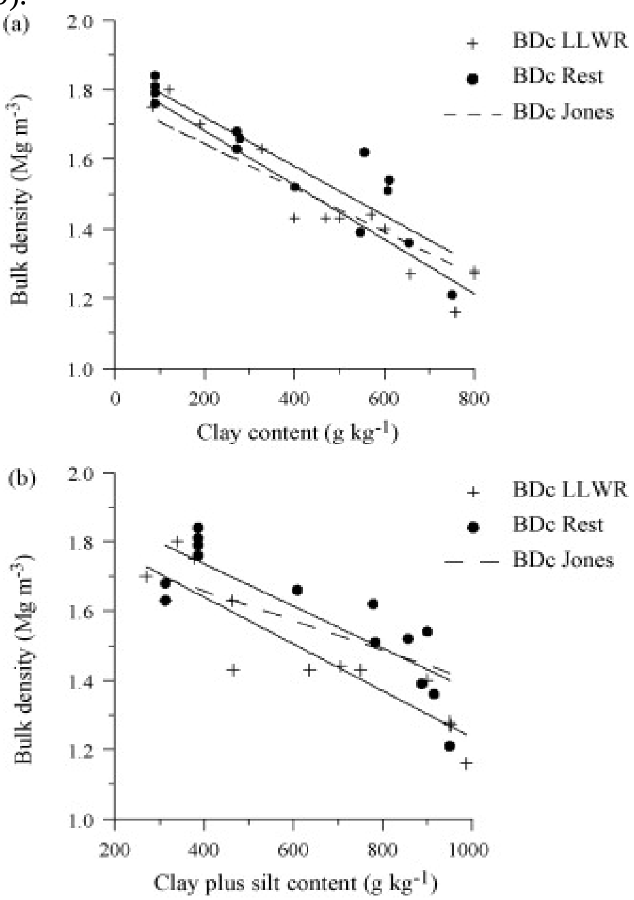

Figure 1 Critical previous bulk density considering the least limiting water range (BDc LLWR), restriction to root elongation or yield decrease (BDc Rest) and considering the equation of Jones (1983) (BDc Jones), as functions of clay (a) and clay plus silt content (b).

Measured values of reduced bulk density are presented in Fig. 2. According to a scale developed by Arshad *et al.* (1996), which classifies soils according their texture and is based on the limitation of growth of plants as a basic criterion, the minimum value of bulk density causing a limitation of root growth in loamy and loamy-clay-sandy soils is 1.70 $g.cm^{-3}$. According to Kutílek (1978) values of bulk density up to 1.4 $g.cm^{-3}$ are good, values between 1.4 and 1.6 $g.cm^{-3}$ mean that the structural status of soil is unsatisfactory, and values above 1.6 $g.cm^{-3}$ indicate that the soil is a non-structural condition. According to results of a programme of basal monitoring of soils (Kňákal, 2000), the average values of bulk density in loamy soils are 1.40 $g.cm^{-3}$ and 1.51 $g.cm^{-3}$ in the ploughing layer and in the subsoil, repsectively.

Under all crops, the determined bulk density exceeded the limit for loamy soils (i.e. 1.45 $g.cm^{-3}$). An increase in the bulk density is not necessarily detrimental to crop growth because at certain limits this increase may contribute to soil water storage and load support ability when trafficked with machines or animal trampling (Reichert *et al.*, 2009). As far as the bulk density was concerned, no statistically significant difference was found out between both variants of tillage. However, in Variant 1, the observed values of bulk density were slightly higher in all depths and under nearly all crops (with the exception of maize for grain). Kay (2002) found out that the soil under non-tillage generally had higher bulk density within the plough layer than under cultivation tillage. Lower values of bulk density observed in Variant

2 indicated that the processing of ploughing layer down to greater depths showed a positive effect on the bulk density (and thus also on the degree of compaction of soil within the ploughing layer.

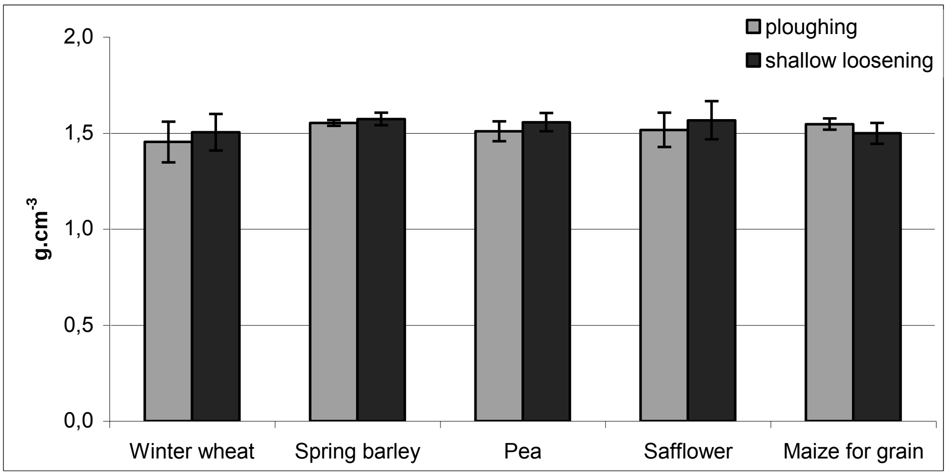

Figure 2 Average values of reduced bulk density (2007 – 2010, $g.cm^{-3}$)

Due to its close relationship to the environment, especially to the gas exchange with the atmosphere (Horn *et al.*, 1995) and surface run off and erosion (Hamza and Anderson, 2005), soil porosity can be evaluated as an ecological property.
Soil porosity can be defined as the total sum of free space in soil that is not filled up with soil particles. In average, this space makes up approximately 50% of the total volume of pedon.
In the Czech Republic, the basic criteria for the evaluation of soil porosity in agriculture were defined by Kutílek (1966). According to results of the basal monitoring of agricultural land (Kňákal, 2000), the average values of porosity in loamy soils are 47.08% and 43.75% within the ploughing layer and subsoil, respectively. When evaluating the texture (structural condition) of the humus horizon on the base of its porosity (Kutílek, 1966, Annex n° 8 of the Public Notice n° 275/1998 Sb.) the structural status of the humus horizon can be evaluated as excellent to good if the porosity value is at least 46%. Values below 46% indicate that the structural condition of this horizon is unsatisfactory and values lower that 39% indicate that the humus horizon is classified as non-structural.
Values of total porosity are presented in Fig. 3. The highest values of soil porosity in Variant 2 were recorded under winter wheat while in Variant 1 the best porosity was observed under maize for grain. On the contrary, the lowest value of porosity was recorded under the spring barley crop in both variants of tillage. Similarly, there were no statistically significant differences between both variants of soil processing (ANOVA P>0.05). Under nearly all crops under study, slightly better values of soil porosity were recorded in Variant 2. Maize for grain was the only exception of this rule because a better soil porosity was observed in Variant 1.
The loss of porosity when converting from the conventional tillage to the non-tillage system is also associated with changes in pore size distribution. The volume fraction of pores 30 – 100 mm may account for much of the decrease, whereas that of pores 100 – 500 mm may increase. It can be expected that a reduction in tillage will result in a progressive change in total porosity with time and in the approach of a new ‘‘steady state’’. However initial changes may be too small to be distinguished from the natural variation. As compared with conventional tillage, the total porosity was often reduced under conditions of no-till soil processing (results of comparisons <10 years). In 15-year comparisons, however, differences in the total porosity between methods of tillage were more consistent. These longer-term data

provide information on the cumulative effects on total porosity of fragmentation, inversion, compaction, plough pan development, soil faunal activity and organic matter distribution (Kay, 2002).

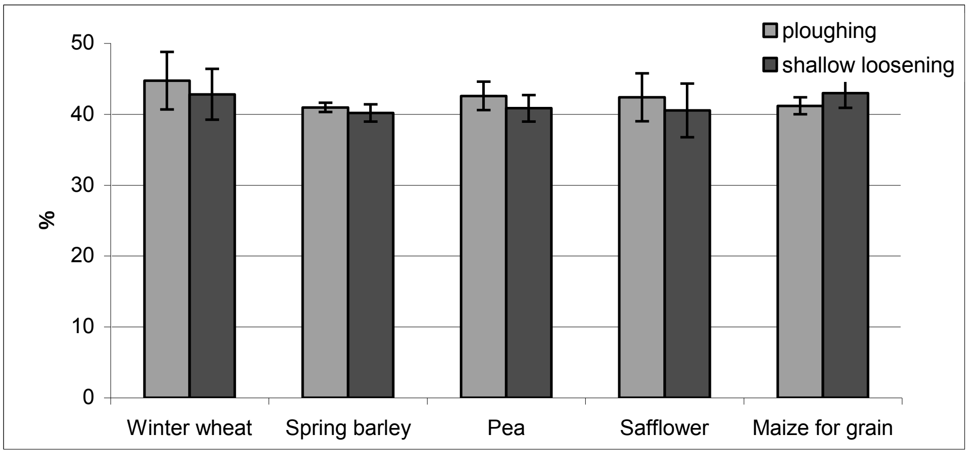

Figure 3 Percentages of soil porosity (average values, 2007 – 2010)

Agricultural activities frequently lead to a degradation of a soil structure and consequently to changes in porosity. The soil structure of permanent grassland proved to be better than that of young arable land. Kodešová *et al.*, 2011 concluded that 10 years after conversion of cropland to grassland, grasses had not fully ameliorated changes in pore structure caused by tillage. The coefficients of structurality of soil samples collected after the harvest of individual plant species as well as the subsequent crops are presented in Tab. 2. The coefficient of structurality expresses the relationship between agronomic valuable and less valuable soil aggregates. The application of this soil property for legislative purposes is rather problematic due to a subjective character of soil structure evaluation and description. However, in general descriptions of soils this characteristic of the structural condition should not be omitted. Overall average values recorded in both experimental variants under the subsequent crop (i.e. spring wheat) are presented in the bottom rows of Tabs 5 and 6. After ploughing, values of the coefficient of structurality were higher under all crops (and also subsequent crops) than those recorded after a shallow loosening but the statistical difference between Variant 1 and Variant 2 was not significant. Due to the periodical tillage, consequent soil structure breakdown and particle transport, the fractions of the large capillary pores and also matrix pores were smaller in A1, A2 and Bt1 horizons of the arable land than that in grassland horizons. On the other hand, however, due to the seasonal soil structure changes (tillage, soil cracking, biopores, etc.), the fractions of gravitational pores in arable land horizons were larger than those in grassland horizons (Kodešová *et al.*, 2011).

Table 2 Average values of the coefficient of structurality (2007 – 2010)

Crop	**Ploughing**	**Shallow loosening**
Winter wheat	1.89	1.38
Spring barley	1.33	1.28
Pea	1.47	1.09
Safflower	1.33	1.08
Maize for grain	1.30	1.30
Spring wheat	1.31	1.20

The maximum amount of water stored in soil and available for plants is one of the most important parameters used to characterize its capacity to provide water for plant growth. This is expressed by values of the soil water holding capacity (SWHC), which is defined as the difference between the water contents at field capacity and wilting point (specified in cm of water for a soil of a given depth). The stability of soil aggregates is also one of the most important factors that influence its resistance to effects of water erosion. Piedallu *et al.*, 2011 explored whether collecting a large number of plots with basic soil information would make it possible to map the soil water holding capacity (SWHC) and conclude that the SWHC can be mapped with sufficient accuracy to predict species growth using basic soil parameters collected from inventories plots. Values of stability of soil aggregates recorded in this experiment are presented in Tab. 3. Under conditions of a more intensive tillage, the content of organic matter decreases and this decrease is associated also with a decrease in stability of soil aggregates. Many authors, who studied relationships existing between intensity of tillage and its effect on the water stability of soil aggregates, concluded that under conditions of a more intensive tillage the percentage of water-stable aggregates decreased and *vice versa*. This fact was corroborated also in our experiment because all crops under study showed higher values of water stability on plots with a shallow soil loosening (i.e. in Variant 1). Nevertheless, these differences between Variant 1 and Variant 2 were statistically insignificant (ANOVA P>0.05).

Table 3 Percentages of stable aggregates (average values. 2007 – 2010)

Crop	**Ploughing**	**Soil loosening**
Winter wheat	30.13	31.22
Spring barley	28.81	30.82
Pea	30.38	34.65
Safflower	35.11	30.21
Maize for grain	14.93	18.55
Spring wheat	27.95	33.46

Conclusions

As far as the reduced bulk density of soil was concerned, there was no statistically significant difference between both variants of soil processing. However, values of soil bulk density recorded in Variant 1 were slightly higher in all depths and under nearly all crops; maize for grain was the only exception of this rule. In Variant 2, the best values of soil porosity were recorded under winter wheat while in Variant 1 the best soil porosity was observed under maize for grain. On the other hand, however, spring barley showed the most adverse effect on soil porosity in both variants of tillage. There was no statistically significant difference between both variants in values of soil porosity.

Values of the coefficient of structurality were higher under all crops in Variant 2 than in Variant 1 but the difference between both experimental variants was not statistically significant. All crops under study showed higher values of water stability on plots with a shallow loosening of soil (Variant 1). Nevertheless, these differences between the shallow soil loosening and ploughing were statistically insignificant.

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CONTENT

The influence of soil packing and different soil cultivation ways on the infestation of weeds of the winter wheat

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Abstract

The influence of soil packing and its four cultivation ways (traditional, combined, simplified U-1, and simplified U-2) on the infestation of weeds of the winter wheat has been carried out. In the spring season the least number of weeds was stated as a result of a traditional plough soil cultivation system (a variant without soil packing). In turn at objects with soil packing took place the opposite situation. After plough soil cultivation the highest infestation of a cornfield was stated, while the least one at plots where after a fore crop a disk harrow was used, and before sowing ploughing was carried out.

Towards the end of vegetation season, the number of weeds (packed and unpacked plots) in comparison with the spring state has decreased. In crops dominated *Agropyrum repens*, its highest number was stated at plots with soil packing after a traditional plough soil cultivation, while in the case of objects without soil packing where after fore crop subsoiling was used, and a single ploughing (U-2) before sowing have been carried out.

Keywords: soil packing, soil cultivation, infestation of weeds, winter wheat

Introduction

Quick pace of soil cultivation mechanization, fertilization and protection of plants and first of all their crop causes the intensification of degradation processes in the environment and changes the balance between a plant and soil.

At Polish agriculture to this day dominating soil cultivation system is plough soil cultivation called as a classical or traditional one (Gawrońska 1997). It is based on repeated use of different machines and tools in a top layer of soil and a main treatment is soil ploughing. Except advantages (good opening, turning over, breaking of soil, covering crop residues and organic fertilizers, killing weeds) the main danger of such procedure is progressing soil packing process (Dzienia et al. 1988, Domżał and Słowińska-Jurkiewicz 1995, Malicki at al. 1998).

The damage caused by soil packing is so considerable (lowering a productive potential of soil, decreasing plant crop and in some cases a stable degradation of ploughland), new more effective agrotechnical methods (and not only them) are tried to find in order to eliminate negative effects of that phenomenon.

One of ways to decrease soil packing is the implementation of environment friendly and more rational, and at the same time economically justified soil cultivation technologies (Malicki et al. 1997). Trends take into considerations not only a limited number of treatments but also their depth. Modern active machines and multifunctional units are used for soil cultivation. The shallow aeration and cyclic subsoiling are more and more common soil cultivation ways as well as the most extreme simplification form – a direct sowing (Dzienia and Sosnowski 1991).

Results of many researches show that simplifications in soil cultivation can limit in a considerable degree soil packing but can also cause among others the infestation of weeds at fields and decrease plant crop (Blecharczyk et al. 1999, Radecki 1986). Radecki, Opic (1995) and Skrzypczak et al. (1995) maintain that among agrotechnical factors, the soil cultivation (and mainly its simplification) except prophylaxis and direct chemical treatments are the most

effective ones as regards the modification of agrophytocoenosis structure especially in simplified crop rotations.
That paper substantially refers to the above-mentioned issues and it presents some topics of these researches. The main aim of the paper is the evaluation of soil packing and four soil cultivation ways on the infestation of weeds of the winter wheat.

Material and methods
The experiment started in 2008 at Productive and Experimental Company in Bałcyny village (53°42'N, 20°25'E), which belongs to the University of Warmia and Mazury in Olsztyn. The field experiment was located at medium soil, rated to RIII b valuation class and a good wheat complex of agricultural usability. The experiment was carried out at random system of blocks in 4 repetitions at all plots at the same time. The experiment included 32 plots each of the harvest area – 40 m^2.
The comparison of object are four soil cultivation ways in three-field crop rotation: the winter rape – the winter wheat – the spring barley. Results presented in that paper concern the vegetation season 2009 – 2010.
Experiment control**.**
I – the degree of presowing soil packing

- control object without soil packing
- object with soil packing after fore crop harvest. The ride of machines set weighing 6 tonnes track after track (tractor + trailer).

II – four different field preparation systems for sowing a tested plant.
Detail selection and soil cultivation sequence for sowing the winter wheat is shown in Table 1.

Table 1. Experimental design comprised the following cultivation sequence

Soil cultivation way	Traditional soil cultivation- control object	Combined soil cultivation	Simplified soil cultivation U - 1	Simplified soil cultivation U – 2
After harvest	Skimming 10 cm + maintenance	Soil miller	Disk harrow+ maintenance	Chisel (40 cm)
Before harvest	Sowing ploughing 20 cm	Sowing ploughing 20 cm	Sowing ploughing 20 cm	Single ploughing 30 cm
Sowing	Plough and sowing set	Plough and sowing set	Plough and sowing set	Plough and sowing set

The winter wheat of Ludwig variety was sown at optimal agrotechnological term in the amount about 205 $kg \cdot ha^{-1}$. Doses of mineral fertilizers at all objects were unified and amounted: 220 kg/NPK (N-40; P_2O_5-80 and K_2O-100). Weeds were killed chemically in the period when a plant achieved the phase of 6th-7th leaf, Atlantis preparations were used 0.15 $kg \cdot ha^{-1}$+ Sekator 0.15 $l \cdot ha^{-1}$ + Actirob 1 $l \cdot ha^{-1}$
The number and species composition of weeds in the wheat cornfield was determined in the spring when started the vegetation (before chemical weed killing), and at the maturity phase, its dry matter was also determined in the second term. Measurements were carried out at the area of 1m^2 (in two repetitions at every plot). The results were statistically verified using analysis of variance at $p = 0.05$.

Results and discussion
The evaluation of the winter wheat infestation of weeds in the first term (the spring) has shown the influence of soil packing and tested soil cultivation systems on the number of weeds. At pressed plots in comparison with objects without soil packing the number of weeds

was by 38.1% higher. Among compared cultivation variants in the case of a traditional plough cultivation (the object without soil packing) the least infestation of weeds was stated (42 pieces per $1 \cdot m^{-2}$); the opposite (the highest density of weeds per an area unit) were objects, where in the after harvest cultivation system, subsoiling was used, and before sowing a single ploughing has been carried out (U-2 cultivation). In comparison with a control object (traditional soil cultivation) the increase of infestation of weeds was about 57.1%. In the cornfield dominated *Thlaspi arvense, Stellaria media* and *Lamium amplexicaule,* consituted in total 67.7% of all identified weeds (Table 2).

Table 2. Infestation of weeds of the winter wheat in the spring period

Specification	Soil cultivation system				Average
	Traditional	Combined	Simplified U-1	Simplified U-2	
Object without soil packing					
Weeds in total per 1 m^2	42	49	58	66	53,8
Thlaspi arvense	16	23	23	20	20,5
Lamium amplexicaule	6	5	13	9	8,3
Stellaria media	3	4	10	14	7,8
Capsella bursa pastoris	5	4	1	9	4,8
Tripleurospermum inodorum	5	3	3	4	3,8
Viola arvensis	1	4	5	4	3,5
Chenopodium album	2	2	3	4	2,8
Veronica arvensis	4	2	-	-	1,5
Remaining	-	2	-	2	1,0
Species number in the community	8	10	7	9	8,3
Object with soil packing					
Weeds in total per 1 m^2	87	62	59	88	74,3
Thlaspi arvense	24	18	15	28	21,3
Stellaria media	13	8	14	27	15,5
Viola arvensis	15	11	6	11	10,8
Lamium amplexicaule	15	7	10	9	10,3
Capsella bursa pastoris	6	7	-	8	5,3
Tripleurospermum indorum	4	5	3	3	3,8
Poa annua	7	5	1	1	3,5
Chenopodium album	3	-	8	1	3,0
Remaining	-	1	2	-	0,8
Species number in the community	8	8	9	8	8,3

$LSD_{(0.05)}$ – for soil packing– n.s., for soil cultivation way – n.s., for interactions (soil pressing x soil cultivation way) – n.s., dry matter – n.s.

In the case o packing soil (similarly as at objects without soil packing) the highest number of weeds was stated after simplified soil cultivation (U-2). The least number of weeds, however was at objects when in the set of after crop soil packing a disk harrow was used, and before sowing of a tested plant a sowing ploughing at a depth of 20 cm (U-1) has been carried out. In tested soil cultivation variants , communities of weeds formed a similar number of species

(from 8 to 9 pieces per m^{-2}). Similarly as at plots without soil packing dominated: *Thlaspi arvense, Stellaria media, Viola arvensis and Lamium amplexicaule.*
The appropriate density of plants of the winter wheat cornfield including a chemical crop protection, effectively limited a competitive power o weeds (Table 3). Towards the end of vegetation the number of weeds in comparison with the spring state has decreased by over 67 % at plots with soil packing, and by 32.6% at objects without soil packing. The highest number of weeds was stated in the case of U-2 variant (chisel and a single ploughing 30 cm), the least one (23 pieces per m^{-2}) at a control object (a traditional ploughing). In turn at plots with soil packing the opposite situation has occurred. The highest density of weeds per an area unit was stated after a traditional soil cultivation (36 pieces/m^{-2}). In crops dominated *Agropyrum repens* at objects without soil packing. Simplifications in soil cultivation increased its density at the same time the highest density was stated in the case o U-2 simplified soil cultivation while at plots with soil packing the opposite situation has occurred – the highest number of that taxon (17 pieces/m^{-2}) was stated at a control object (a traditional soil cultivation).
Similarly a dry matter of weeds was diversified among compared soil cultivation ways (Table 3). The biggest biomass (objects with soil packing) was stated after a traditional soil cultivation (10.3 g/m^2). At remaining objects a dry matter of weeds has been decreased significantly, showing the lowest values at plots with subsoiling and a simple ploughing (1.2 g/m^2). In turn at plots without soil packing the opposite situation was stated. The U-2 simplified soil cultivation (chisel and a single ploughing 30 cm) created the most favourable conditions for the development of weeds, its dry matter in comparison with a control object (plough soil cultivation) was over 7-fold bigger.
The results presented in that paper are generally in accordance with data shown by Dzienia, Wrzesińska (2003), and Malicki et al. (2000). The above-mentioned authors have show that use of simplified techniques including their the most extreme form (a direct sowing) cause a general increase of the infestation of weeds. It concerns not only annual weeds but oppressive many years' weeds as well. Kordas (2004) states the departure from classical soil cultivation treatments only in the initial period causes the increase of the infestation of weeds. In next years the infestation of weeds is decreased even below the level existed in the case of a traditional soil cultivation. However, Budzyński et al. (1995) and Rola et al. (1994) did not stated any increase of the infestation of weeds at objects with a simplified soil cultivation and sometimes they have stated the decrease of a total number of weeds. Pałys and Podstawka-Chmielewska (1995) state the general diversity of weeds depends not only on a used soil cultivation but also on a cultivated plant where a given phytocoenosis is formed. It has been confirmed by Malicki et al. (2000) who on the basis of experiments with the winter wheat stated that plough soil cultivation created favourable conditions for species diversity of short duration weeds, while a simplified soil cultivation causes their compensation. The authors inform that the effect of a diversified soil cultivation in shaping phytocoenosis of a cornfield can depend on other factors, among others on wheather conditions in the vegetation season. Jędruszczak and Antoszek (2004) after the evaluation of the influence of different simplified forms of soil cultivation on the infestation of weeds of wheat have shown the diversity of weeds before a crop did not depend on soil cultivation ways. However in the spring the infestation of weeds has shown a bigger diversity of species after a traditional soil cultivation than soil cultivations limited to the disk harrow and cultivator tillage. In turn, Stupnicka-Rodzynkiewicz et al. (2004) stated, the additional use of chisel during after harvest soil cultivation in comparison with a traditional plough soil cultivation significantly decreased species diversity of weeds in the winter wheat.

Table 3. Infestation of weeds of the winter wheat during the crop

Specification	Soil cultivation way				Average
	Traditional	Combined	Simplified U-1	Simplified U-2	
Object without soil packing					
Woods in total per 1 m^2	23	28	44	51	36.5
Agropyrum repens	-	3	19	22	11.0
Myosotis arvensis	4	4	8	8	6.0
Galinsoga parviflora	9	3	5	5	5.5
Veronica arvensis	5	3	5	2	3.8
Poa annua	-	3	2	4	2.3
Viola arvensis	3	3	3	-	2.3
Veronica persica	-	3	-	4	1.8
Plantago maior	-	-	1	4	1.3
Remaining	2	6	1	2	2.8
Number o species in a community	6	13	8	10	8.3
Dry matter of weeds in g/m^2	1.2	2.0	7.4	9.2	5.4
Object with soil packing					
Woods in total per 1 m^2	36	21	18	22	24.3
Agropyrum repens	17	12	9	1	9.8
Echinochloa crus-galli	1	-	1	15	4.3
Viola arvensis	11	5	-	-	4.0
Polygonum aviculare	1	2	2	-	1.3
Poa annua	-	1	1	1	0.8
Remaining	6	1	5	5	4.3
Number o species in a community	10	5	7	6	7
Dry matter of weeds in g/m^2	10.3	7.0	3.4	1.2	5.5

$LSD_{(0.05)}$ – for soil packing– 8.3, for soil cultivation way – n.s., for interactions (soil pressing x soil cultivation way) – n.s., dry matter – n.s.

Conclusions

1. The researches did not show the influence of compared soil cultivation ways on a quantitative state of the infestation of weeds of the winter wheat in the spring season. At soil packing plots in comparison with soil without packing, the infestation of weeds was bigger. Among compared soil cultivation variants, a traditional plough soil cultivation was the most favourable (an object without soil packing) in contrast with plots where subsoiling in the after harvest soil cultivation set was used, and before sowing a single ploughing (the biggest amount of weeds per an area unit) has been carried out. In the cornfield dominated *Thlaspi arvense, Stellaria media i Lamium amplexicaule.*
2. In the case of soil packing (similarly as at objects without soil packing) the least number of weeds was stated for U-1 simplified soil cultivation (disk harrow and sowing ploughing 20 cm). In tested soil cultivation variants communities of weeds formed a close number of species (from 8 to 9 pieces/m^{-2}).
3. Towards the end of vegetation, the number of weeds at plots with or without soil packing in comparison with a state of the spring season has decreased. The highest density of weeds was

stated at U-2 soil cultivation variant (chisel and a single ploughing 30 cm). The least one at a control object (a traditional soil cultivation). The opposite situation took place at plots with soil packing. *Agropyrum repens* dominated in crops. At objects without soil packing, simplifications in soil cultivation have increased their number, while at plots with soil packing have decreased its number.

4. The biggest biomass of weeds (plots with soil packing) was stated after a traditional soil cultivation, while the least one at plots with subsoiling and a single ploughing. At objects without soil packing the opposite situation was

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Minimum tillage and environmental aspects

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Abstract

In Austria due to the cultivation of corn, sugar beets, sunflowers, soybeans, potatoes, including wine and fruit, about 450,000 hectares of farmland are at potential risk of erosion. For this reason the cause of soil erosion and the possibilities for reduction and prevention will be investigated.

From 1994 to 2010 eight different tillage systems were tested at three locations in Lower Austria. Four tillage systems were tested in Tulln – located 30 km from Vienna, beginning 2006 on other additional locations in Lower Austria. The system includes conventional tillage with a plow as well as mulch and direct drilling of cover crops in autumn. No-tillage was tested also. The Institute of Hydraulics and Rural Water Management of the University of Natural Resources and Applied Science Vienna (Prof.A.Klik, Ph.D.) measured surface runoff, soil loss, nitrogen, phosphorus, and herbicide loss. Mycotoxins were analysed in an institute in Tulln. Between 1994 and 2010 the average soil loss at the three locations dropped from 6.7 t/ha/year (conventional tillage) to 2.2 t/ha/year with conservation tillage in cover crops, and to 1.1 t/ha/year with direct drilling systems. Nitrogen and Phosphorus losses showed similar tendencies. Herbicide loss declined by 2.2 % at the application rate in conventional tillage; 1.0 % in conservation tillage and 0.6 % in direct drilling systems.

In another project different soil tillage systems were investigated with respect to their impacts on Carbon dioxide emissions due to soil respiration and on carbon sequestration in the soil, carbon dioxide emissions due to machine use and agro – economical aspects.

Key words: soil erosion, soil tillage, cover crops, Nitrogen and Phosphorus loss, carbon dioxide emission, carbon sequestration

Introduction

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

Reasons for minimum tillage and no tillage:

- Lowering of production cost
- Fewer passes – less work time → less soil compaction
- Increased productivity – cultivation of larger area possible
- Reduction of fuel consumption (250 l/ha → < 80 l/ha)
- Lower machine use
- Prevention of wind – water – tillage erosion
- Increased humus content, better aggregate stability – better carrying capacity of the soil (plant protection, fertilizing, harvesting), low erosibility
- Improved water retention

- Better yield
- Lower carbon dioxide release from the soil → climate – and soil alliances

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

Material and methods

Different cultivation systems were examined at several locations in Lower Austria in the dry Hungarian climate (Pannonicum) and in the moderate transition climate. The climate is characterized by an annual precipitation amount of 500 mm in the Hungarian Climate (Pannonicum), 650 mm in the transition climate and by an annual average temperature of 8.5 °C – 11 °C.

Besides the conventional seed bed preparation with plow and chisel plow, different cover crops such as yellow mustard, California bluebell (Phacelia tanacetifolia), oil radish, clovers, green rye, buckwheat followed by mulch and direct seed were tested. Two tests of minimal cultivation using only a disk harrow and a No-Tillage variation were examined for yield achievement and the Mycotoxin content.

The conventional seeding was accomplished with use of a plow and cultivator plus harrow or rotary harrow for seedbed preparation. The mulch seeding was accomplished after two passes with the chisel plow followed with the cover crop. After mulch cultivation with a rotary harrow or seedbed combination implements, the direct drilling with cover crop management was just like the mulch seeding, yet the seedbed preparation was omitted (ZeroTillage). All three aforementioned systems were cultivated with a direct seeding machine.

Results and discussion

4.1. Soil erosion tests

Following in Table 1 are the results of the three locations: Mistelbach (wine quarter, 30 km north of Vienna), Tulln (30 km west of Vienna) and Pyhra around St. Pölten (50 km west of Vienna). Mentioned are the three cover crops and tillage links, which were also tested for soil erosion. Besides the soil loss in t/ha/year the table also refers to the nutrient losses of Nitrogen and Phosphorus separate from the herbicide shift. The calculated grain yields - corn crop rotation (Mistelbach 1 x sugar beets, 1 x sunflowers, and Tulln 1 x sugar beets instead of corn in the crop rotation) are likewise represented in Table 1. No fall cover crop was done with the conventional seeding (disk harrow- cultivator, plow, seedbedprepartion with rotary harrow). The mulch seeding, added in beginning - mid-August, consisted of 7.5 kg vetchling, 11 kg winter tares, 3.7 kg buckwheat, 1.1 kg Egyptian clover, 1.1 kg Persian clover, and 0.4 kg yellow mustard as fall cover crops. In springtime seedbed preparation was done by a rotary cultivation and so mulch prepared. The direct seed without any tillage in springtime of 3 kg yellow mustard and 7 kg California bluebell were sown at the aforementioned date.

Table 1: Measured yearly erosion and yield 1994 – 2010 in Lower Austria - Mistelbach, Tulln, Pyhra
(Klik et.al. 2010)

Cultivation method	**Conventional Tillage**	**Mulch Seeding**	**Direct Drilling**
Soil loss t/ha/Year Reduction	6.7	2.2 67 %	1.1 84 %
Nitrogen loss kg/ha/year Reduction	12	6.5 46 %	3.8 68 %
Runoff mm/ha/year 1994-2010	24.3	20.9	19.4
Runoff mm/ha/year 2007	109	47	5
$C_{organic}$ loss kg/ha	76.7	27.5	19.2
Phosphorus loss kg/h/year	5.0	1..5	0.8
Herbicide loss % sprayed active substance	2.2	1.0	0.6
Yield in % Conventional	**100**	**104**	**100**

As shown in Table 1, notable reductions in soil, nutrient, organic C loss and herbicide erosion are determined. The runoff could be reduced 2007 in the trials near Tulln (40 km west of Vienna situated on the river Danube) the first time significantly – the infiltration rate increased noticeable. In the conventional plots 2007 - 20 % of the annual rainfall run off, in the direct drilling plots approximate zero. The yields do not differ significantly in the erosion trials on 3 locations in Lower Austria in the period 1994 – 2010.

4.2. Cultivation tests Lower Austria

Four soil conservation method trials, listed in Table 2, were set-up in 7 locations in Lower Austria. In addition to conventional cultivation methods with plow and chisel plow, cultivation using two passes with a disk harrow was tested. One test link was minimum tilling with a single disk harrow. For this method a seed bed was prepared with a rotary harrow or seed bed combination implements until 2008 –later it was stopped, but when the NoTill method (zero Tillage) is used the soil will not be cultivated. Here several centimeters of soil were more or less worked by direct drilling with a disk coulter from a seed drill, in the spacing drill there was no soil preparation.

Next to the yield results in kg/ha 1999-2010 in Table 2 are the net profits indicated. Net profit is calculated net yield minus expense from machinery and is an indicator for the profit of the farmer.

Table 2: Cultivation test results (yield and net profits) Lower Austria on 7 locations several years:

Tillage method	**Yield in % Conventional**	**Netprofit in % Conventional**
Conventional Tillage Cultivator-Plow-Seedbed preparation	100	100
Reduced - Chisel Plow/disc harrow 2 x	99	111
Minimum Tillage (Disc Harrow 1x)	93	108
No Tillage NT	88	104

The yields are significantly different within the tillage systems. The minimum and No Tillage plots showed significant lower yields, caused by problems in single space drill and closing the slots. Incomplete crop densities are the results of not adapted single space drill in corn, sunflowers, sugar beets and other row crops in Europe while in the USA, Canada and South America these No Till – spacing drills are adapted with coulter discs in front of the planter to produce loosening soil for closing the slots. The germination occurred in our tests but then the seedlings dried in the case without soil cover.
The reduced machinery costs make better net profits possible and make minimum tillage and no tillage competitive. The crop rotation must be adapted and consider plant diseases like Fusarium sp., which produces high poisonous mycotoxines.

4.3. Tests of CO_2 emission by cultivation
Soils play a key role in the global carbon cycle. They can act as source as well as a sink for carbon and therefore influence the carbon dioxide concentration in the atmosphere. Carbon is fixed by assimilation of plants and transferred into the soil by their roots. The release into the atmosphere in the form of CO_2 occurs mainly due to soil respiration of microorganisms. The intensity of these processes depends mainly on environmental conditions for the soil organisms like kind of substrate, soil water content, aeration, soil temperature and pH-value. In addition the intensity is also heavily affected by the soil management and tillage system.
Different soil tillage systems should be investigated with respect to their impacts on:
carbon dioxide emissions due to soil respiration and on carbon sequestration in the soil
carbon dioxide emissons due to machine-use.
The experiments are carried out at four sites in Lower Austria and Styria on fields with different crop rotations. The average annual precipitation at the sites ranges from 645 to 945 mm with a mean annual temperature between 9.1 and 9.6 °C. The soil textures cover loamy clay, sandy and loamy silt and loamy sand.

The following soil tillage systems are compared:
Conventional tillage (CT) with plough with and without cover crop during winter period

Conventional tillage with mechanical weed control (only at two sites)
Reduced tillage (RT) with cultivator with cover crop during winter period
No-Till (NT) with cover crop during winter period.
Since April 2007 CO_2 emissions have been measured in Pixendorf and Tulln in weekly intervals. From April to November 2007 average carbon losses due to CO_2-emissions from the soils between 4.81 and 6.93 $t.ha^{-1}$ were determined. Corresponding values for the period from February to July 2008 ranged between 3.91 and 6.85 $t.ha^{-1}$. NT mostly delivered lowest emissions with about 82 % of the CT-values. Reduced tillage showed no significant change in soil respiration compared to CT.
A single measurement of nitrous oxide emissions in June 2008 in Pixendorf showed that NT released highest fluxes (0.23 mg $N_2O.m^{-2}.h^{-1}$) while no significant difference occurred between CT and RT (0.19 and 0.17 mg $N_2O.m^{-2}.h^{-1}$, respectively). This result represents only a snap-shot.
Soil tillage affects also the stability of soil aggregates. Laboratory experiments for Pixendorf soil indicate that due to conventional tillage soil aggregate stability is reduced by more than 50 %. Therefore they are more susceptible to soil erosion by wind and water. This decline in aggregate stability is mainly induced by the lower organic carbon contents.
The operational carbon dioxide emissions are determined by the fuel consumption for the different tillage operations. Measurements of fuel consumption for planting of winter wheat in Tulln in autumn 2007 resulted in 10-times higher fossil CO_2 emissions for CT than for NT. Compared to CT reduced tillage (RT) reduced carbon dioxide emissions by about 50 %.
The results of the first year of this research project indicate that soil tillage system but also the soil environmental conditions affect soil respiration of microorganisms and therefore carbon dioxide emission from soils. Systems with reduced tillage intensity tend to decrease the loss of organic carbon by reduced soil respiration. In addition less frequent passes of agricultural machinery reduces fossile carbon dioxide release by up to 90 %.

Conclusion

Mulch –and direct –seeding systems are fully developed and go well in practice.
The economical benefits must not ignore the nutrient – pesticide and soil movement (erosion).
Cereal – maize crop rotation needs a shallow mulch of crop residuals for a fast decomposition as a phytosanitary need (Fusarium disease → mycotoxines)
After harvest the growth of volunteer cereals has to be interrupted, they stand for a green bridge for plant diseases like barley yellow dwarf virus or Fusarium sp. and pests like aphids as a vector for the virus.
An immediately seeding of cover crops after harvest within a few days for a good development of the green manure.
The production of Mycotoxins by Fusarium disease is to be interrupted by shallow soil tillage and an adopted crop rotation.
Measurement of fuel consumption for planting resulted in 6 -10-times higher fossil CO_2 emissions for CT than for NT. Compared to CT reduced tillage (RT) reduced carbon dioxide emissions by about 50 – 60 %.
A reduction of the costs is possible and realistic.
A prescription is not possible and depends from the crop rotation and natural situation.

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CONTENT

Controlled traffic farming as a strategy to reduce compaction risks

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Abstract
Reducing the risk of soil compaction asks for machinery adapted to the limitations of soil strength in the single wheel track, but also for strategies of field traffic organization to control the distribution of wheel tracks in the field. On the other hand promoting soil structure formation is closely linked to tillage practices and the degree of mechanical structure disturbance. Studying the combined effects of different field traffic organizations and tillage practices on structural development of arable soils and on crop development is the aim of a field experiment at Tänikon, Switzerland. In this article, the concept of soil management treatments combining random and controlled field traffic with plough tillage and no-tillage is presented. First results three years after the start of the field experiment show that effects on soil structure caused by these combinations of tillage/seeding technique and field traffic organisation are not very clear-cut yet.
Keywords: Soil compaction, field traffic organisation, tillage system, soil structure evolution, macropore volume, air permeability, yield

Introduction

Sustainable soil management relies on the proper maintenance of soil structure. This means on the one hand reducing the risk of soil compaction and on the other hand promoting the formation of soil structure.
Reducing the risk of soil compaction asks for machinery adapted to the limitations of soil mechanical properties. To this end the size and load of the contact area between machine and soil have to be controlled, optimizing machinery properties like arrangement of wheels, wheel load, tyre type, tyre dimension and inflation pressure. At the same time the consideration of soil structural strength during field operations, especially its short term aspect related to soil moisture, is crucial for reducing the risk of structure deterioration (Alakukku et al. 2003). Besides these efforts to reduce mechanical impacts in the single wheel track, there is also the important goal of reducing mechanical impacts on the whole managed field area, calling for strategies of field traffic organization (Chamen 2006).
Promoting soil structure formation in order to alleviate structural damages and to improve structural quality is closely linked to tillage practices. Especially the degree of mechanical disturbance, or soil loosening, is important for the equilibrium between stability and functionality of soil structure. Effects of different tillage intensities on the properties and the evolution of soil structure are elements of many field experiments comparing e.g. plough tillage to no tillage (Anken 2003).
Whereas the assessment of soil compaction risk in wheel tracks and the corresponding adaptation of farm machinery are well known and part of good management practices (Stettler et al., 2010), the interaction between field traffic organization and tillage systems and its effects on the quality of soil structure the whole field area is not well studied and therefore not easily accessible for practical optimisation.
Studying the combined effects of field traffic organisation and tillage system on agronomic and environmental aspects is the aim of a field experiment at Tänikon, Switzerland. On an arable soil and in a crop rotation, typical field mechanisation is used to apply two field traffic and three tillage treatments as experimental factors, resulting in well-defined field areas with characteristic wheeling and tillage history, and therefore presumably with a particular evolution of soil structure.

Today a typical field traffic organisation in Switzerland is defined by a) the use of field operations with different working widths and depths, b) a mostly random traffic pattern for tillage, fertilization and harvest operations, and c) temporary traffic lanes for spraying and fertilization operations. In most cases, the aim is to eliminate adverse effects of field traffic on soil structure before installing the next main crop by a deep tillage of the whole field area, thereby increasing porosity and reducing stability of the soil.

With respect to sustainable soil management, this way of soil structure evolution may be questionable: Randomly affecting the soil structure of a high proportion of the field area and afterwards routinely alleviating structural damages may not be the optimum solution regarding soil quality, ecological side-effects and management expenditures (Weyer 2007). Given the increasing availability of low-intensity tillage and seeding techniques as well as precise guidance systems, other solutions may be more promising.

In random traffic farming (RTF), machine widths are chosen as available and field traffic is only in certain crops and for certain operations organised, generally leading to the wheeling of practically the whole cultivated area in the course of time. In controlled traffic farming (CTF), machine widths of the different field operations are closely matched and all field passages are restricted to permanent traffic lanes (Chamen, 2006, Webb & Blackwell, 2004, Hamza & Anderson, 2005), leaving areas between the traffic lanes which are no longer wheeled (Fig. 1). As a consequence the soils of these no longer affected areas should develop an improved structure with e.g. better water infiltrability, permeability and storage capacity as well as rootability (Chamen et al, 2003).

Because of its specific mechanisation, CTF in a strict sense, as introduced e.g. on millions of hectares in wheat and sugar cane production fields of Australia, cannot simply be copied to every production region. In order to minimize the share of unproductive permanent traffic lanes, track and working widths of the agricultural machinery are widened. This results in elevated investments as well as in restricted versatility and usability of specific CTF machinery under typical central European production conditions, especially regarding field sizes and forms, topography, and road traffic system (Holpp et al, 2009).

In order a) to check the feasibility and the agronomic as well as the ecologic potential of CTF combined with reduced tillage and b) to compare CTF to other management systems under Swiss conditions, a field experiment was started in 2008 at Tänikon, Switzerland. In this paper the basic considerations regarding CTF solutions for Swiss conditions by the use of available standard machinery, the layout of the field experiment at Tänikon and first results on the effects of the investigated management systems on parameters of soil structure are presented.

Material and methods

Experimental design and treatments

In 2008 the CTF field trial was installed at the Swiss Federal Research Station in Tänikon on 539 m above sea level. The soil is a deep orthic luvisol with a loamy texture and an elevated content of stones (approx. 10 vol.% in the 0-90 cm depth range). Table 1 characterises the site with information on soil properties and on mean annual temperatures and total annual precipitations.

The intention was to test the feasibility of a CTF version adapted to Swiss site and management conditions, to combine it with no-tillage, and to compare this soil management treatment with other typical traffic x tillage-solutions. The comparison is done by monitoring the impacts of the different traffic patterns and the effects of the different tillage systems on soil structure, soil processes and agronomic parameters.

Table 1: Site characteristics of the CTF field trial at the Swiss Federal Research Station in Tänikon.

Soil characteristics	Topsoil 0-20 cm	Subsoil 30-50 cm
Clay [w/w]	19	20
Silt [w/w]	27	28
Sand [w/w]	52	51
org. C. [w/w]	1.16	0.94
pH (H_2O)	6.10	6.43

Weather characteristics	2009	2010	Long term mean[1)]
Precipitation [mm]	1138	1227	1042
Temperature [°C]	9.3	8.3	8.5

[1)] average for 1961-1990

On plots of 12 m width and of 30 m length, three combinations of tillage/seeding techniques and field traffic organisation were installed as soil management treatments: CTF no-till, RTF no-till and RTF plough (Table 2). The basic experimental layout corresponds to a randomized block design with three soil management treatments and four replications. In each soil management treatment, sub-areas are defined and monitored as follows: unwheeled, moderately wheeled and intensively wheeled in CTF, randomly wheeled in RTF (Table 2). Because there was a preceding experiment on effects of tillage/seeding techniques on soil properties and processes running at this field until 2007 (Anken et al., 2003), the layout of the soil management treatments in the CTF experiment starting in 2008 was adapted to the existing layout of tillage/seeding treatments, which offered the possibility to benefit from established tillage treatments: RTF plough followed the former plough treatment and RTF no-till followed the former no-till treatment; in contrast CTF no-till followed the shallow (10 cm) mulch seeding treatment. Therefore, at least in the first few years of establishing the CTF no-till system after the shallow mulch seeding, direct comparisons between the two no-till treatments (CTF no-till and RTF no-till respectively) have to be judged with care (Table 2).

Table 2: Treatments and sub-treatments of the CTF experiment. Unwheeled traffic zones occur in CTF no-till only. Whereas the traffic lanes Di and Pi are used for spraying of plant protection products and application of fertilizers, the permanent traffic lane Ci is used for all field operations. The moderately wheeled traffic zone in Cm is used for controlled field traffic during tillage and harvest operations. The area of the sub-treatments Dr and Pr is randomly wheeled during tillage, fertilizing and harvesting operations.

	Sub-treatment (traffic zone)		
Treatment	unwheeled	moderately (CTF) or randomly (RTF) wheeled	intensively wheeled
C (CTF no-till)	Cn	Cm	Ci
D (RTF no-till)		Dr	Di
P (RTF plough)		Pr	Pi

The adaptation of the CTF treatment to Swiss conditions consisted in two aspects. Firstly, a working width typical for Swiss farms was chosen (4.5 m). This lead to a traffic pattern resulting in three typical traffic zones: the unwheeled zone, the moderately wheeled zone and the intensively wheeled zone (Fig. 1).

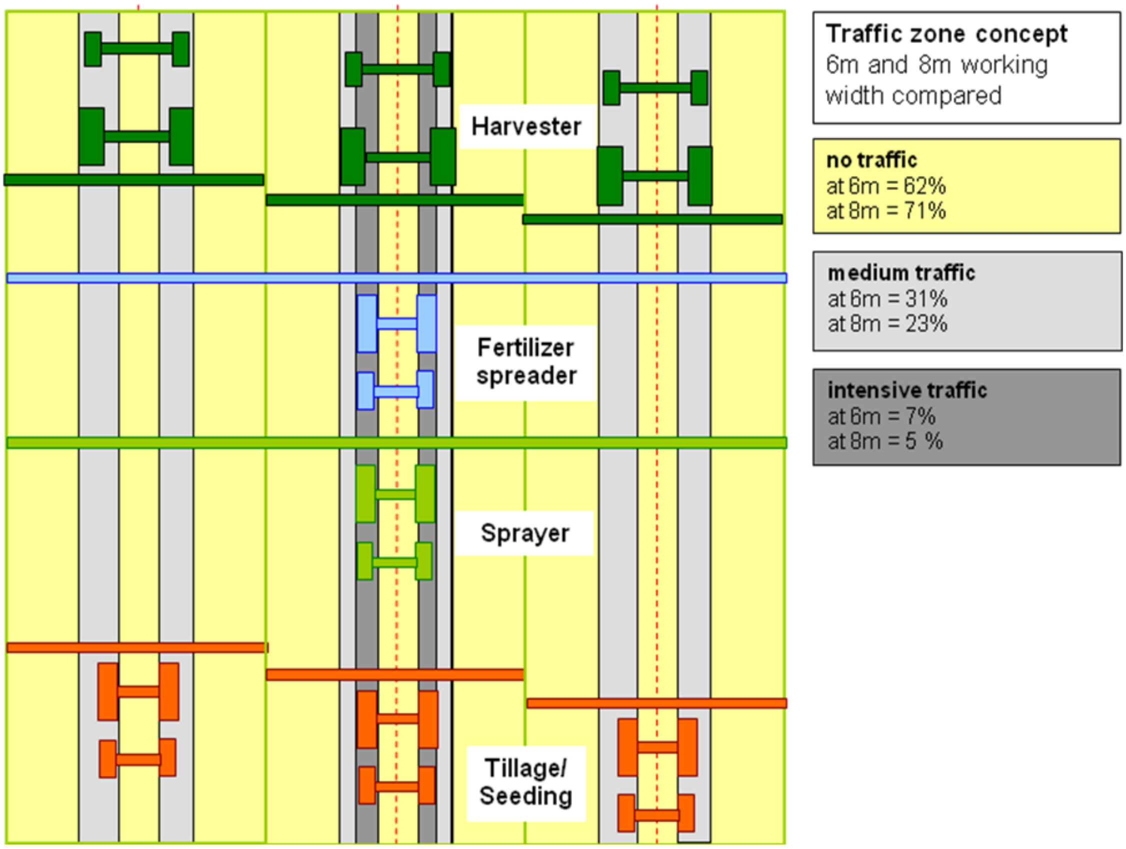

Figure 1: CTF adapted to available standard machinery leads to three traffic zones with differing mechanical impacts on soil structure: intensive traffic is concentrated on less than 10% of the cultivated area, whereas more than 60% of the cultivated area remains totally unwheeled. The moderately wheeled traffic zone is owed to the concessions to smaller working widths for tillage/seeding and harvesting operations and to low pressure tyre equipment respecting the requirements of physical soil protection.

Secondly all the traffic lanes must – according to the Swiss ordinance on impacts on soil – be part of the productive soil surface and are therefore subject to soil protection measures. Because of that the machines driving on the traffic lines have to meet the requirements of physical soil protection and will be equipped with the necessary (wide) tyres. This means also that the traffic lines in both the moderately and the intensively wheeled zone are cultivated in the same way as the unwheeled zone. Altogether, these two adaptations of the CTF treatment are leading to a higher proportion of wheeled zones, especially moderately wheeled zones, as compared with CTF solutions in e.g. Australia.
The three soil management treatments are running in the crop sequence winter wheat (2009), winter barley (2010), two years of ley (2011/12), and presumably silage maize (2013). Field operation dates as well as fertilization and plant protection were the same in all three treatments.

Mechanisation
Specific tillage/seeding machines: in the RTF plough treatment a two-furrow plough of 0.70 m working width and a 3 m rotary harrow seeding combination is used; in the RTF no-till a 2.25 m no-till seed drill, and in the CTF no-till treatment a 4.50 m no-till seed drill, respectively, is used.
Harvesting machines: in all treatments a combine harvester with a working width of 4.50 m and a tractor-driven mowing combination for forage harvest are used (Table 3).
The rest of the machines is the same for all three treatments - only the field traffic organisation differs. Spraying of plant protection products and application of fertilizers are carried out from a traffic lane in the middle of each experimental plot. In agreement with best

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practice in physical soil protection, all self-propelled machines are equipped with appropriate tyres, which are operated with the minimum necessary tyre inflation pressure (Table 3).

Table 3: Machines, tyres and tyre inflation pressures used in the CTF experiment.

Machine	Empty weight [kg]	Front axle Tyre	Front axle Inflation pressure [kPa]	Rear axle Tyre	Rear axle Inflation pressure [kPa]
Same Dorado 75: plough, cultivator	3’950	360/70R20	80	420/70R30	80
John Deere 6920S: no-till	7’320	540/65R28	80	650/65R38	80
Fendt 411: plough/seed drill	5’770	420/70R24	80	460/85R34	80
John Deere 2254: combine harvester	12’900	800/65R32	100	540/65R24	120

Parameters and methods

Soil structure is characterized by bulk density, total porosity, macropore volume and air permeability. These structural parameters are determined from the same cylindrical soil samples of 100 mm diameter and 60 mm height; in the sub-treatments Ci, Cm, Cn, Dr and Pr (see Table 2) of blocks 2 and 3 soil samples are taken in 8 replications from 10 to 16 (topsoil) and from 35 to 41 cm depth (subsoil) every year in spring (with appropriate soil conditions during April and May) after structural equilibration during winter. Bulk density is determined by weighing and measuring the saturated height of the samples, total porosity by calculation using bulk density and analyzed particle density. Macropore volume is analysed by determining the height and weight of the soil samples after saturation and following desorption to 60 hPa; air permeability is determined by measuring the air flow passing the sample conditioned to 60 hPa vertically with an overpressure of 2 hPa.

The experimental harvest is done by hand in order to characterize plant productivity in the partially narrow traffic zone areas. Due to a hailstorm in May 2009, winter wheat was severely harmed, so no yield measurements were possible. Winter barley in 2010 and ley in 2011 (several cuts) could be harvested as intended.

Statistical analysis

Data were statistically analyzed using the software STATISTICA 9.1 of StatSoft Inc. In ANOVA sub-treatments were analyzed in a univariate design with fixed factors; means were compared using the grouping procedure of Tukey (1949). In nonparametric comparison of multiple samples sub-treatments were used as grouping factors.

Results and discussions

Results of topsoil measurements in winter wheat as the first crop of the CTF experiment in April 2009 clearly indicated that topsoil structure of Pr was of a totally different quality compared to the no-till treatments with CTF and RTF respectively: all soil structure parameters showed that the topsoil of the no-till treatments was much more compact than that of Pr (Fig. 2).

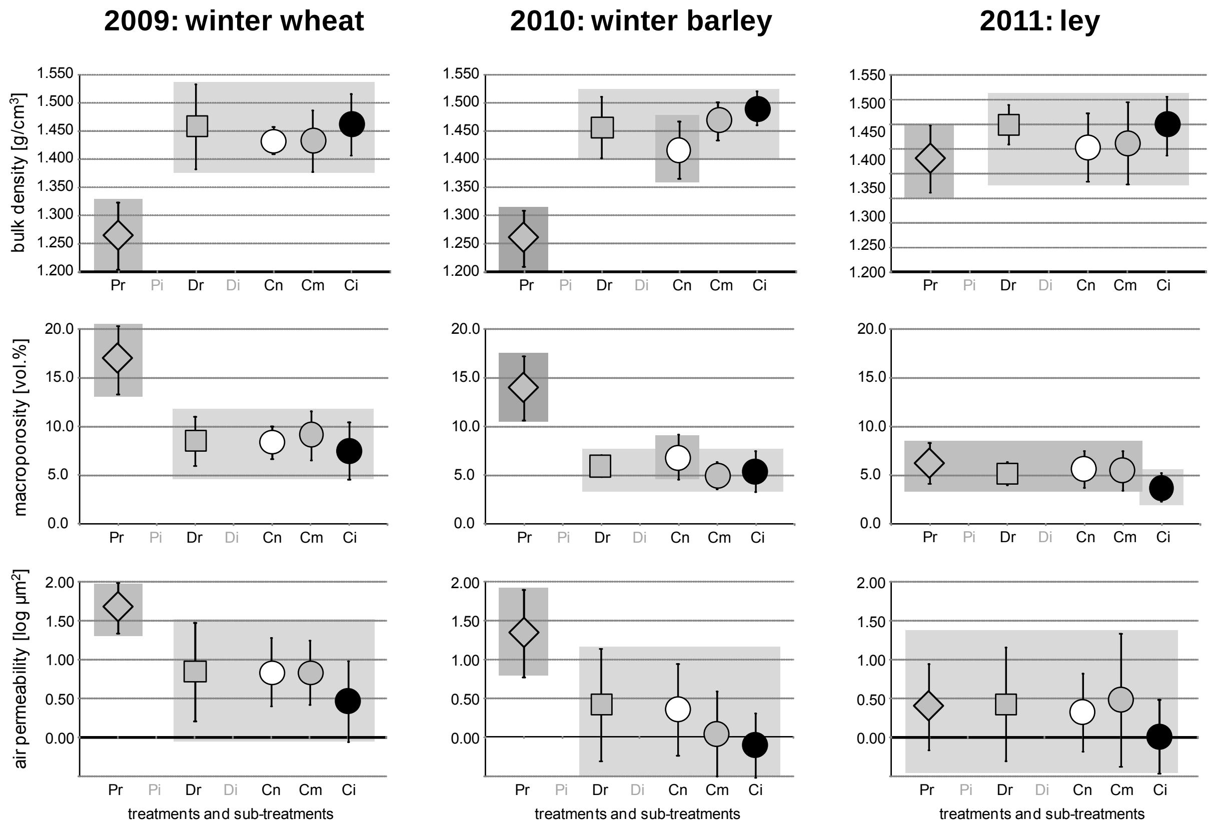

Figure 2: Topsoil structure, expressed as bulk density, macroporosity and log of air permeability (both at 60 hPa) in the first three years of the CTF experiment at Tänikon. In each case soil sampling was done in spring at a soil depth of 10-16 cm in two field blocks. Plotted are means and standard deviations; means in the same rectangle (same shade of grey) are statistically equivalent according to Tukey (1949).

At the same time, no statistically significant differences between the no-till treatments and any of its traffic zone sub-treatments could be detected; only a tendency of Ci to have the densest structure was identifiable in all topsoil parameters.

In the second experimental year 2010, with winter barley, soil in the Pr treatment was still considerably less compact than in the no-till treatments (Fig. 2). Again, no statistically significant differences were noticeable in the no-till treatments and the traffic zone sub-treatments; however a tendency of Cn to have slightly better values than the remaining no-till sub-treatments Cm, Dr and Ci could be detected.

In the third experimental year (2011), the values of soil structure parameters for Pr were no longer clearly higher than in the other treatments, so the differences to the other treatments were only small (Fig. 2). Comparing the traffic zone sub-treatments in CTF and RTF no-till treatments, the parameters characterizing soil structure did not differ in a statistically significant way; still, Ci had a tendency to a worse structural quality.

The effects of the experimental treatments on soil structure in spring are quite clear in the first three experimental years: ploughing the topsoil (before winter wheat and winter barley) resulted in a much looser soil than no-tillage, irrespective of the traffic scheme. However, as

soon as ploughing was skipped, as before ley in 2011, soil structure quality of the Pr treatment approximated that of the no-till treatments. The field traffic organisation in the CTF no-till treatment proved to be of minor importance during these first experimental years: whereas the sub-treatments Cm and Dr did not differ at all, slight indications of an improvement of soil structure in Cn could be found only in 2010. One reason for this could be that the CTF no-till treatment was installed on a soil which had been managed by shallow mulch seeding before; and so - in contrast to the Dr treatment, which had been established on a long-term no-till soil – the soil structure of the CTF no-till treatment was not yet adapted to the new management regime.
Winter barley yield was higher in the Pr and Cn sub-treatments than in Cm and Dr (Fig. 3). The reason for the low yield level was probably a drought period during early summer, resulting in a low thousand seed weight. The first two harvests of ley in 2011 showed lower yields in the Ci sub-treatment for both cuts. The highest yields were found in the ploughed and randomly trafficked treatment Pr. The remaining sub-treatments did not show statistically significant differences.

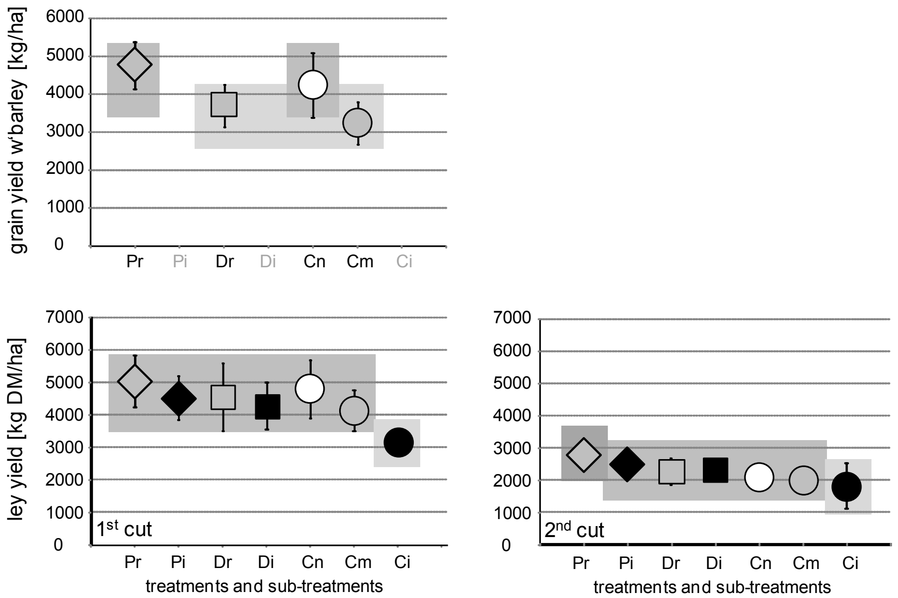

Figure 3: Yields of winter barley in 2010 (standardized at 15% humidity) and the first two cuts of ley in 2011 (dry matter). Plotted are means and standard deviations; means in the same rectangle (same shade of grey) are statistically equivalent according to Tukey (1949).

Conclusions

Theoretical considerations suggest that a stricter organisation of field traffic (“controlled traffic”) could have advantages for the evolution of soil structure.
First results after three experimental years show clear differences between the topsoil structure of ploughed and no-till treatments, but only small and inconsistent differences in soil structure depending on the traffic impact.
As far as yield results may be related to soil structure, higher yields in the CTF experiment are generally associated with a better soil structure quality. In this respect the RTF plough treatment Pr shows consistently high yields. Astonishingly, a marginally better soil structure quality in the Cn compared to the remaining sub-treatments correlated also with a better yield.
After three experimental years the available results are not sufficiently significant, and the structural development of the treatments cannot yet be clearly identified. Therefore the applicability of a CTF concept at the arable experimental site cannot be assessed properly at the moment.

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Section IV

CONTENT

Agricultural drought and its impact within yields of selected crops in Czech Republic

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Abstract
The consequences of agricultural drought defined on the relative Palmer´s Z-index (rZ-index) basis within the period 1961-2000 were analyzed. Namely, impacts on yields of eight crops (spring barley, winter wheat, maize, winter rape, oat, winter rye, potato and hay from permanent grasslands and meadows) were assessed. For the identification of drought severity the rZ-index was summed within the periods of crop sensitivity to drought (PCSD). It was proved, that drought was highly significant stress factor reducing yields in some years. It could be concluded, that the spring crops (except maize as C_4 crop) are more susceptible to drought conditions than winter crops.
Keywords: Palmer´s Z-index, Soil water holding capacity

Introduction

Drought is one of the major natural hazards for agricultural production since availability of water in soil is essential for plant growth and other key physiological processes. Water deficit could be very significant stress factor and can lead to the yield reduction, quality decreases and even to crop failure. Importance of this phenomenon in context of the Czech Republic conditions could be illustrated by the severe drought spells in 1935, 1947 and 1976 (Možný, 2004) or recent episodes within 2000, 2001 and 2003. Agricultural drought could be described as a situation, when the soil of selected region is consistently below the appropriate moisture for crop production (e.g. Palmer 1965, Quiring and Papakryiakou 2003). On the other hand the question is how to ideally quantify this complex and non-linear phenomenon.

The main aim of submitted study was to evaluate the influence of drought on yield variability of 8 selected crops (at district level) during the period 1961-2000 in the Czech Republic conditions. For this purpose the cumulative values of Palmer´s relative Z-index (rZ-index) was applied as an agricultural drought indicator (Dubrovský et al., 2009).

Material and methods

Within the presented study the yield variability of eight crops (spring barley, winter wheat, maize, rape, oat, winter rye, potato and hay from permanent grassland and meadows) at district level from 1961 to 2000 was analyzed. This set of crops occupied about 2.5 million ha during the study period. The database of yields and acreage from individual district was provided by the Czech Statistical Office (CSO). In the first step, the district with low production area of a given crop were excluded (sowing area less than 0.5 % of the total national acreage for given crop in more than 2/3 of analyzed years). Consequently, the trend (e.g. caused by innovation, new cultivars, changes in fertilization) from original yield data were removed (separately for each district). For this purpose the second order polynomials (constructed for each crop and district) were used to obtain residuals as a measure for inter-annual yield fluctuations.

The monthly relative Palmer´s Z-index was derived using algorithms for water balance based on monthly air temperature and precipitation (Heim, 2002, Dubrovský et al., 2009). Maximum Soil Water Holding Capacity (MSWHC) was used as one of the crucial parameter while soil profile was divided into two layers (top layer has the retention capacity of 25 mm). Potential evapotranspiration (PE) was estimated on the basis of Thorthwaite (1948) method. The negative values of rZ-index indicate drought and positive values wet conditions. Finally, the spatially averaged (based only on arable land within selected district) rZ-index values were used. The regional drought conditions through the Czech Republic were described by Tolasz et al., (2007) and results are apparent from the Figure 1.

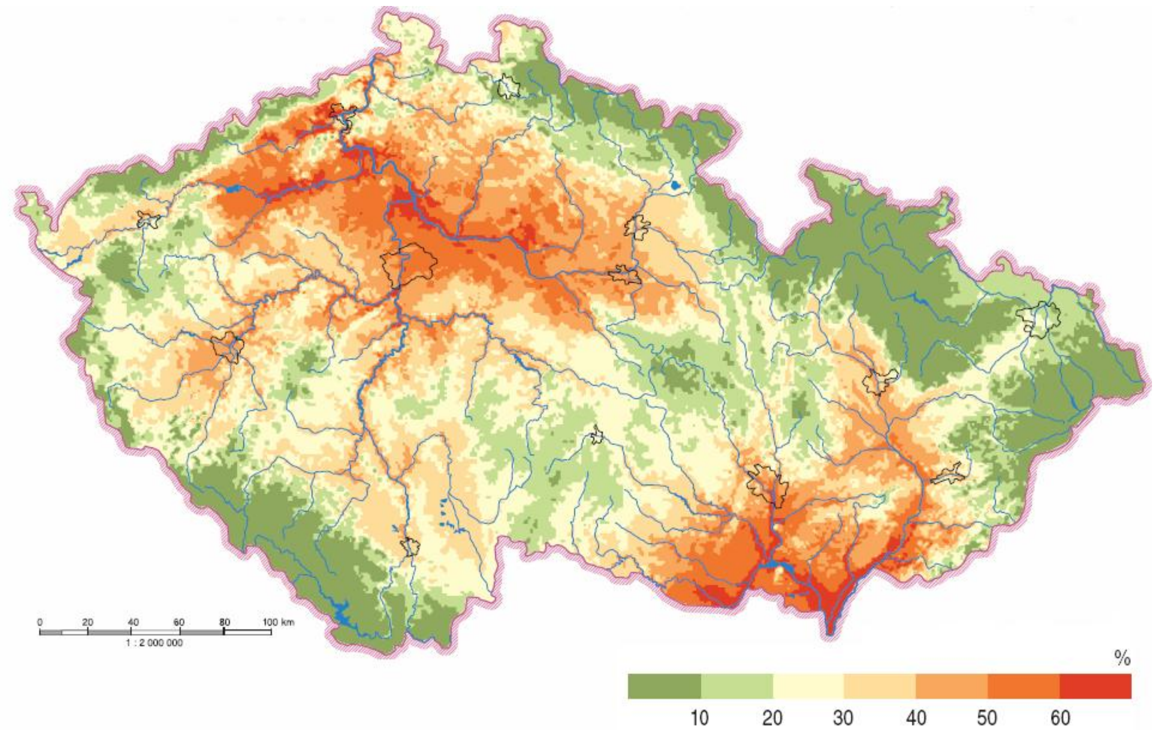

Fig. 1 Ratio of the months with drought episodes according to r Z-index (from April to September) (Tolasz et al., 2007).

The rZ-index values used within this study were derived on the basis of monthly mean temperatures and precipitation sums observed from 1961 to 2000 within 233 weather stations through the Czech Republic (i.e. one station pre 335 km^2 on average) as prepared for Climatic Atlas of Czechia.

The spatial distribution of the soil properties described by MSWHC in the rooting zone was estimated using a combination of soil physics data from 1073 soil pits compiled during the Czech National Soil Survey and digitized maps of soil types (Tomášek, 2000).

The assessment of drought impact within the yields of selected crops was conducted on the basis of relationship (quantified by Pearson correlation coefficient) between the sum of monthly rZ-index for sensitive period (as independent variable) and detrended yields of selected crops (dependent variable). The periods of crop sensitivity to drought for selected crops are depicted within the figure 2 (Hlavinka et al., 2009).

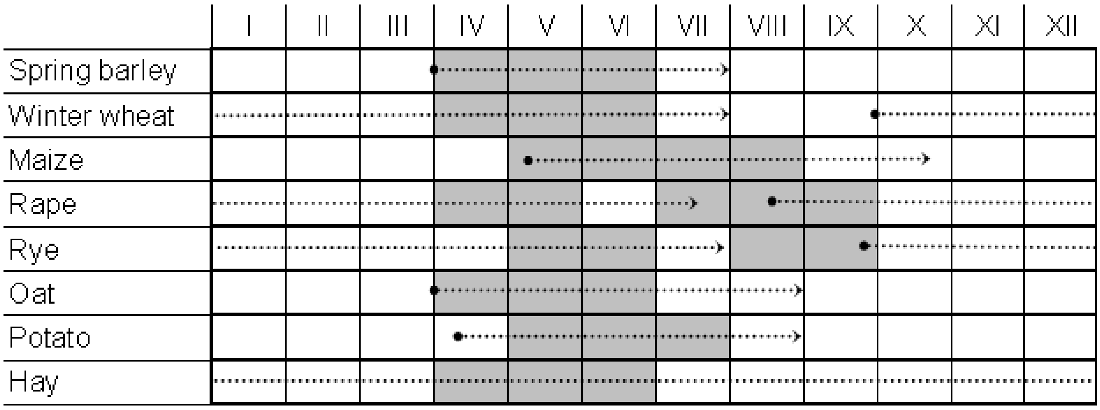

Fig. 2 Periods of crop sensitivity to drought (PCSD) within the vegetative season of 8 crops are marked as shaded area. Approximate sowing date of crops within the Czech Republic is depicted by bold dots, duration of growth shown by dotted lines and harvest by arrows.

Results and discussions

Within the first step, the series of yields departures and the sum of rZ-index per PCSD were compared for each crop and district separately. The example for spring barley and winter wheat for Břeclav district is shown in the Fig. 3a-c. The coefficient of correlation for spring barley was 0.56 and for winter wheat was 0.5. This is in accordance with average results within the rest of districts where higher correlation was observed for spring barley, oat, potato and hay against winter wheat, winter rye or winter rape (Table 1). The coefficient of correlation for spring barley was higher than 0.5 (than 0.4) within 22 (35) districts, for winter wheat within 7 (24) districts, maize 2 (10), potato 17 (41), oat 21 (34), winter rye 5 (13), rape 6 (10) and for hay within 13 (23) districts.

Consequently, the average yields departure under specific drought conditions within all included districts and crops were analysed (Fig. 4a-h). This analysis proved that the sum of the rZ-index (April-June) below -10 (severe drought) caused a spring barley yield departure of about -1500 kg/ha on average (Fig 4a). If the rZ-index for the same period was in the interval -9 to -8 (more frequent) the average yield departure was around -500 kg/ha and the negative influence of dry conditions was apparent when the rZ-index dropped below -5. Drought had a very similar impact within reducing the average oat (spring crop with the same PCSD) yields (Fig. 4f). Figure 4g indicates that potatoes (PCSD May-July) were also drought sensitive while the rZ-index threshold was -6, and for rZ-index lower than -10 the average yield departure was -3000 kg/ha (it was in 28 cases). The average grain maize yield reduction as a result of water deficit during PCSD was not so significant (Fig. 4). When the rZ-index was below -12, average departure was slightly more than -500 kg/ha. The relatively low sensitivity of grain maize to drought in comparison with other spring crops is most likely a consequence of the different physiological make up of this C_4 plant and also likely helped by better soils on which it is usually grown compared to other crops. The consequence of a dry PCSD (also April-June) on winter wheat average yield departure was about -800 kg/ha for an rZ-index lower than -10. The rape (PCSD July-September and April-May) was affected by drought occurrence before sowing, at the beginning of vegetation and also during the spring months April and May. When the sum of the rZ-index for PCSD dropped below -15, the departure from average yield was about -550 kg/ha (see Fig. 4d). The yield of rye is only slightly negatively influenced during a severe drought spell within PCSD (Fig. 4e). In this study, drought susceptibility was also identified within hay harvests (PCSD April-June) even though hay is a perennial crop. The main cause of the high drought susceptibility of grassland production could be a shallow rooting zone and inferior soil quality used for hay production.

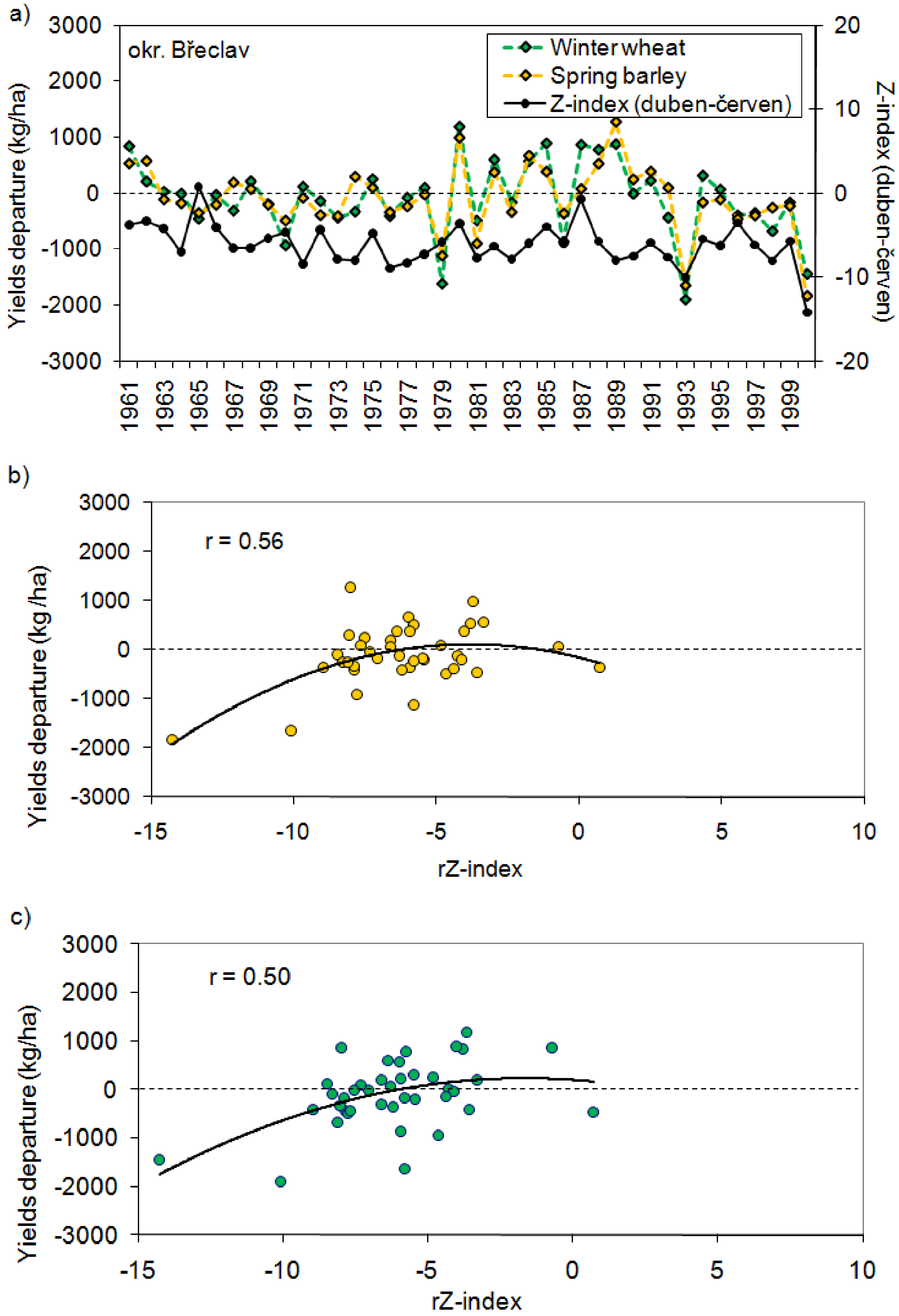

Fig. 3 Time series of rZ-index during PCSD (April-June) and yields departure of spring barley and winter wheat for Břeclav district (a) and the quantification of relationship between rZ-index and yields departure of spring barley (b) and winter wheat (c) for the same district.

Table 1: Overview of relationship between sum of rZ-index during PCSD and district yields departure of 8 selected crops (expressed with coefficient of correlation). Combination of district and crop which wasn't analyzed are marked as "Not an.".

	SPRING BARLEY	WINTER WHEAT	MAIZE	POTATO	OAT	RYE	RAPE	HAY
Středočeský kraj								
Praha hl.m.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.
Benešov	0.55	0.44	Not an.	0.40	0.59	0.30	0.20	0.57
Beroun	0.52	0.44	Not an.	Not an.	0.53	Not an.	0.20	0.46
Kladno	0.51	0.42	0.10	0.49	0.57	Not an.	0.10	Not an.
Kolín	0.40	0.28	0.49	0.40	0.48	0.22	0.48	Not an.
Kutná Hora	0.58	0.47	0.24	0.48	0.53	0.22	0.24	0.28
Mělník	0.42	0.44	0.10	0.33	0.22	0.00	0.46	Not an.
Mladá Boleslav	0.24	0.17	0.30	0.47	0.47	0.00	0.20	0.26
Nymburk	0.26	0.17	0.10	0.33	0.45	0.10	Not an.	Not an.
Praha - východ	0.33	0.30	0.00	0.14	0.35	0.00	0.28	Not an.
Praha - západ	0.40	0.36	0.26	Not an.	Not an.	Not an.	Not an.	Not an.
Příbram	0.56	0.41	Not an.	0.36	0.47	0.24	0.00	0.47
Rakovník	0.49	0.44	Not an.	0.39	0.59	0.37	0.35	Not an.
Jihočeský kraj								
České Budějovice	0.49	0.51	Not an.	0.50	0.55	0.37	0.24	0.32
Český Krumlov	0.46	0.28	Not an.	0.59	0.40	0.52	Not an.	0.35
Jindřichův Hradec	0.52	0.49	Not an.	0.49	0.57	0.36	0.24	0.14
Pelhřimov	0.53	0.42	Not an.	0.52	0.59	0.36	0.14	0.32
Písek	0.57	0.49	Not an.	0.32	0.53	0.40	0.14	0.57
Prachatice	0.44	0.37	Not an.	0.59	0.32	0.37	0.10	0.33
Strakonice	0.51	0.39	Not an.	0.17	0.60	0.28	0.20	0.51
Tábor	0.55	0.56	Not an.	0.46	0.55	0.45	0.17	0.49
Západočeský kraj								
Domažlice	0.36	0.28	Not an.	0.24	0.57	0.14	0.24	Not an.
Cheb	0.24	0.30	Not an.	0.41	0.46	0.37	0.35	Not an.
Karlovy Vary	0.39	0.32	Not an.	0.24	0.37	0.36	0.37	Not an.
Klatovy	0.49	0.35	Not an.	0.41	0.53	0.36	0.17	Not an.
Plzeň-město	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.
Plzeň-jih	0.40	0.28	Not an.	0.39	0.48	0.41	0.30	Not an.
Plzeň-sever	0.49	0.53	Not an.	0.35	0.64	0.22	0.20	Not an.
Rokycany	0.51	0.41	Not an.	Not an.	0.49	0.50	0.30	Not an.
Sokolov	Not an.	Not an.	Not an.	Not an.	0.22	0.24	0.33	Not an.
Tachov	0.36	0.20	Not an.	0.22	0.24	0.24	0.36	Not an.
Severočeský kraj								
Česká Lípa	0.24	0.24	Not an.	0.20	0.37	0.56	0.52	Not an.
Děčín	Not an.	Not an.	Not an.	Not an.	0.36	0.40	0.62	Not an.
Chomutov	0.59	0.57	Not an.	Not an.	0.28	0.24	0.42	Not an.
Jablonec nad Nisou	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.
Liberec	0.26	0.33	Not an.	0.26	0.20	0.57	0.58	Not an.
Litoměřice	0.57	0.58	Not an.	0.44	0.40	0.17	0.57	Not an.
Louny	0.50	0.52	0.10	0.41	0.24	0.22	0.36	Not an.
Most	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.
Teplice	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.
Ústí nad Labem	Not an.	Not an.	Not an.	Not an.	0.20	0.32	Not an.	Not an.
Východočeský kraj								
Havlíčků Brod	0.61	0.32	Not an.	0.51	0.66	0.40	0.17	0.20
Hradec Králové	0.40	0.35	0.46	0.52	0.37	Not an.	0.17	0.53

Chrudim	0.46	0.36	0.17	0.65	0.40	0.36	0.10	0.41
Jičín	0.35	0.26	0.32	0.35	0.44	0.41	0.30	0.28
Náchod	0.37	0.22	Not an.	0.49	0.42	0.28	0.37	0.48
Pardubice	0.52	0.40	0.14	0.53	0.55	0.24	0.10	0.57
Rychnov nad Kněžnou	0.33	0.30	0.45	0.55	0.37	0.14	0.17	0.54
Semily	0.37	0.30	Not an.	0.49	0.41	0.41	0.52	0.36
Svitavy	0.40	0.22	Not an.	0.58	0.42	0.36	0.20	0.36
Trutnov	0.40	0.26	Not an.	0.46	0.24	0.39	0.33	0.42
Ústí nad Orlicí	0.39	0.26	Not an.	0.60	0.35	0.20	0.22	0.58
Jihomoravský kraj								
Blansko	0.49	0.44	Not an.	0.40	0.56	0.10	0.17	0.56
Brno-město	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.
Brno-venkov	0.70	0.48	0.45	0.47	0.49	Not an.	0.50	Not an.
Břeclav	0.56	0.50	0.37	0.39	Not an.	Not an.	0.24	Not an.
Zlín	0.20	0.10	0.46	0.54	0.14	Not an.	0.17	0.30
Hodonín	0.45	0.44	0.22	0.61	Not an.	0.24	0.39	0.44
Jihlava	0.57	0.44	Not an.	0.46	0.63	0.42	0.10	0.51
Kroměříž	0.24	0.14	0.10	0.39	Not an.	Not an.	0.14	Not an.
Prostějov	0.52	0.20	0.48	0.50	0.32	0.10	0.37	Not an.
Třebíč	0.62	0.54	Not an.	0.35	0.65	0.58	0.33	0.63
Uherské Hradiště	0.36	0.14	0.28	0.48	0.10	Not an.	0.35	0.30
Vyškov	0.63	0.28	0.46	0.44	Not an.	Not an.	0.36	Not an.
Znojmo	0.62	0.49	0.52	0.46	0.66	0.53	0.53	Not an.
Žďár nad Sázavou	0.49	0.36	Not an.	0.52	0.56	0.35	0.10	0.66
Severomoravský kraj								
Bruntál	0.24	0.14	Not an.	0.41	0.46	0.20	0.20	0.17
Frýdek-Místek	Not an.	0.20	Not an.	0.53	0.30	0.24	0.33	0.45
Karviná	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	0.33	Not an.
Nový Jičín	0.24	0.00	0.48	0.58	0.30	0.37	0.10	0.52
Olomouc	0.24	0.33	0.32	0.53	0.35	0.46	0.22	0.45
Opava	0.22	0.00	Not an.	0.44	0.35	0.24	0.14	0.57
Ostrava-město	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.
Přerov	0.26	0.26	0.10	0.51	0.37	0.44	0.28	0.47
Šumperk	0.42	0.39	0.58	0.47	0.33	0.22	0.30	0.32
Vsetín	0.34	0.17	Not an.	0.50	0.17	0.26	Not an.	0.33
Jeseník	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.	Not an.

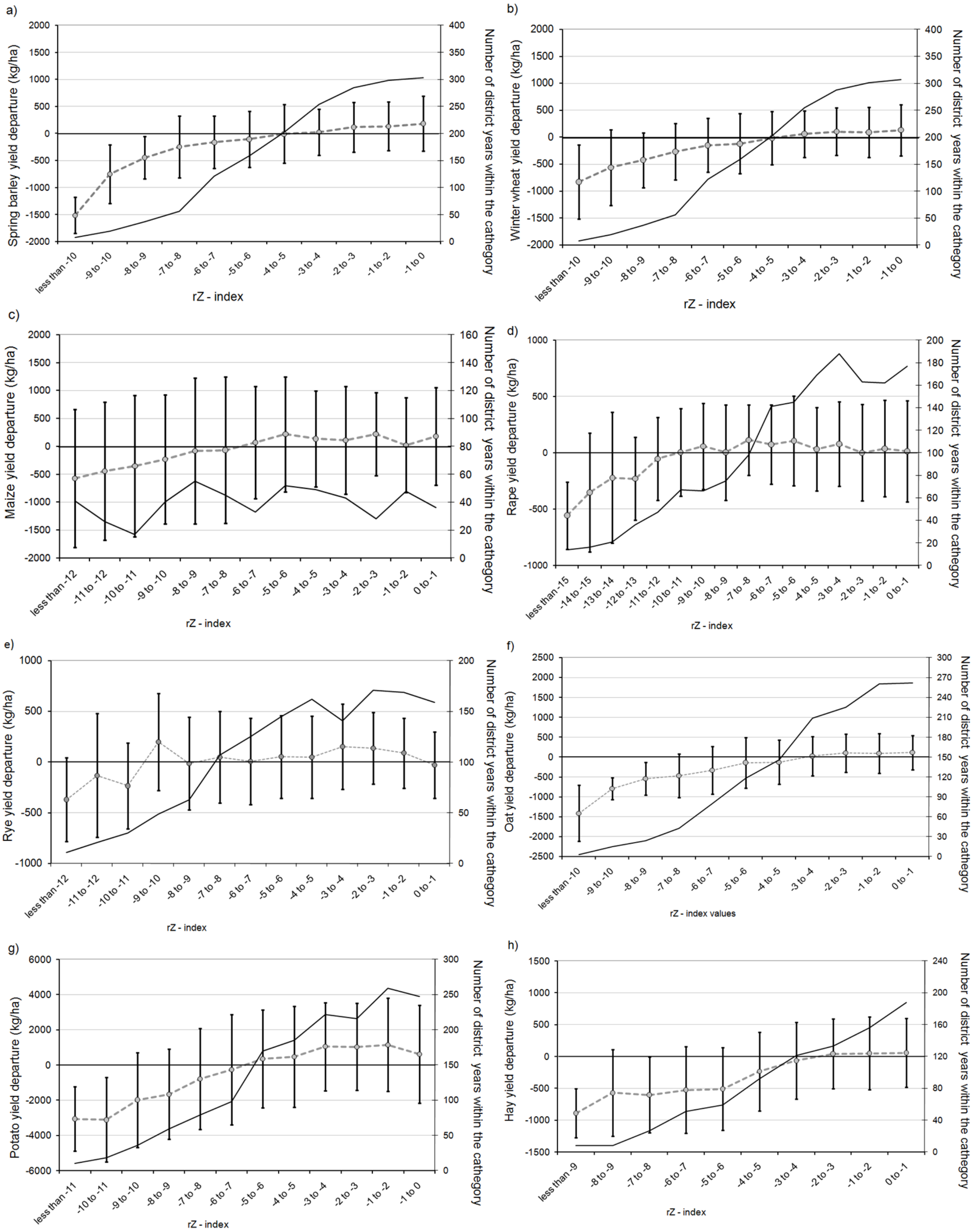

Fig. 4 Average yields departure (in kg/ha) within all analyzed districts for defined drought severity (broken line) with +/- standard deviation. Number of district-seasons under appropriate drought are depicted by black line. The graphs demonstrate situations for spring barley (a), winter wheat (b), grain maize (c), rape (d), rye (e), oat (f), potato (g) and hay (h).

Conclusions

It was shown that the rZ-index might be successfully used for detection of agricultural drought. The advantage of this approach is low input data demand (compared to e.g. crop models). Statistically significant relationships between the sum of the rZ-index and the variability of detrended yields of selected crops were found in a many districts of the Czech Republic. Spring cereals were found to be more vulnerable to drought than winter ones, and C_3 crops more vulnerable than C_4 crops. Lower susceptibility of winter crops could be partially explained by the fact that these crops usually have relatively deeper rooting systems during the spring and can get the deeper soil water if drought conditions occur.

Acknowledgements

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Soil as moderator of extreme hydrological events: drought – flood/waterlogging

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Abstract

The generally **favourable natural resources** of the Carpathian Basin show high and irregular (consequently hardly predictable) spatial and temporal variability, often extremes and sensitively react to various natural or human-induced stresses. Due to the irregularity of atmospheric precipitation; the increasing frequency of intense heavy rains („rain bomb”); heterogeneous macro-, meso- and microrelief; unfavourable soil properties; improper land use and cropping pattern the risk, frequency, duration and intensity of **extreme weather and water situations** (floods, waterlogging, over-moistening ⇔ drought) will increase, often in the same year on the same territory. Under such conditions it is an inevitably important fact that **soil is the largest potential natural water reservoir.** This huge potential water storage capacity, however, cannot be used efficiently because:

– infiltration of water into the soil is limited (saturation of soil pores; frozen topsoil; compacted surface or near surface soil horizon with low permeability);
– the infiltrated water is not stored within the soil because of low water retention.

Due to these facts the water **losses** by surface runoff, evaporation and deep infiltration increase. Soils with good agronomic structure may efficiently *moderate* the risk (frequency, duration, intensity) of **extreme hydrological situations** and may reduce their unfavourable economical/environmental/social consequences. On the contrary, the infiltration/storage limitations may even *magnify* these threats.

Consequently, all efforts must be taken **to help infiltration into and useful storage of water in soil,** elaborating, adapting and implementing *site-specific water-saving technologies.*

Key words: extreme moisture regime; waterlogging; drought; infiltration; water storage capacity of soils.

Introduction

The natural conditions of the Carpathian Basin are *generally favourable for rainfed biomass production.* These conditions, however, show extremely high, irregular, consequently hardly predictable spatial and temporal variability, often extremes, and sensitively react to various natural or human-induced stresses (Láng et al., 1983; Várallyay, 2007; Várallyay & Farkas, 2008).

Water resource show a “double face” character in the Carpathian Basin (Figure 1). This well-defined geographic region is *generally rich* in water resources, especially in the low-lying parts of the Pannonian Plains, as the bottom of this large water catchment area. On the contrary, during certain “critical periods” in some “critical areas” the water resources are limited and “extreme” hydrological situations and soil moisture regimes:

– surplus amount of water: flood, water-logging, “over-moistening” hazard;
– shortage of water: drought sensitivity

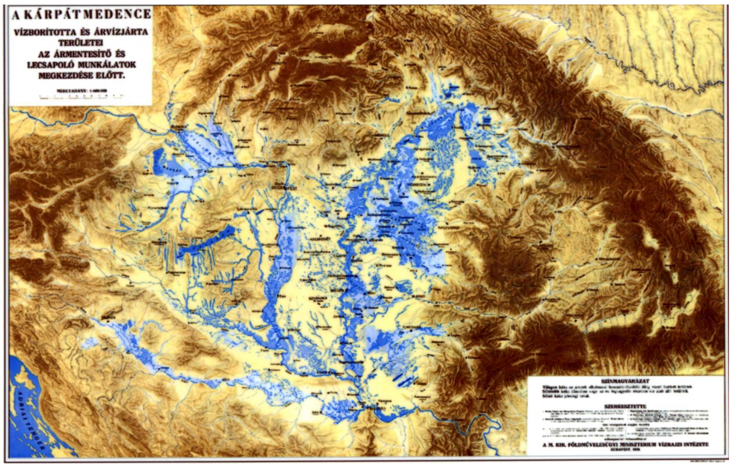


Figure 1. The Carpathian Basin

are characteristic, occurring sometimes in the same year, at the same place (which is quite natural because of the artificially drained water and the evaporation and filtration losses are missing from the soils during the dry summer months) (Pálfai, 2000; Várallyay, 2007b).
According to the meteorological/hydrological/ecological forecasts the risk, probability, frequency, duration and intensity of *extreme meteorological* (thunderstorms, high intensity rains, hail) *and hydrological* (floods, water-logging, over-moistening vs. droughts) *events* will be increasing in the future and their unfavourable economical, ecological and social consequences will be more and more serious, sometimes catastrophic. Consequently, the **improvement of water use efficiency** will be the key issue of biomass production, rural development and environment protection (Várallyay, 2007a, 2010a).

Limited and irregular water resources

1. Changing climate, atmospheric precipitation

The average 450–600 mm annual precipitation in the Carpathian Basin may cover the water requirement of the main crops even at high yield levels. But the average shows *extremely high territorial* (Fig. 2A) *and temporal* (Fig. 2B, 2C and 2D) *variability* – even at micro-scale (Láng et al., 1983; National Atlas of Hungary, 1989).
A certain part of the atmospheric precipitation falls as snow (or similar "unidentified flying object") or as highly intensive rain or hail. Their frequency, duration and intensity have considerably increased during the last years, resulting in serious, sometimes catastrophic consequences: intense surface runoff and erosion (soil losses and sedimentation hazards) or even landslides, infrastructure damages, etc. Under such conditions a part of the precipitation is lost by surface runoff, deep filtration and evaporation and only a limited (reduced) part of atmospheric precipitation is stored in the soil and is available for the biota, natural vegetation and cultivated crops, resulting water deficiency for plants or even serious droughts during the hot and dry summer months. According to climate forecasts the annual precipitation will not be more in the future and its unfavourable spatial and time distribution will even be less favourable. The risk, probability, frequency, duration and intensity of extreme weather situations are expected to increase (Láng et al., 1983; Pálfai, 2000; Várallyay, 2007a).

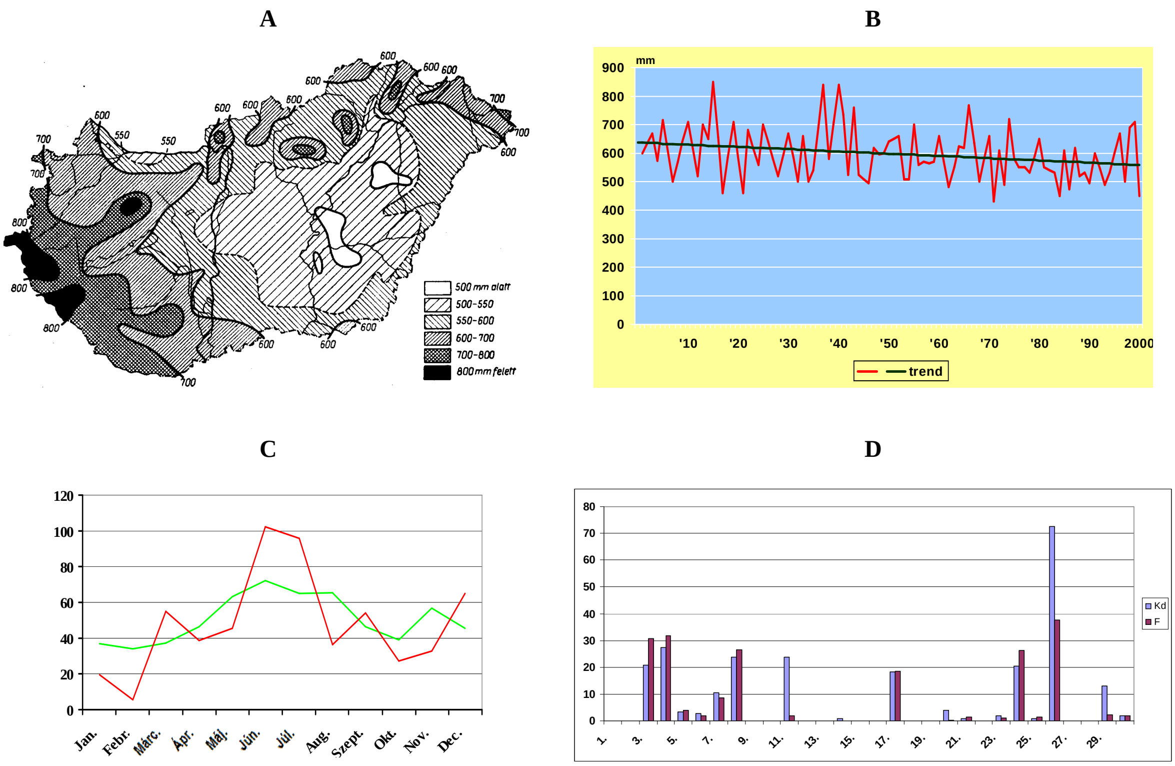


Fig. 2. Territorial and time distribution of atmospheric precipitation in Hungary. A. Geographical distribution of the 100-year average annual precipitation. B. Average annual precipitation in Hungary in the 20th century. C. Monthly distribution of the long-term average and 2008 annual precipitation. D. Daily distribution of monthly precipitation (May 2008) at two nearby meteorological stations

2. Surface and subsurface water resources

Surface waters. – The average quantity of incoming rivers is about 110–115 km³/year in Hungary and it will not increase, particularly in the critical low-water periods because of two reasons:

- decreasing quantity and higher spatial and time variability of atmospheric precipitation, increasing risk of high-intensity rainfalls, changes in the rain: snow ratio and snow-melt behaviour, land use changes and surface runoff characteristics of the Upper Danube Basin areas;
- a certain quantity and quality of transboundary surface waters must be guaranteed for the Lower Danube Basin countries (at present this outflow is about 115–120 km³) (Pálfai, 2000).

Subsurface waters. – The average depth of the groundwater table in Hungary is shown in Figure 3. It can be concluded from the Figure that the possibility of capillary transport from the groundwater to the overlying soil horizons, especially to the active root zone can be significant only in the lowlands. But, a considerable part of subsurface waters (especially in the poorly drained East Hungarian Plain) is of poor quality (high salinity, alkalinity, sodicity), threatening with harmful salinization/sodification processes (Várallyay, 2006). In the Danube–Tisza Interfluve sand plateau the consecutive dry years and the overexploitation of subsurface waters result in a sink of the groundwater table and in its sensitive moisture regime consequences: increasing aridity and even "desertification symptoms". Only in small areas can the good quality groundwater contribute efficiently to the water supply of plants. This quantity, however, is more than double of the irrigation capacity of Hungary! (Pálfai, 2000; Várallyay, 2010a,c).

CONTENT

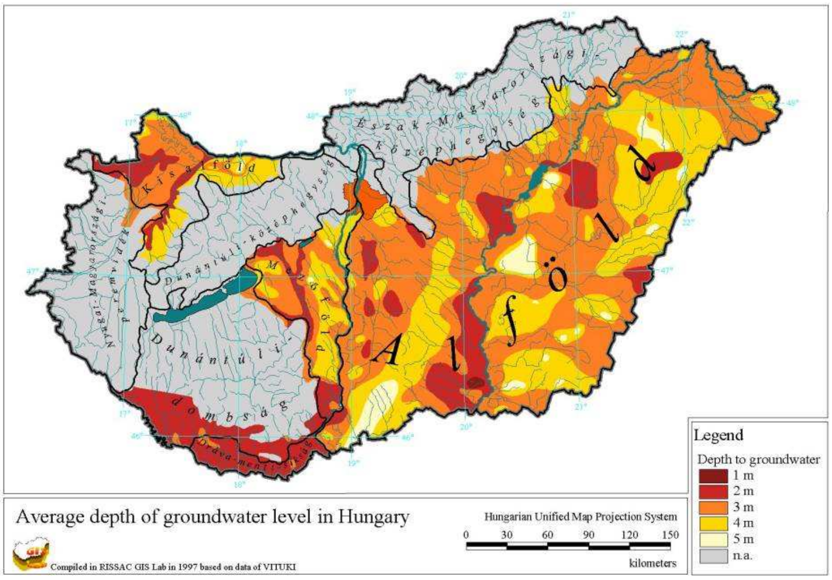


Figure 3. Average depth of the groundwater level in Hungary

During the last years a 5-step model was elaborated in the Research Institute for Soil Science and Agricultural Chemistry (RISSAC) of the Hungarian Academy of Sciences (Várallyay & Rajkai, 1989) for the calculation of the quantity of the capillary transport of water and solutes from the fluctuating groundwater to the overlying soil horizons: Figure 4.

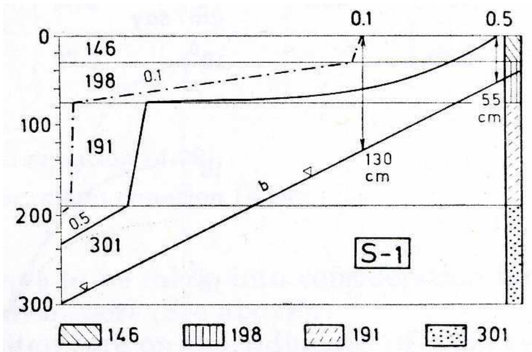


Figure 4.
Rate of capillary transport (V = cm/day) from a fluctuating groundwater to the overlying soil horizons in a stratified soil profile (S-1) from the Danube Valley.
146, 198, 191, 301: register number of the soil layer; z = cm; b: rising water table

The model was applied to determine the *optimum depth* (optimum regime) of *good quality groundwater* (contributing to the satisfaction of the water requirement of plants); and the *critical depth* (critical regime) of *poor quality groundwater* (preventing the secondary salinization/sodification of soil) (Várallyay & Rajkai, 1989).

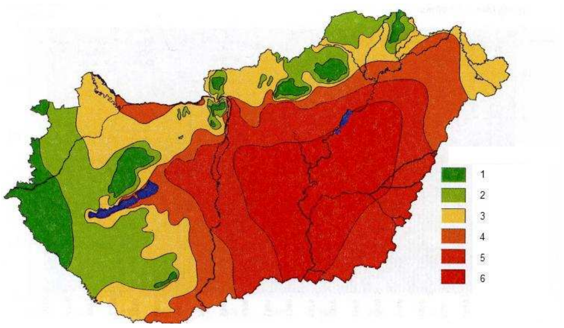
Soil, as the largest natural water storage capacity

Under the given environmental conditions it is an important fact that *soil is the largest potential natural water reservoir* (water storage capacity) in the Carpathian Basin. The 0–100 cm soil layer may store more than half of the average annual precipitation (500–600 mm). About 50% of it is „available moisture content".

This favourable fact is quite contrary with the high and increasing risk, hazard, frequency and duration of extreme hydrological events (flood, waterlogging, over-moistening vs. drought) sometimes in the same place in the same year (Figure 5) (Pálfai, 2000; Várallyay, 2006, 2007b; Várallyay & Farkas, 2008).

CONTENT

A



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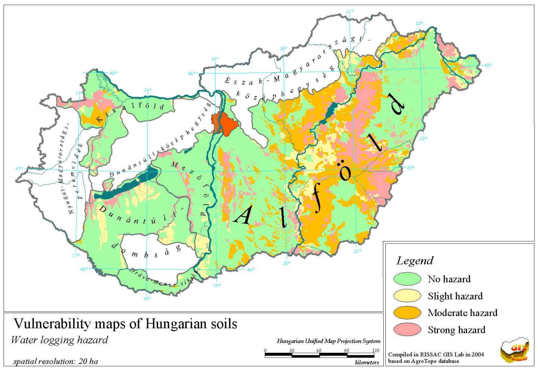


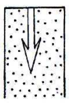
Figure 5. Extreme hydrological and moisture situations in Hungary.
A. Drought sensitivity. Legend: 1. No drought. 2. Mildly, 3. Moderately, 4. Middling, 5. Strongly, 6. Extremely sensitive to drought.
B. Water-logging hazard.

The main reasons and consequences of extreme hydrological events and soil moisture situations are as follows:

Reasons:
- high spatial (territorial) and temporal variability of atmospheric precipitation
- rain:snow ratio – snowmelt characteristics
- relief [macro, meso, micro]
- soil conditions
- vegetation cover
- land use forms and soil management practices

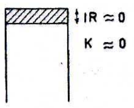
Consequences:
- water losses (← evaporation; surface runoff; deep filtration)
- soil losses [organic matter, plant nutrients]
- biota losses
- vegetation losses
- yield losses
- energy losses

1. Limited water retention



IR, HC > FC → drought sensitivity

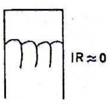
2. Limited infiltration
A. Impermeable layer (crust) on the soil surface



a) cemented by salts
  – Na salts
  – gypsum
b) compacted by improper soil management
  – over-tillage, heavy machinery
  – improper irrigation methods

B. Shallow wetting zones (low water storage capacity)

impermeable layer near to the soil surface
a) solid rock
b) hardpans (fragipans, duripans, orstein, ironpan etc.)
c) layer cemented by exch. Na^+, clay, $CaCO_3$ and other factors (clay-pan, concretionary horizons, petrocalcic horizons, etc.)
d) layer compacted by improper soil management (plough pans, etc.)



↓
extreme water regime
→ oversaturation (aeration problems)
waterlogging problems
surface runoff – water erosion
→ drought sensitivity

Figure 6. Main reasons of extreme moisture regime

What is the main reason of this *“huge water storage capacity” – “extreme moisture regime” contradiction?* The *potential* water storage capacity cannot be used because of the following reasons (Várallyay, 2005, 2010a; Várallyay & Farkas, 2008):

- the water retention of soil is poor and the infiltrated water is not stored in the soil, it only percolates through the soil profile: *„leaking bottle effect” (Fig. 6, No. 1);*
- the pore space is not „empty”, it was filled up to a certain extent by a previous source of water (rain, melted snow, capillary transport from groundwater, irrigation etc.): *„filled bottle effect”;*
- the infiltration of water (rain, melted snow) into the soil is prevented by the frozen topsoil: *„frozen bottle effect”;*
- the infiltration is prevented or reduced by a nearly impermeable soil layer on, or near to the soil surface: *„closed bottle effect” (Fig. 6, No. 2).*

The main reasons and consequences of these limiting factors are summarized in Figure 6.

Hydrophysical properties and moisture regime of soils in Hungary

According to our comprehensive assessment 43% of Hungarian soils can be characterized by unfavourable, 26% by moderately (un)favourable and 31% by favourable moisture regime, as illustrated by Figure 7, indicating the main reasons of various moisture conditions (Várallyay, 1985; Várallyay et al., 1980).

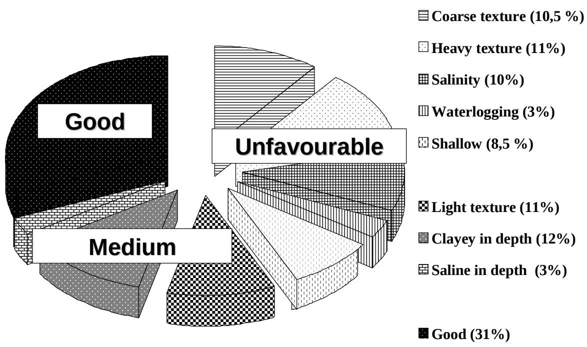


Figure 7. Hydrophysical properties of soils in Hungary (%) and their reasons

In the last years a comprehensive soil survey–analysis–categorization–mapping–monitoring system was developed in Hungary for the exact and quantitative characterization of hydrophysical properties, modelling and forecast of water and solute regimes of soils. The digital soil physical/hydrophysical database includes a *category system and a 1:100 000 scale map of the hydrophysical characteristics of soils* (Várallyay, 2005, 2010a; Várallyay et al., 1980). Nine main categories were distinguished according to textural class; total porosity as maximum water storage capacity (WC_t), field capacity (FC), water retention (WR), wilting percentage (WP), and available moisture range (AMR); infiltration rate (IR), permeability (P) and saturated hydraulic conductivity (K). The subcategories were classified according to the layer sequence of the soil profile and the main reason of the limited FC, WR or IR. The schematic map of the distinguished subcategories is presented in Figure 8, and their limit values are summarized in Table 1.

On the basis of our comprehensive digital soil physical/hydrophysical database the main characteristics can be *quantitatively* interpreted for soil layers, soil profiles; physico-geographical, administrative, farming or mapping units (e.g. ecological region, water catchment area, county, settlement, farm, agricultural field, etc.). The database serves as a

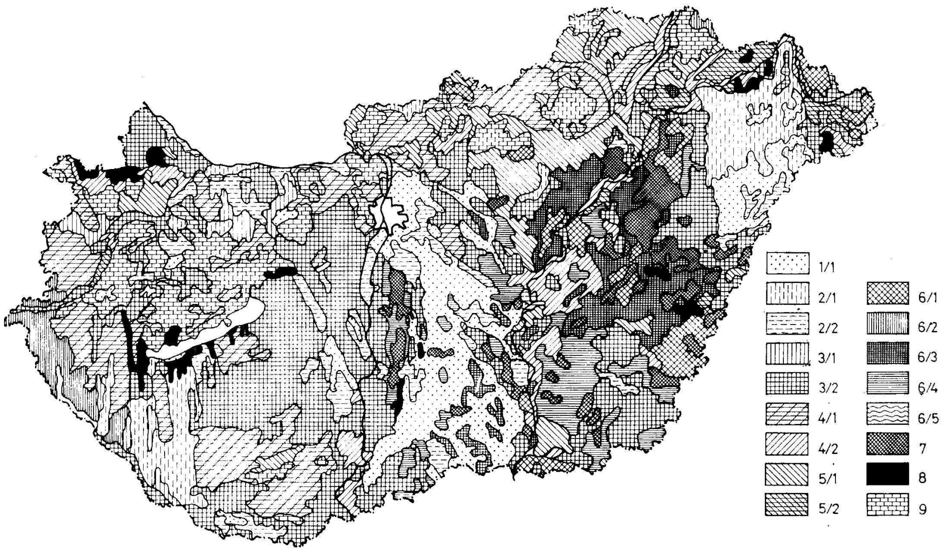


Figure 8. Hydrophysical characteristics of soils in Hungary

The 9 main soil water categories are as follows: 1. Soils with very high infiltration rate (IR), permeability (P) and hydraulic conductivity (HC); low field capacity (FC); and very poor water retention (WR). 2. Soils with high IR, P and HC; medium PC; and poor WR. 3. Soils with good IR, P and HC; good FC; and good WR. 4. Soils with moderate IR, P and HC; high FC; and good WR. 5. Soils with moderate IR, poor P and HC; high PC and high WR. 6. Soils with unfavourable water management: low IR, extremely high WR. 7. Soils with extremely unfavourable water management: very low IR, extremely low P and HC; and very high WR. 8. Soils with good IR, P and HC; and very high FC. 9. Soils with extreme moisture regime due to shallow depth. The main profile variants: (1) texture becomes lighter with depth (soils formed on relatively light-textured parent material): 2/1, 3/1. (2) uniform texture within the profile: 1/1, 2/2, 3/2, 4/2, 5/2. (3) relative clay accumulation in the horizon B: 4/1, 4/1. Profile variants of category 6: 6/1: heavy-textured soils with poor structure and a compact layer formed under the influence of misguided soil management; 6/2: pseudogleys; 6/3. deep meadow solonetzes, solonetzes turning into steppe formation and solonetzic meadow soils (with an A horizon thicker than 15 cm); 6/4: soils with salinity/alkalinity in the deeper horizons

Table 1. Limit values of the subcategories of hydrophysical soil characteristics

Category, subcategory		Genetic horizon	Texture class	FC	WP	AMR	IR	K
				mm/10 cm layer			mm/h	cm/day
1.	1/1	0–50	h	< 15	< 5	5–10	> 500	> 1000
		50–100	h	< 15	< 5	5–10		800–1000
		100–150	h	< 15	< 5	5–10		500–800
		150–200	h	< 15	< 5	5–10		500–800
2.	2./1	a	hv	15–25	5–10	10–15	300–500	800–1000
		b	vh	10–20	4–8	6–12		100–500
		c	h	< 15	< 5	5–10		500–800
	2/2	a	hv	15–25	5–10	10–15	150–300	500–1000
		b	hv	15–25	5–10	10–15		100–500
		c	hv	15–25	5–10	10–15		300–500
3.	3/1	a	v	25–35	10–20	15–22	120–150	10–20
		b	v	25–35	10–20	15–22		10–50
		c	hv	15–25	5–10	10–15		100–500
	3/2	a	v	25–35	10–20	15–22	100–300	10–100
		b	v	25–35	10–20	15–22		10–30
		c	v	25–35	10–20	15–22		30–100
4.	4/1	A	v	25–35	10–20	15–22	80–100	10–30
		B	av	35–42	20–27	12–17		1–5
		C	v	25–35	10–20	15–22		10–30
	4/2	a	av	35–42	20–27	12–17	70–100	1–10
		b	av	35–42	20–27	12–17		3–7
		c	av	35–42	20–27	12–17		5–10

Table 1 continued

Category, subcategory		Genetic horizon	Texture class	FC	WP	AMR	IR	K
				mm/10 cm layer			mm/h	cm/day
5.	5/1	A	av	35–42	20–27	12–17	60–70	1–5
		B	a	42–50	27–35	10–15		0,1–0,5
		C	av	35–42	20–27	12–17		0,5–2,0
	5/2	a	a	42–50	27–35	10–15	50–70	0,1–1,0
		b	a	42–50	27–35	10–15		0,1–0,5
		c	a	42–50	27–35	10–15		0,5–1,0
6.	6/1	a	a	42–50	27–35	10–15	30–50	0,1–1
		b	a	42–50	27–35	10–15		0,05–0,25
		c	a	42–50	27–35	10–15		0,1–0,5
	6/2	A					10–50	0,1–1,0
		B						0,01–0,1
		C						0,1–0,5
	6/3	A					10–50	0,1–1,0
		B						0,01–0,1
		C						0,1–0,5
	6/4	a					10–50	0,5–1,0
		b						0,1–0,5
		c						0,01–0,1
	6/5	a	L	> 50	> 35		10–50	
		b	L	> 50	> 35			
		c	v, av	30–40	15–25	15–20		1–10
7.	7/1	A					< 10	0,01–0,1
		B						< 0,01
		C						0,01–0,05
8.	8/1	a	L	> 50	> 35			
		c	hv	15–25	5–10	10–15		
		c	v	25–35	10–20	15–22		
		c	av	35–42	20–27	12–17		
		c	a	42–50	27–35	10–15		
9.	9/1	a(+b)	hv	15–25	5–10	10–15		
			v	25–35	10–20	15–22		
			av	35–42	20–27	12–17		
			a	42–50	27–35	10–15		
			L	> 50	> 35			

Remarks: Genetic horizons: a-b-c: profiles without or with negligible texture differentiation; A-B-C: profiles with significant texture differentiation. Soil textural classes: h: sand; vh: loamy sand; hv: sandy loam; v: loam; av: clay loam; a: clay; L: organic soils.

basis for the evaluation of the water storage capacity of soil, the waterlogging or over-moistening hazard and drought sensitivity of a certain area; as well as for rational regional or local water management activities: for the efficient use of soil as water reservoir and so reducing the risk and frequency of extreme hydrological events and moisture situations, preventing or at least moderating their unfavourable economical–ecological–environmental–social consequences (Láng et al., 1983; Várallyay & Farkas, 2008; Várallyay, 2010b,c).

Conclusions

Soil water management and soil moisture control are of priority significance in rational land use and sustainable soil management in the Carpathian Basin. The hazard, present and expected future risk, increasing frequency, duration and intensity of extreme (and irregular, consequently hardly predictable) climatic and hydrological events and moisture situations may result in serious (or even catastrophic) damages, unfavourable economical/ecological/environmental/social consequences. Soil – in the case of adequate, permanent and efficient soil and soil water management – may prevent, eliminate, reduce or *moderate* these harmful

situations and their unfavourable consequences. Without this permanent care, however, these undesirable facts may be magnified. Consequently, efficient **soil moisture control** is a key issue of the "quality maintenance" of soil, this important conditionally renewable natural resource, using its three unique characteristics: resilience; fertility/productivity; multifunctionality (Birkás, 2008; Farkas et al., 2009; Várallyay, 2010b).
As the direct moisture control actions, irrigation and drainage are faced with serious limitations in the Carpathian Basin (limited quantity of good quality irrigation water, relief; poor horizontal and vertical drainage conditions) all efforts have to be taken for the *improvement of "rainwater efficiency"* by the more efficient use of the water storage capacity of soil, by a *double face moisture control*, to (Birkás, 2008; Farkas et al., 2009; Várallyay, 2010b,c):

- help water *infiltration* into the soil and water *storage* within the soil in plant available form (reduce the evaporation, surface runoff and deep filtration losses: reduce drought sensitivity);
- improve the vertical and horizontal *drainage* conditions of the soil profile or/and the given area: reduce the waterlogging or over-moistening hazard.

Most of these „moisture management actions" are – at the same time – efficient environment control measures and reduce the risk and unfavourable consequences of other stresses (soil degradation processes, nutrient stress, pollution hazard, etc.) (Várallyay, 1985, 2006, 2007b, 2010c; Várallyay & Farkas, 2008).

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Section V

Step-by-step adoption of adaptable soil tillage in Central Europe

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Abstract

For centuries, tillage was regarded by classical authors as a means of ensuring that crops' needs are met. That period is therefore now referred to as the era of crop-focused tillage. Attention shifted to soil conservation later on, thus that period is called the era of soil-focused tillage. A new challenge to be faced in the near future is how to reduce climate-induced damage by the use of climate mitigation tillage. The relationship between soil tillage factors and climate impacts has been studied in parallel in our countries in long-term tillage experiments and by field monitoring. Some of the most important factors that can be used in a step-by-step approach to the adoption of adaptable soil tillage have been identified. Changing tillage practices is considered to be crucial in Central European region and the recommended techniques include a long-term solution.

Keywords: soil, climate, water, conservation, tillage

Introduction

For centuries, tillage was regarded by 'classical authors' as a means of ensuring that crops' needs are met, which is why that period is referred to as the era of crop focused tillage. Later on, between 1975 and 2000 more attention was paid to soil conservation, therefore that period is referred to as that of soil quality focused tillage (Figure 1). Since the increasing frequency of the climate extremes, there is a growing need for turning tillage towards climate focused activities. For this reason the aim of tillage now is to alleviate climate-induced losses through reducing the sensitiveness of the soils (Birkás et al., 2008, Jug and Birkás et al., 2010, Várallyay, 2011). Combinations of the climate phenomena, e.g. high air temperature coupled with water shortage or low air temperature coupled with abundant precipitation, have also been causing severe losses in cropping (Birkás, 2010, Várallyay, 2010, Szalai, 2011).

				+ harmony between environment, climate and land use	
				+ climate threat mitigation tillage for production stability	
		+ soil quality condition focused tillage			
	+ stressing crop focused tillage				
+ improvement of soil biological condition					
establishment of crop demands					
~1800 - 1930	**1930 - 1950**	**1950 - 1980**	**1980 –1990**	**1990 – 2015**	**?2015-**

Figure 1 Objectives of the land use in Central Europe (~1800 -)

Some authors argue that identifying the shortage or the excessive abundance of precipitation as the cause of yield losses without reference to the physical and biological state of the soil may lead to wrong conclusions (Riley et al., 2005, Badalíková and Červinka, 2010, Birkás and Bottlik et al., 2010, Birkás and Stingli et al., 2010, Morris et al., 2010, Smutný, 2010, Kalmár et al., 2011, Macák et al., 2011).

Table 1 Soil tillage development in Central European region

Eras of soil tillage development	Shortcomings and challenges
1. Early (-1600)	Lack of tools and expertise
2. Low intensity farming (1600-1800)	New demands on crop production
3. Multi-ploughing systems (1750-1900)	Soil quality deterioration
4. Early adaptable tillage (1860-1930)	Adaptation to soil condition
5. Conventional tillage (1800-1988)	
5.1. based on animal draught power (1800-1950)	Climate / draught power dependence
5.2. partially mechanized (1900-1960)	Possibility of deeper tillage
5.3. technology focused (1975-1988)	Overestimation of the potentials of mechanization
6. Energy saving and soil conservation (1975-1988)	Need to improve soil condition
7. Modern adaptable tillage (1988-2015-)	
7.1. declining period (1988-2000)	Soil quality deterioration
7.2. period of transition (2000-2015)	Necessity of climate threat mitigation
7.3. sustainable period (?2015-)	Recognition of sustainability principles

Trends of improvement and deterioration in the quality of soils have been affected by tillage practices applied for long periods of time and they can be only slightly altered by the last applied tillage technique. In the history of the development of soil tillage in the Pannonian region scholars now distinguish a number of clearly identifiable periods, such as harmful (1, 3, 5, 7.1), neutral (2, 7.2) and soil quality improving (4, 6, 7.3) (Table 1). The length of each of these periods is also important, e.g. during the three centuries of cropping based on ploughing the fields several times over year after year the original organic carbon content of the soils must have been reduced by about 50 % (ECAF, 1999) the consequences of which have to be faced today. When a decision is made to improve the soil quality one must be aware of the fact that this work has to be started with soils in a very poor condition in many places (Birkás, 2011). In view of the practices prevailing in this region a gradual approach – through unceasing improvement – should be targeted for the adoption of tillage to soil and climate (Jug and Sabo et al., 2010, Lacko-Bartosová, 2011).

The first tasks are to take account of the possibilities and potentials – arable sites, soils, climate, economy, experimental data etc. – (Bašić et al., 2010, Birkás and Jug et al., 2010, Jug and Birkás et al., 2010, Křen and Valtýniová, 2010, Jolánkai et al., 2011) and to draw lessons from past mistakes (Table 2). The next task is to provide scientific proof of the benefits of soil quality improvement and to disseminate various tillage techniques that are suitable for reducing the soil sensitiveness and vulnerability to the frequent climate stresses.

Material and methods

This paper is based on works discussing our subject (Bašić et al., 2010, Birkás and Jug et al., 2010, Jug and Birkás et al., 2010, Křen and Valtýniová, 2010, Jolánkai et al., 2011) and on findings of long term experiments underway in our countries as well as on the conclusions drawn from them (Birkás, 2010, Birkás and Stingli et al. 2010, Josipović et al., 2010, Jug and Sabo, 2010, Smutný, 2010, Jurišić et al., 2011, Kalmár et al., 2011).

Results and discussion

The need for a change

The standards of land use in our countries have been affected, to varying degrees in the different eras, by traditions, the ecological (including climate, soil quality etc.) and the economic background and by progress in science and expertise. Foreign trends – e.g. the American Campbell's dry farming 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. Imported machines, however, have been in use practically ever since such those have been manufactured. The practice of ploughing to depths exceeding 25 cm was increasingly widely adopted in response to the encouragement of sugar bet production (from 1860 on). The standards of soil tillage declined in the wake of the two World Wars, as a consequence of distribution of land and – rather surprisingly – as a result of the privatisation of land as well. Farmers failed to recognise the importance of applying the relevant findings of the study of soil physics for quite some time but they were quick to respond to changes in the economic conditions. 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 (as could be observed from about 1750 up to the late 1990s).

Table 2 Land use and conventional soil tillage affecting soil damage

Damage caused by land use	Soil layer	Soil condition	Damage caused by tillage
• Loss of organic matter • Loss of soil, nutrients and water • The soil biological mellowing restrained and/or degraded • Degradation of earthworm habitat	top layer tilled layer	degraded structure	• Bare surface • Extreme water loss – soil desiccation • Cyclical clod and dust formation
• Diminishing activity of beneficial organisms • Beneficial biochemical processes stagnation	root zone	compaction and recompaction	• Water and wind erosion occurrence and extension • Water-logging on compacted surface and/or tillage pans
• Anaerobiosis – stimulation of the activity of pathogenic organisms • Intensification of unfavourable chemical processes • Deterioration of soil culture condition	subsoil	natural and/or human-induced compaction	• Cyclical compaction and recompaction – alleviation of extreme climatic effects does not occur • Deterioration in soil workability and trafficability

Climate challenges have grown increasingly frequent since 1999-2000, conveniently coinciding with the subsiding of the uncertainties entailed by the changes in land ownership and with an increase in the appreciation of professional expertise. Those continuing to apply their conventional tillage methods however, regarded drought damage phenomena not as challenges but – owing to a multitude of different types of damage caused to their soils (Table 2) – as natural disasters beyond their control. The condition of the soil created by conventional tillage (e.g. ploughing in the spring and summer resulting in loss of water) failed to provide effective protection against the situation caused by the increasingly unfavourable climate conditions (Birkás et al., 2008). Field monitoring data (Birkás and Jug, 2010) show that during the adverse climate phenomena observed during the past ten years – years of extreme drought: 2000, 2003, 2007 and 2009; or too much rain: 2010 – only fields under adaptable tillage offered any chance for alleviating the damage. Research has shown (Badalíková and Červinka, 2010, Birkás and Bottlik et al., 2010, Smutný, 2010, Kalmár et al., 2011, Macák et al., 2011) that improving the quality of soils, including the alleviation of soils susceptibility to damage through conserving their organic matter contents, and controlling the soil water transport mechanisms and moisture balance, are crucial elements of the preparations for the increasingly frequent extreme weather and soil moisture conditions.

Climate scenarios and adaptation

Long term scenarios forecast mild winters in the Pannonian region with somewhat more precipitation as well as dry and hot summers, with increasingly extreme distribution of precipitation (Bartholy and Pongrácz, 2008, Bozán et al., 2011, Szalai, 2011). The extreme weather conditions may involve an increased number of windy and stormy days.

The promise of mild and wet winters calls for improving the soil's water intake and storage capacity. To get prepared for frequent windy winter primary tillage in the autumn should always be followed by surface forming before the winter. Harvesting in the late autumn in wet fields entails soil damage by traffic, leading to diminishing water intake capacity and soil structure degradation (Jurišić et al., 2011). The remaining moisture content of the soil after the harvest of the previous crop will have to be retained if the spring-sown crops are to be produced reliably. Regardless of the tool applied, primary tillage should be aimed at achieving a soil state that is conducive to water storage and to minimising the water loss in and out of the growing season (Birkás and Kisić et al., 2009, Birkás and Botlik, 2010).

No frost will crumble large clumps of soil during milder winters but that will be favourable for soils whose structure has already been degraded. In degraded soils covering the surface with crop residues is growing in importance. The lack of frost impact necessitates secondary tillage in the soils in which ploughing created large clods. Crops' growing periods and their yields are shortened and reduced by hot and dry summers. Stress-induced ripening may be avoided by growing drought-tolerant varieties and hybrids (Jug and Sabo et al., 2010, Josipović et al., 2010). Particular attention must be paid to weeds owing to their water consumption, as a number of weed species are drought tolerant and their seeds mature more quickly (Galzina et al., 2010). The summer is a critical period during which considerable amounts of water are lost from disturbed soils. As Birkás pointed out (2010), notoriously water loss increasing tillage techniques (ploughing or loosening without surface pressing) should be replaced by moisture and carbon conserving techniques. Harvesting should be followed by creating a covered soil surface that is suitable for retaining water and ploughing should be substituted by some soil-crumbling and loosening form of tillage. Soaring fuel prices may also necessitate shallower primary tillage in the late summer, but the need for alleviating climate induced damage calls for eliminating soil compaction and tillage pan layers. Damage caused by the extreme distribution of rains (short periods of heavy rains) in the summer – as noted by Várallyay (2011) – can be alleviated by maintaining the soils water intake capacity and by preventing desiccation and dust forming in the topmost soil layer.

Tillage practices aggravating the soil's exposure to damage by extreme climate phenomena

Particular emphasis was laid in the course of our experiments and monitoring on summing up the tillage practices that lead to increased damage (Table 3) since they are in stark contrast to the proposed adaptable tillage patterns (Birkás and Kisić et al., 2009, 2011, Birkás, 2010, Smutný, 2010, Jug and Sabo et al., 2010, Jurišić et al., 2011).

Table 3 Types of soil damage caused by tillage and their consequences

Tillage practices aggravating damage	Consequences
The risks of soil damage by tillage:	
- soil structure degradation, clod and dust forming	- increasing exposure to damage by climate phenomena
- compact, water-impermeable layer at/below depths of 10, 15, 20 or 25 cm	- impeded water transport, losses caused by drought or waterlogging
- impervious, compact, 5-20 cm thick layer	
- lack of knowledge of the soil condition	- over-estimation of the expected harvest
- compaction close to the soil surface	- loss of harvest in a *favourable* season: 1-5 %, in a *dry* season: 20-35 %, in a *wet* season: 18-50 %
- unsuitable tools and techniques	- they may be acceptable only in the case of ‘average’ soil moisture content
- carbon wasting tillage technique/system	- soil quality deterioration, great climate exposure
Wrong tillage in the summer:	
- removal of the straw (which would have served as a heat insulating and water retaining layer)	- *dry* season: heat stress, loss of water - *wet* season: rain stress, silting, crust forming and soil settling
- ploughing (large surface)	loss of water: 15-27 mm/30 days
- disturbed and bare surface (‘field *tilled black* after harvest’)	- *dry* season: loss of water; *wet* season: over-settlement; the crop residues do not decompose in the inactive layer
Wrong tillage in the autumn:	
- ploughing when the soil moisture content is not suitable	- *dry* soil: clod and large clump forming, *wet* soil: puddling and smearing; remediation is expensive
- ploughing of wet soil	- plough pan (water-impervious layer) is formed
- ploughing of dry soil	- large clumps are formed, uneven drying in the spring, inadequate seedbed quality
- no surface forming in the autumn	- loss of water (76-148 mm/ 90 days), seedbed and germination problems - frost impact on a large surface, dust forming, wind erosion, silting
- subsoiling	- *wet* soil: low effectiveness, recompaction - *desiccated* soil: large soil clumps are formed and surface forming is made more difficult
Wrong secondary tillage practices	
- surface forming in wet soil after ploughing with conventional disks	- compact layer underneath the disking depth, shallow rooting zone
- seedbed preparation in wet soil	- too compact seedbed base, shallow rooting
- desiccation of the soil	- uneven, protracted emergence

The results of the experiments show that the extent to which a soil is easily affected by settling and compaction is closely related to the management of its organic matter content. Most of the ‘unexpected’ damage is caused by the shortage or extreme abundance of water is caused to soils getting depleted of their OM content as a consequence of farming (Birkás and Kisić et al., 2011). For this reason, the breaking of the continuity of the recycling of OM and the removal of crop residues for use by industry must be regarded as a major climate damage aggravating action. Soils’ deficient nutrient supply is a risk factor because it increases the plants’ water consumption, reduces the efficiency of their water utilisation and their competitiveness against weeds. Wrong practices in crop protection qualify as climate damage increasing factors owing to the increasing of plants’ stress-sensitiveness. Adaptation requires knowledge of the damage and defects caused by farming (cropping, tillage), recognition of the need for change (improvement) and preparation for difficult (unusual) conditions, very much rather than just passively letting damage and problems occur.

Adaptation and alleviation of damage – step by step

The first step in the adaptation in tillage involves recognition of the risks – wrong practices or habits, poor soil quality, extreme climate phenomena etc. – and an urge for improvement, while the second step involves improvement of the soil quality, in harmony with ecological, mechanisation and the farm management conditions. The long term goal of adaptation is to enhance the soil resistance by reasonable controlling of the soil moisture and carbon balance (Birkás, 2011). The principles of adaptable tillage – from stubble tillage to sowing, based on long term trials and soil condition monitoring – as follows (Birkás et al., 2008, Jug and Birkás, 2010, Birkás and Kisić et al., 2011, Várallyay, 2011):

- The shading that was removed by harvest must be replaced by a new protective layer, for which the well-chopped and evenly spread crop residues are highly suitable (*primary* protection). The decomposing cover layer can then be replaced by the residues of the sprayed weeds and volunteers that have emerged by that time (*secondary* protection).
- The purposes of stubble tillage include alleviating heat and rain stress, conserving soil moisture and protecting the soil structure and useful soil-borne organisms as well as naturally deepening the depth of the biologically active layer.
- The depth and mode of stubble tillage as well as the surface left behind should be soil regeneration: shallow disturbance, 35-45 % coverage and a pressed surface is required.
- If the straw is removed or little amounts of residues are left on the surface after the harvest a crumbly insulating layer should be created to protect the soil (*substitutive* protection).
- Mulch material should be incorporated in the soil after the critical period as it is OM source.
- Soil condition should be checked four times in fields under highly valuable crops and where the soil was damaged by waterlogging and/or droughts during the preceding five years.
- Soil state defects are important facts to the planning of the tillage before the next crop.
- Compaction impeding the water transport to the root zone must be eliminated and the soil's harmonious water transport mechanisms must be restored.
- Climate extremes call for continuous soil moisture storage, for optimising the soil water intake and for minimising the loss of water.
- The depth of the loosened layer is not the result of the most recent tillage activities; the deep loosened layer is, indeed, a result of conserving land use over a long term period.
- Varying the depth of primary tillage and alternating the use of pan forming and loosening tools are indispensable for avoiding tillage pans.
- Tools conducive to pan forming should not be used in wet soils. The optimum soil moisture range for driving over the land and for its cultivation must be known.
- Circumstances leading to clod or dust forming should be prevented, i.e. a dry soil may be disturbed only in a careful way, gradually deepening the working depth.
- Crumb forming requires tillage focused on conserving the soil structure and its moisture and organic matter content, along with earthworm activity.
- A wet (trafficable) soil should be tilled causing the least possible damage (e.g. cultivator).
- Maintaining the favourable water transport and balance in the soil or even improving it is crucial (regardless of the type of tillage or sowing).
- The occasional rainy periods do not decrease the importance of moisture conservation.
- Tillage should encourage the water infiltration from the soil surface (capable of taking water in) and the retaining of soil moisture (evaporation minimising surface).
- Minimising the water-waste soil surface should be aimed at in all seasons. In the summer the soil surface should be pressed while before wintering an evened surface should be created.

- It should be pointed out – in contrast to previously prevailing views – that the evened soil surface does take water in but it reduces the water lost in mild and windy winter days.
- Snow may or may not be ‘caught’ by the furrows in the field after ploughing but after a mild winter the soil will definitely lose a lot of its moisture content if its surface is not evened.
- A dust layer of at least 10 mm is formed in the wake of the frosts on the large ploughed soil surface (about 55-85 % of a given amount of soil), which is eroded by the high spring winds and is deposited in places where it is not welcome (as witnessed in the April of 2011).
- The well-workable soil can be evened without causing damage, thereby reducing the surface affected by frost and the amount of dust (15-25 % of a given amount of soil) so formed.
- Conserving organic matter is a key element of the alleviation of climate induced damage through retaining the soil water content: (i) Create OM conserving soil surface in any tillage season. (ii) Clod forming must be avoided because it causes loss of water in the same year, along with carbon loss over several years. (iii) The crop residues should not be removed where little farmyard manure or green manure is applied. (iv) Continuous conserving land use contributes to reducing the soil exposure to climate-induced damage.
- Documentation of climate phenomena and investigation of the circumstances leading to damage should make more effective preparations for protection.

Conclusions

The future possibilities of field crop production are likely to be expanded or restricted by increasing adaptation to the climate changes therefore it is crucial that information should be disseminated and farmers should be assisted in mastering the possible methods of adaptation. The first step in the process of adaptation in 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. The authors consider it fairly safe to declare that climate-induced damage could be effectively mitigated by employing adequate expertise and adaptable tillage.

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Production and quality of forage under different systems of nitrogen fertilisation

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Abstract

Effects of the nitrogen fertiliser SAM (ammonium sulphate + urea) applied by means of the method CULTAN (Controlled Uptake Long Term Ammonium Nutrition) and of the conventionally broadcasted fertiliser LAV (lime salpeter) on dry matter (DM) production and qualitative parameters of forage crops (intergeneric hybrids Perseus and Felina) were investigated in the company Zemědělský výzkum s.r.o. Troubsko, Czech Republic (sugar beet growing region). In the experiment, altogether three variants of nitrogen fertilisation were used, 0; 90 and 180 kg N ha^{-1} within the growing season. Within a period of two years, grass stands were harvested three times in the stage of heading. As far as the DM production was concerned, there were no statistically significant differences between compared systems CULTAN and LAV. When using the method CULTAN, a decrease in qualitative parameters NS (nitrogen substances), NEL (net energy for lactation), NEF) net energy for fattening), and PDIN (proteins truly digestible in intestines of ruminants) was recorded in some cuttings. However, no decrease in these values was demonstrated when evaluating the sum of all cuttings harvested within the growing season.

Keywords: CULTAN; LAV; Perseus; Felina; dry matter

Introduction

The application of nitrogen fertilisers is one of important agronomical measures that influence yields and quality of forage. At present, the CULTAN (Controlled Uptake Long Term Ammonium Nutrition) method is being tested in practice; this system is based on a single injection of liquid nitrogen fertiliser containing ammonium ions (i.e. a solution of ammonia, ammonium sulphate, ammonium nitrate, urea, etc.) into the root system space in soil where it creates the so-called "depot", i.e. a place with a high concentration of ammonium ions, which are bound to clay particles and organic matter present in soil. Roots penetrate to this depot depending on their nitrogen requirements. The ammonium form of nitrogen is used for synthesis of organic compounds directly in roots and this process results in their more intensive growth. In contradistinction to the ammonium form, the nitrate form is at first transported into assimilation organs where it must be reduced to ammonium nitrogen, which can be used for the formation of organic compounds.

A high concentration of ions in this depot is another positive feature of the CULTAN method because it is toxic for nitrification bacteria, which oxidise ammonium to nitrates (NO_3^{-1}). In contradistinction to ammonium form, nitrates are very mobile within the soil profile and this may result either in losses of nitrogen because of their penetration into deeper soil layers or in the denitrification, i.e. transformation of nitrates to elementary nitrogen (N_2).

In general, it is possible to prevent or inhibit losses of ammonium form of nitrogen (i.e. its volatilization) by incorporation of ammonium ions into the soil to the depth of 50-70 mm; as compared with conventional broadcasting, the overall losses may be reduced by approximately 30% (Nyord *et al.*, 2008). When using the CULTAN method, the nitrogen fertiliser can be applied to the depth of as much as 200 mm.

The CULTAN method was tested in many crops and the obtained results were positive. Experiments with spring barley (Sedlář *et al.*, 2009) demonstrated an increase in grain yields after the application of liquid fertilisers by the CULTAN method. However, in other experiments with spring barley (Kozlovský *et al.*, 2009a) and winter wheat (Kozlovský *et al.*, 2009b) no differences in grain yields (and/or in production of aboveground DM were found out when comparing the CULTAN method with conventional broadcasting of nitrogen fertilisers. It is also known that the CULTAN method is not suitable for fertilisation of some members of the family *Fabaceae* because they show a negative sensitivity; this observation concerns for instance damaged roots of broad bean *(Vicia faba)* (Feng *et al.*, 1997) or a decreased formation of aboveground biomass of red clover *(Triforium pratense)* (Neuberg *et al.*, 2010) .

Some experimental results concern not only plant nutrition but also other domains. Blanke *et al*. (2001) demonstrated that the CULTAN method reduced the content of nitrates in kohlrabi tubers. A different structure of growing plants enabled their quicker drying after the rain and, thus, an accelerated washing-off of spores from leaves and reduced risk of infection. These authors also mentioned that, as compared with the conventional method of fertilisation, nitrate residues after the harvest were lower by 45%. Results of other experiments with the CULTAN method demonstrated an increased water stress resistance of plants (Kreusel, 1992).

Material and methods

An exact small-plot experiment with grass hybrids Perseus and Felina was established in Troubsko (sugar-beet growing region) in two subsequent sowing cycles. Each of them lasted three years and the first year was not evaluated because of sowing and stand establishment. The second and the third year were analysed as production years and involved altogether three cuttings (the first one was performed in the stage of heading, the following two always after sixty days). Samples of forage were collected, dried and analysed by NIRS (near infrared spectroscopy). Evaluated were the following parameters: DM yield, fibre content, content of nitrogen substances (NS), net energy for lactation (NEL), net energy for fattening (NEF), and proteins truly digestible in intestines of ruminants (PDIE, PDIN).

Experimental stands were fertilised using either the CULTAN system (SAM – ammonium sulphate + urea) or conventional broadcasting of LAV (lime saltpeter). There were altogether three variants of nitrogen fertilisation:1) without N; 2) 90 kg N ha^{-1} (applied in a single dose in the spring); and 3) 180 kg N ha^{-1} (90 kg N ha^{-1} in the spring, 60 kg N ha^{-1} after the first cutting and 30 kg N ha^{-1} after the second cutting). Each variant had four replications. Values obtained in both production cycles were statistically processed using the method of multi-factorial variance (ANOVA P>0.01) with a subsequent testing by Tukey's test.

Results and discussion

When comparing values DM yield obtained in individual cuttings of both grass hybrids, no differences were found out between variants fertilised using the CULTAN method and conventional LAV broadcasting neither in the first nor in the second production year (Tab. 1). Similar results were presented also by Balík *et al*. (2008) who found out that there were no differences in DM production of grass/clover mixtures fertilised with CULTAN and LAV systems. Similarly as in the case DM yield, also contents of fibre did not show differences between both fertilisation systems and/or production years (Tab. 2).

Table 1: DM production (t ha^{-1}) of grass hybrids in individual cuttings within a two-year experimental period (comparison of LAV broadcasting and CULTAN systems)

System of fertilisation x Grass species	DM (t ha^{-1})							
	First year				Second year			
	Cutting			Total per year	Cutting			Total per year
	1st	2nd	3rd		1st	2nd	3rd	
LAV x Perseus	5.91	3.57	1.00	10.47	2.36	2.55	0.68	5.58
LAV x Felina	6.79	3.44	2.43	12.66	6.77	3,00	1.85	11.61
CULTAN x Perseus	5.73	3.69	1.04	10.45	2.07	2.36	0.64	5.06
CULTAN x Felina	6.43	3.27	2.55	12.25	6.99	2.93	1.65	11.56
$D_{T\ 0.01}$	0.64	0.57	0.33	1.01	1.60	0.61	0.44	2.34

Table 2: Fibre production (g kg^{-1} DM) of grass hybrids in individual cuttings within a two-year experimental period (comparison of LAV and CULTAN systems)

System of fertilisation x Grass species	Fibre (g kg^{-1} DM)							
	First year				Second year			
	Cutting			Mean per year	Cutting			Mean per year
	1st	2nd	3rd		1st	2nd	3rd	
LAV x Perseus	220.81	289,00	265.59	258.47	192.43	291.43	307.50	263.79
LAV x Felina	263.44	269.64	277.46	270.18	254.56	275.93	299.91	276.80
CULTAN x Perseus	219.47	300.10	269.11	262.89	189.48	302.24	313.19	268.30
CULTAN x Felina	271.35	276.39	278.9	275.54	259.06	281.66	303.95	281.56
$D_{T\ 0.01}$	20.40	11.28	13.56	9.36	15.34	12.30	13.44	8.11

As far as the content of nitrogen substances (NS) was concerned, a difference was found out in the first production year (2nd cutting) of grass hybrid Felina. Samples of grass hybrids fertilised with LAV contained greater amounts of NS (130.1 g kg^{-1} DM) than those fertilised with the CULTAN system (115.4 g kg^{-1} DM). In the second production year, the inter-generic hybrid Perseus contained more NS in the second cutting in variant with LAV (125.6 g kg^{-1} DM) than in variant with the CULTAN method (106.8 g kg^{-1} DM) (Tab. 3).

Table 3: Production of nitrogen substances (g kg^{-1} DM) of grass hybrids in individual cuttings within a two-year experimental period (comparison of LAV and CULTAN systems). Coloured boxes indicate statistically significant differences between both fertilisation systems.

System of fertilisation x Grass species	NS (g kg^{-1} DM)							
	First year				Second year			
	Cutting			Mean per year	Cutting			Mean per year
	1st	2nd	3rd		1st	2nd	3rd	
LAV x Perseus	118.01	99.04	138.97	118.67	113.19	125.57	138.47	125.74
LAV x Felina	130.33	130.07	122.65	127.68	103.32	126.04	115.54	114.97
CULTAN x Perseus	114.92	89.27	132.91	112.37	109.45	106.74	131.07	115.75
CULTAN x Felina	126.86	115.36	117.74	119.99	99.22	110.37	107.87	105.82
$D_{T\ 0.01}$	16.40	14.48	12.83	9.60	12.66	16.98	12.29	10.41

Differences in NEL values were recorded in the second production year in the third cutting of both hybrids; in both cases, contents of NEL were higher in the variant with LAV. The inter-generic hybrid Felina fertilised with LAV, produced 5.2 MJ kg^{-1} DM while in the variant with the CULTAN system the value of this parameter was only 5.0 MJ kg^{-1} DM. The inter-generic hybrid Perseus fertilised with LAV, produced in the third cutting 5.5 MJ kg^{-1} DM while in the CULTAN system only 5.3 MJ kg^{-1} DM (Tab. 4). NEF values were influenced by different systems of fertilisation in the third cutting of the second production year. In case of Felina hybrid fertilised with LAV, the NEF value was 5.0 MJ kg^{-1} DM while in the variant with the CULTAN system the recorded NEF value was 4.8 MJ kg^{-1} DM (Tab. 5).

Table 4: NEL values (MJ kg^{-1} DM) of grass hybrids in individual cuttings within a two-year experimental period (comparison of LAV and CULTAN systems). Coloured boxes indicate statistically significant differences between both fertilisation systems.

System of fertilisation x Grass species	NEL (MJ kg^{-1} DM)							
	First year				Second year			
	Cutting			Mean per year	Cutting			Mean per year
	1st	2nd	3rd		1st	2nd	3rd	
LAV x Perseus	5.45	4.89	5.41	5.25	5.35	5.02	5.47	5.28
LAV x Felina	5.13	5.14	5.41	5.23	5.15	5.15	5.23	5.18
CULTAN x Perseus	5.67	4.79	5.53	5.33	5.57	5.14	5.30	5.34
CULTAN x Felina	5.18	5.07	5.41	5.22	5.27	5.13	5.05	5.15
$D_{T\ 0.01}$	0.25	0.20	0.24	0.13	0.26	0.25	0.17	0.13

Table 5: NEF values (MJ kg^{-1} DM) of grass hybrids in individual cuttings within a two-year experimental period (comparison of LAV and CULTAN systems). Coloured boxes indicate statistically significant differences between both fertilisation systems.

System of fertilisation x Grass species	NEF (MJ kg^{-1} DM)							
	First year				Second year			
	Cutting			Mean per year	Cutting			Mean per year
	1st	2nd	3rd		1st	2nd	3rd	
LAV x Perseus	5.31	4.58	5.20	5.03	5.20	4.72	5.29	5.07
LAV x Felina	4.86	4.87	5.19	4.97	4.90	4.87	5.00	4.93
CULTAN x Perseus	5.56	4.47	5.34	5.12	5.45	4.87	5.08	5.13
CULTAN x Felina	4.92	4.79	5.18	4.96	5.04	4.85	4.78	4.89
$D_{T\ 0.01}$	0.31	0.23	0.29	0.16	0.30	0.30	0.21	0.16

In values of PDIN, a difference between both systems of fertilisation was recorded in the first production year (second cutting) of Felina hybrid. In variant with LAV, recorded PDIN values were higher (76.3 g kg^{-1} DM) than in the variant with CULTAN (66.1 g kg^{-1} DM) (Tab. 6). No differences were observed in values of PDIE (Tab. 7).

Table 6: PDIN values (g.kg^{-1} DM) of grass hybrids in individual cuttings within a two-year experimental period (comparison of LAV and CULTAN systems). Coloured boxes indicate statistically significant differences between both fertilisation systems.

System of fertilisation x Grass species	PDIN (g kg^{-1} DM)							
	First year				Second year			
	Cutting			Mean per year	Cutting			Mean per year
	1st	2nd	3rd		1st	2nd	3rd	
LAV x Perseus	68.65	53.70	82.13	68.16	62.68	69.82	78.64	70.38
LAV x Felina	78.28	76.29	70.28	74.95	59.70	72.00	63.30	65.00
CULTAN x Perseus	66.70	47.21	76.21	63.37	61.09	59.72	73.56	64.79
CULTAN x Felina	76.05	66.13	66.05	69.41	57.47	62.31	58.50	59.43
$D_{T\ 0.01}$	10.01	9.48	9.10	6.21	7.62	10.93	7.65	6.43

Table 7: PDIE values (g kg^{-1} DM) of grass hybrids in individual cuttings within a two-year experimental period (comparison of LAV and CULTAN systems).

System of fertilisation x Grass species	PDIE (g kg^{-1} DM)							
	First year				Second year			
	Cutting			Mean per year	Cutting			Mean per year
	1st	2nd	3rd		1st	2nd	3rd	
LAV x Perseus	79.03	73.10	77.07	76.4	76.34	75.12	76.77	76.08
LAV x Felina	79.77	79.32	76.03	78.38	76.19	78.00	75.46	76.55
CULTAN x Perseus	79.09	71.65	76.31	75.69	77.14	74.67	76.11	75.97
CULTAN x Felina	79.52	77.49	75.48	77.49	75.98	76.6	74.64	75.74
$D_{T\ 0.01}$	2.24	2.44	2.23	1.42	2.24	2.56	1.76	1.44

However, differences between both systems under study in qualitative parameters (as recorded in individual cuttings), were not manifested in sums of all cuttings calculated for the whole growing season. Also our earlier results (Lang et al., 2010), which were obtained from partial sowing cycles, did not corroborate differences in effects of both fertilisation systems on production and quality of harvested forage.

Conclusions

When comparing the fertilisation system CULTAN with the conventional method of fertiliser broadcasting (LAV) no difference in production of DM was observed between both inter-generic hybrids under study neither in individual cuttings nor in their sums for the whole growing season. Lower values of qualitative parameters (NS, NEL, NEF, PDIN) were recorded in individual cuttings in the experimental variant with the CULTAN system. In sums of individual cuttings for the whole growing season, however, the differences in qualitative parameters were not manifested. The inter-generic hybrid Felina showed a more sensitive response to different systems of fertilisation.

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Mapping the spatial variability of soil using indirect methods

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Abstract

Within field mapping of soil spatial variability using soil sampling is too cost and time consuming. 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 conditions, measurement of soil electrical conductivity and aerial imaging, was verified. There were moderately strong correlations between the sensor data and soil properties (pH, content of P, K, humus and clay) found at the locality with higher heterogeneity and low relationship at the latter. Both methods showed similar potential to identify the differences in soil conditions but their use for detailed determination of soil parameters is limited due to the complexity of influencing factors.

Keywords: spatial variability, soil sampling, electrical conductivity, remote sensing, precision agriculture

Introduction

Mappig of spatial variability of soil properties using conventional methods, such as soil sampling, is cost and time consuming especially in precision agriculture. Site specific management, known as a precision agriculture, takes into consideration spatial variability within fields and optimizes the production inputs, thus fulfilling the objectives of sustainable agriculture (Corwin and Plant, 2005).

Assessing variability is the critical first step in precision agriculture since it is clear that one cannot manage what one does not know (Pierce et al., 1999). The potential for economic and environmental benefits of precision agriculture increases with increasing spatial variability of soil and crop conditions.

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.

The objective of this study was to compare traditional methods for the assessment of soil environment properties and indirect sensor methods (measurement of soil EC, remote sensing in visible, NIR and thermal part of electromagnetic radiance). The main goal is to verify the efficiency of these indirect methods for the assessment of spatial variability of soil properties in precision agriculture.

Material and methods

Verification was carried out at two different localities in the Czech Republic: Field "Pachty" (52.5 ha; 48°59'N, 16°37'E) with chernozem soil type and sandy clay loam texture, and Field "Haj" (37.8 ha; 49°15'N, 17°06'E) with haplic luvisol and silt loam texture.

Soil sampling

Soil sampling for nutrient management was made in 2004 (Field "Pachty") and 2007 (Field "Haj") in a regular grid 50 × 50 m (totally 214 samples, 4 samples per ha – Fig. 1). Soil samples were taken from the depth 0 - 30 cm in a circle with a diameter of 5 m and analysed for soil $pH_{(KCl)}$, content of P, K and humus (C_{ox} × 1.724).

Soil samples for soil texture analysis were taken at locality Pachty in 2005 in irregular grid based on soil electrical conductivity (40 samples) and analysed for clay content (soil particles < 0.01 mm). In Field Haj 70 samples in regular grid were taken.

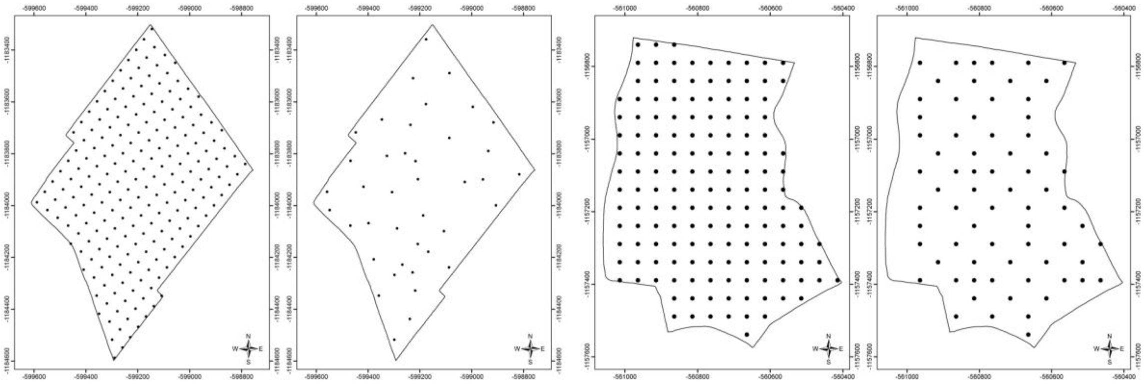

Fig. 1 Sampling designs for mapping of nutrient content and soil texture for Field Pachty (left) and Haj (right)

Mapping of soil electrical conductivity (EC)

In the field Pachty, the measurement of soil electrical conductivity (EC) was carried out in spring 2004 using EM38 device (Geonics Ltd, Canada) drawn by an off-road vehicle in the horizontal dipole of the measurement. In the field Haj, the measurement was performed in 2009 by walking with the device CMD (GF Instruments s.r.o., Czech Republic). Both devices are based on the principle of electromagnetic induction and they have similar construction and function.

Aerial imaging

Aerial survey of bare soil was carried out in March 2008 with Nikon D80 in visible RGB spectrum, multispectral camera DuncanTech MS3100 (G, R and NIR spectral bands) and thermal camera Fluke Ti55FT in flight altitude of 2200 m. The images were georeferenced and downscaled to spatial resolution of 5 m per pixel. A first component from principal component analysis was used for analysis from visible (VIS_c1) and multispectral (MS_c1) images.

Results and discussions

Table 1 presents basic statistical characteristics of soil parameters and indirect methods individually for both fields. Interpolated maps and aerial images are shown in Figure 2.

Tab. 1 Summary statistics of soil parameters and results of indirect methods

		Mean	Min	Max	Std.dev	CV (%)
Field Pachty	pH	6.47	4.40	7.93	0.95	15
	P (mg.kg^{-1})	58.2	13.0	196.0	26.4	63
	K (mg.kg^{-1})	146.1	13.0	395.0	37.1	25
	humus (%)	3.24	1.63	4.77	0.52	16
	clay (%)	33.6	23.0	44.0	4.56	14
	EC (mS.m^{-1})	9.07	1.40	31.40	30.78	61
	Temp. (°C)	10.28	0.06	13.5	1.64	16
Field Haj	pH	6.80	4.86	7.82	0.55	8
	P (mg.kg^{-1})	92.9	28.7	297.9	33.8	36
	K (mg.kg^{-1})	207.6	126.9	432.8	58.2	28
	humus (%)	1.82	0.75	2.77	0.31	17
	clay (%)	39.6	29.1	55.4	5.54	14
	EC (mS.m^{-1})	46.63	21.7	111.7	11.1	24
	Temp. (°C)	4.61	0.01	8.00	1.17	25

CV – coefficient of variation

Temp. – soil surface temperature obtained by thermography

The comparison of soil sampling and indirect methods was made by correlation analysis (Table 2) as an intersection of input data layers (EC, remote sensing) and sampling points with 5m buffer zone.

Tab. 2 Correlation coefficients between soil parameters and indirect methods

		pH	P	K	Humus	Clay
Field Pachty	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	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 *$\alpha = 0.05$; ** $\alpha = 0.01$

The results of comparison of indirect methods with soil sampling were different at both localities. In Field Pachty the moderately strong correlation with soil pH, content of the nutrients (P, K), humus and clay particles were found, while in the field Haj the correlation coefficients were much lower. The reason can lie in the different level of variability of some soil parameters and EC in both locations. The strongest relationships can be expected on high heterogeneous sites.

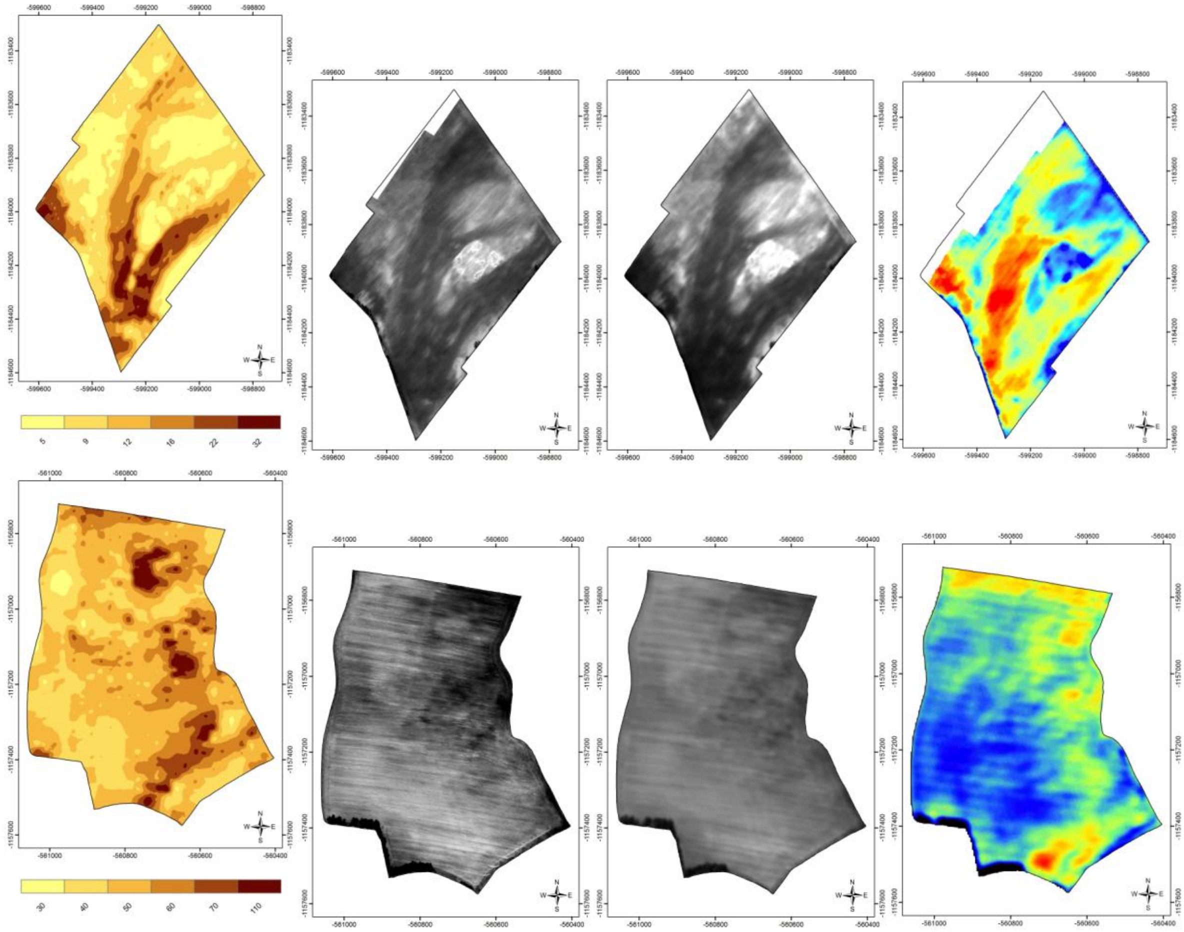

Fig. 2 Maps of interpolated soil EC, images in visible (VIS_c1), multispectral (MS_c1) and thermal spectrum of field Pachty (above) and Haj (bellow)

Finding of moderately strong correlations between the macronutrients content and indirect methods results suggest a use of these methods to map the nutrient status of soil. More than direct influence of nutrient content on the sensor measured variables it is a relationship of agrochemical properties to basic soil parameters which are influencing sensor methods (Lukas et al., 2009). The correlation between the aerial imaging and nutrients content support this theory because there is not known the relationship between the nutrient content and reflectance. Heiniger et al. (2003) confirmed that strong relationship between EC and nutrient content was observed only if the content of nutrients were associated with one of soil properties influencing the EC values.

Despite the differences in measuring principle of remote sensing and electrical conductivity, both methods showed similar potential for mapping of physical and agrochemical properties. The advantage of EC is vertical response and possibility of survey the soil covered by vegetation. Methods of remote sensing offer the higher spatial coverage in short time and possibility to use national or world databases of aerial/satellite data.

Conclusions

Measurement of electrical conductivity and aerial survey showed similar potential for identification of differences in soil conditions. Both methods are influenced by the soil moisture, texture and soil organic matter. The complexity of factors limits the detailed estimation of each soil parameter without conventional methods but can be used to get a comprehensive view at the spatial heterogeneity of soil conditions within the field.

CONTENT

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Effect of different soil tillage on water infiltration into soil

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Abstract

Soil tillage is one of the factors influencing infiltration properties of soil. On experimental site in South Moravia region with loamy haplic Luvisol was observed an influence of different tillage technologies (ploughing, shallow tillage and no tillage – direct drilling) on water infiltration into soil. Measurements of infiltration were made using double ring infiltrometers in period of 2007 to 2011 during vegetation and after crop harvest. Although the results of infiltration rate were different among the tillage variants in individual terms of measurement, statistical evaluation of four year experiment did not prove significant differences among conventional (PL), reduced (ST) and minimization (NT) tillage variants.

Keywords: soil tillage, water infiltration, soil erosion, conservation tillage

Introduction

Soil infiltration properties have an important role in soil protection against water erosion. More than half of agricultural land in the Czech Republic is endangered by water erosion (Janeček, 2007). Rain drops fallen on the soil surface can infiltrate or runoff. Decrease of soil infiltrability in the combination of high intensity precipitations (or their longer duration) leads to the increase of surface runoff and negative phenomena as soil erosion. Moreover, the infiltration increases water store for plants and groundwater recharge (Lipiec et al., 2006).

The rate of infiltration is controlled by the pore size distribution and the continuity of pores or pathways (Kutílek, 2004). One of the factors influencing the soil infiltration properties is soil tillage. Different soil tillage have different impact on the physical soil properties, especially on the bulk density, porosity and soil structure which is then mirrored into infiltration rate.

The effect of soil tillage on soil hydraulic properties is not uniform as illustrates the review of Strudley et al. (2008). To confirm the impact of tillage on soil infiltration, an experiment with three tillage technologies – conventional, reduced and no-tillage (direct seeding) was conducted and after five years evaluated.

Material and methods

The observation was made in stationary field experiment with different soil tillage treatments at locality Visnove (48°58'N, 16°10'E) in South Moravia region (Czech Republic) with loamy haplic Luvisol. The experimental field was cropped with maize monoculture since 2001 (except for year 2009 with spring barley) and treated with following variants of soil tillage:

- ploughing (PL) as traditional tillage system – to the depth of 0.22 m, spring harrowing, cultivation by tiller Horsch Phantom before seeding, seeding with precise drilling seeder Kinze 3600, rolling
- shallow tillage (ST) to the depth of 0.10 – 0.12 m with disc tiller Horsch Phantom, seeding (Kinze 3600), rolling
- no-tillage (NT) – direct seeding with Kinze 3600

Water infiltration into soil was measured from 2007 to 2011 in two terms – during vegetation (June) and after harvest (November) on the same part of the field located by DGPS. A double ring infiltrometers (Fig. 1) with diameter of 0.28 m and 0.54 m in soil depth of 0.1 m were used for soil infiltrability measurement. In smaller ring decrease of water volume in time (for two hours) was monitored and larger ring eliminated horizontal water leakage from smaller ring. Three sets of infiltrometers were used at each tillage variant to get three replications of measurement (2008 – 2011, year 2007 without replications).

Fig. 1 Photo of the double ring infiltrometers and view at the site with three replications (sets of infiltrometers)

Results and discussions

Based on cumulative infiltration, the infiltration rate for each replication was calculated, fitted by exponential trend and averaged in defined time intervals as a final value for soil tillage variants (Table 1). In Fig. 2 are presented examples of infiltration rate curves of 2008 (vegetation) and 2010 (after harvest) measurement.

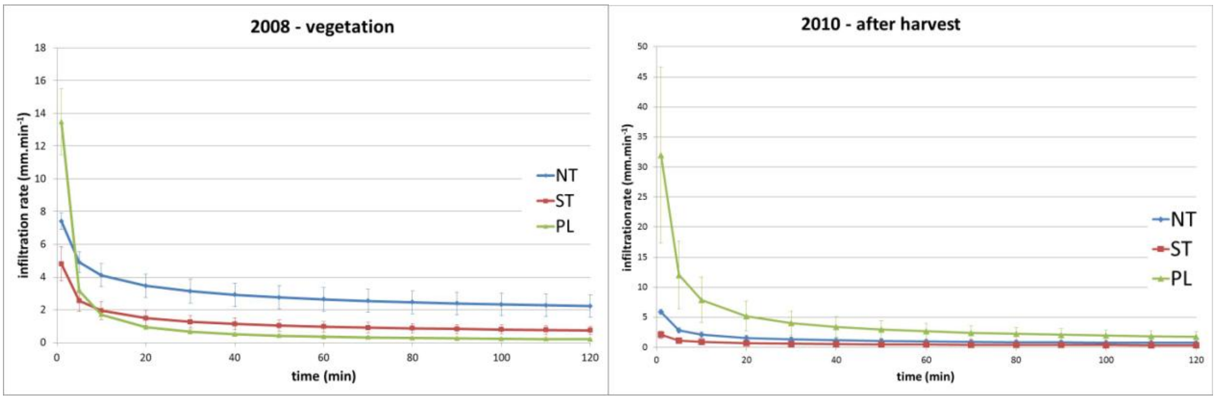

Fig. 2 Examples of infiltration rate curve – 2008 during vegetation and 2010 after harvest

An ANOVA test was used to evaluate the differences between soil tillage variants from year 2008 to 2011 (3 replications of measurement required). Graphical results of ANOVA are presented in Fig. 3.

Table 1 Averaged infiltration rate ($mm.min^{-1}.m^{-3}$) of soil tillage variants in defined time intervals (min)

year	term	var	1	5	10	30	60	120
2007	veg.	PL	17.22	8.96	6.76	4.33	3.27	2.46
		ST	19.75	9.65	7.09	4.35	3.19	2.35
		NT	3.98	3.05	2.72	2.27	2.03	1.81
	aft.harv.	PL	3.99	2.80	2.40	1.88	1.61	1.39
		ST	12.33	9.83	8.91	7.63	6.92	6.28
		NT	13.61	6.18	4.40	2.57	1.83	1.30
2008	veg.	PL	13.48	3.16	1.71	0.65	0.35	0.19
		ST	4.80	2.55	1.94	1.27	0.97	0.74
		NT	7.41	4.90	4.11	3.13	2.64	2.23
	aft.harv.	PL	4.39	1.76	1.19	0.65	0.44	0.30
		ST	18.88	10.40	8.09	5.46	4.28	3.37
		NT	8.86	4.14	3.02	1.87	1.40	1.06
2009	veg	PL	8.90	5.52	4.52	3.31	2.73	2.26
		ST	23.44	6.86	4.11	1.86	1.14	0.70
		NT	16.31	6.69	4.56	2.48	1.69	1.15
	aft.harv.	PL	23.37	11.32	8.31	5.10	3.75	2.77
		ST	20.89	9.08	6.41	3.76	2.73	2.00
		NT	15.33	10.14	8.50	6.44	5.41	4.56
2010	veg.	PL	15.00	9.16	7.47	5.47	4.53	3.77
		ST	2.52	1.78	1.53	1.22	1.05	0.91
		NT	7.98	4.19	3.22	2.18	1.73	1.39
	aft.harv.	PL	31.98	12.03	7.90	4.05	2.66	1.75
		ST	2.09	1.15	0.89	0.59	0.46	0.35
		NT	5.91	2.84	2.09	1.30	0.97	0.73
2011	veg.	PL	5.74	3.57	2.91	2.11	1.72	1.41
		ST	11.51	4.84	3.48	2.20	1.71	1.36
		NT	8.35	5.68	4.83	3.75	3.20	2.74

Veg. / aft.harv. – term of measurement (in vegetation / after harvest)
PL, ST, NT – soil tillage variants (ploughing, shallow tillage, no tillage – direct seeding)

The analysis of variance proved insignificant differences among the soil tillage treatments. Probably one of the reasons are low differences between the tillage variants or instability of the variants order in each term of the measurement. ANOVA graphs in Fig. 3 showed how the differences between the tillage variants were changing in the time intervals of measurement. In first minutes was the highest infiltration rate for PL variant and the lowest for NT variant. But this order was changing through time intervals (1, 10, 30 and 60 min) and the infiltration rate of NT was increasing to the level of PL variant. This corresponds to the review of Strudley et al. (2008), which describes the tendency of NT to increase macropore connectivity and deeper movement of water. Lipiec et al. (2006) noted that the differences in initial infiltration and reduction of infiltration rate with time among tillage treatments imply higher capability of conventional tillage pore system to increase amount of water infiltrating before filling macro-pores and reaching steady state. Kroulík et al. (2007) compared the differences between tillage practices at same locality in 2006. The results were similar – the highest infiltration rate was observed for PL and lowest for ST variant. Coloured water infiltration was used as well, and it showed a water saturation of PL in the top layer, while the variants with reduced tillage (ST, NT) were saturated deeper.

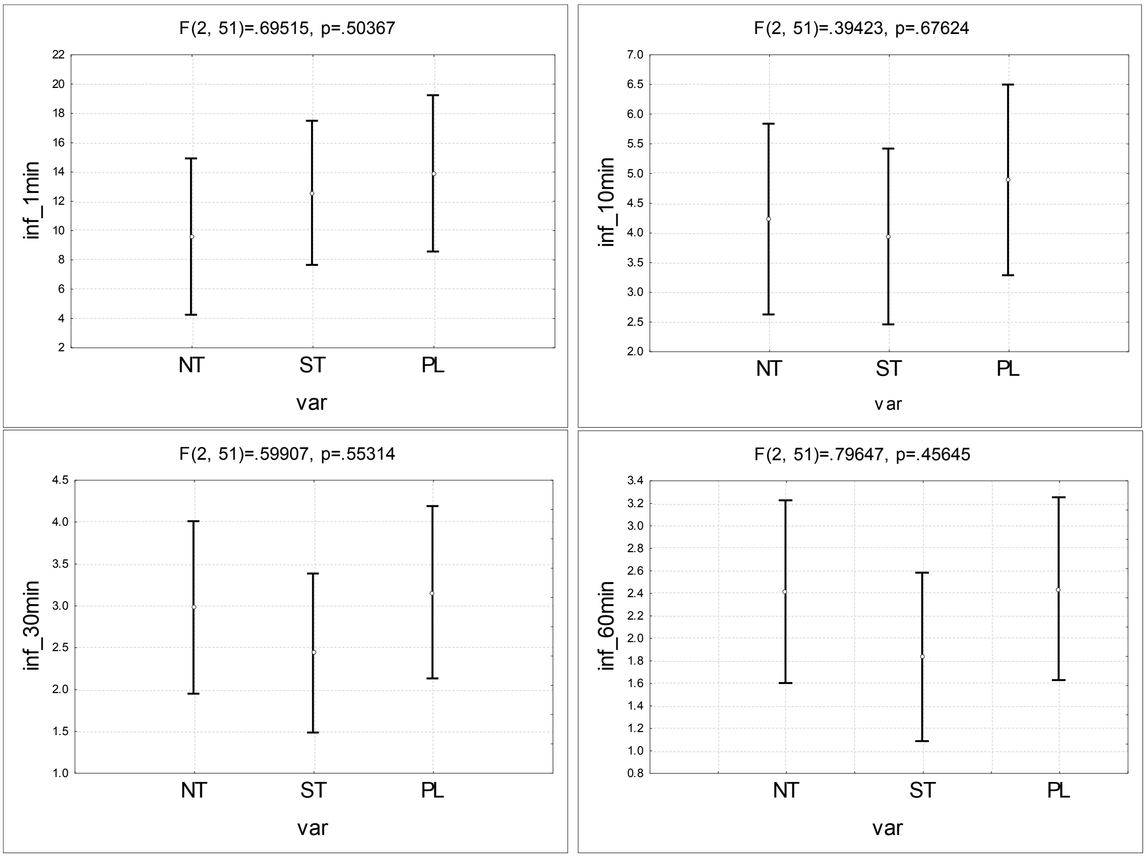

Fig. 3 ANOVA graphs of the infiltration rate in different time intervals (1, 10, 30 and 60 minutes) for the soil tillage variants.

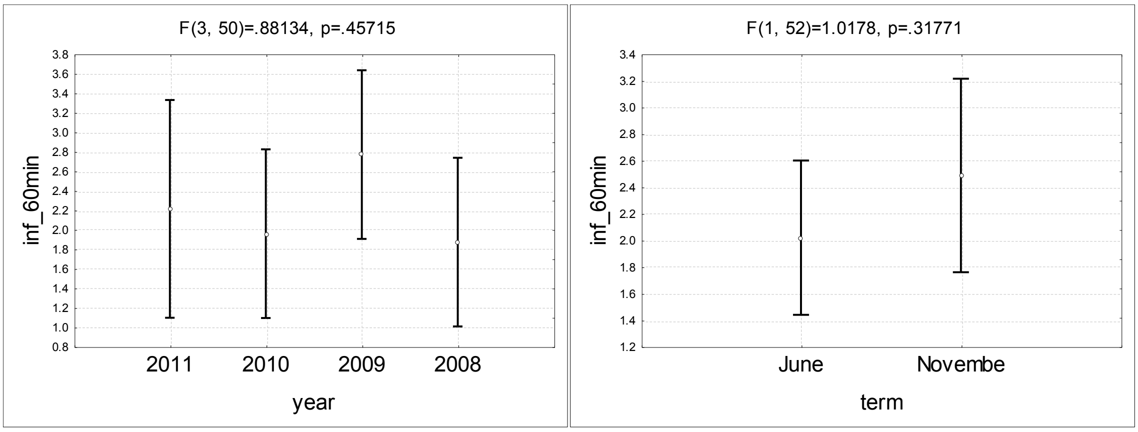

Fig. 4 ANOVA graphs of the changes in 60-minutes infiltration rate during the years and terms of measurement (June – during vegetation, November – after harvest)

The macropore connectivity and crack effects in soil profile are probably reason of the higher infiltration in autumn terms of measurement (Fig. 4). The soil is compacted after maize harvest and the NT variants have more vertical pathways to drain water deeper. However, similar to the comparison of tillage variants, differences between terms were not significant as well.

Conclusions

Although the results of infiltration rate were different among the tillage variants in individual terms of measurement, statistical evaluation of four year experiment did not prove significant differences among conventional (PL), reduced (ST) and minimization (NT) tillage variants.

The results showed higher infiltration rate at PL in the first minutes of measurement, but decline of PL curve was higher than NT and after 30 min interval were PL and NT variants at the same level. Shallow tillage showed the lowest infiltration rate.

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Influence of crop rotation and soil tillage on weeds in spring barley

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Abstract
Weed influence of spring barely was observed in a field experiment with three types of crop rotations. The first variant of crop rotation has 33.33 % rate of cereals, the second variant has 50.00 % rate of cereals and the third variant has 66.66 % rate of cereals. In the experiment there are used four variants of basic soil tillage, it is conventional tillage to 0.22m, conventional tillage to 0.15 m, variant with direct sowing and variant where instead of tillage is used cultivation by disk type equipment. Results were evaluated by *Canonical Correspondence Analysis* (CCA). Reduced ways of soil tillage and higher concentration of cereals supported appearance mainly of late spring species of weeds in spring barley (*Chenopodium album, Echinochloa crus-galli, Amaranthus* sp, *Persicaria lapathifolia*). On variants with common tillage was higher appearance of perennial weed species (*Veronica polita*, *Lamium amplexicaule*, *Galium aparine*, *Viola arvensis*, *Veronica persica*).
Keywords: weeds, soil tillage, crop rotation, spring barely

Introduction
Weed community is influenced by many factors which affect every weed species differently. Among factors which can by influenced by a man belongs soil tillage and crop rotation. Crop rotation changes significantly in these days. Still less crops are grown and among dominate crops belongs mainly winter wheat. Also in soil tillage there is some development aimed on simplified ways of soil tillage which are more low-cost. These trends can influence also weed structure.

Material and methods
Field experiment was established in 1989 on plots of field experimental station in Invanovice na Hané by Research institute of plant production in Prague – Ruzyne. Long-term average annual rain falls are 564 mm, long-term temperature average is 8.6 °C. Elevation above see-level is 230 m. On the experimental plot there is chernozem strongly washed off and soil class is loamy soil. Crops are there grown in three crop rotations with different cereal rate. The first crop rotation (I.) has 33.33 % of cereals rate and crops are there grown in this chronology: lucerne in the first cropping year, lucerne in the second cropping year, winter wheat, maize for silage, sugar beet and **spring barely**. The second crop rotation (II.) has 50.00 % of cereals rate and crops are grown in this chronology: pea, maize for silage, winter wheat, winter wheat, sugar beet and **spring barely**. The third crop rotation (III.) has 66,66 % rate of cereals and crops are grown in this chronology: lucerne in the first cropping year, lucerne in the second cropping year, winter wheat, maize for silage, sugar beet and **spring barley**.
In the experiment there were used three basic ways of soil tillage, it is conventional tillage (with ploughing) to 0.22m (CT 22) and conventional tillage (with ploughing) to 0.15m (CT15), variant with direct sowing without tillage (NoT) and variant where instead of tillage was used cultivation by disk type equipment (MT) to 0,1 m. Size of one plot is 6 m x 12 m.
Weed infestation was observed in the stands of spring barley which were in all crop rotations grown after sugar beet. Evaluation was made during three years, always in spring before herbicide application. Numbers of weeds were counted per 1m^2 in every variant of soil tillage

and every year in 75 repetitions. Terms of evaluation were 26. 4. 2008, 3. 5. 2009 and 1. 5. 2010. Latin names of weeds were used according Kubát (2002).

Results of weed infestation from field experiment were evaluated by multidimensional ecological data analysis was used. Choice of optimal analysis was influenced by length of gradient founded by segment analysis *Detrended Correspondence Analysis*. Also was used *Canonical Correspondence Analysis*. During testing of argumentativeness due to Monte-Carlo test was counted 499 permutations. Data were evaluated by computer program Canoco 4.0. (Ter Braak, 1998).

Results and discussions

During observation there were found 34 species of weed. The most common were *Phacelia tanacetifolia, Chenopodium album, Amaranthus* sp., *Echinochloa crus-galli, Malva neglecta, Veronica polita* a *Lamium amplexicaule.*

Results of weed infestation in 2008 are in Table 1. which shows average numbers of plants of every species, average number of species and average number of weed on every variant of crop rotation and soil tillage.

Results of weed infestation in 2009 are in Table 2. which shows average numbers of plants of every species, average number of species and average number of weed on every variant of crop rotation and soil tillage.

Results of weed infestation in 2010 are in Table 3. which shows average numbers of plants of every species, average number of species and average number of weed on every variant of crop rotation and soil tillage.

An average weed infestation in spring barely in the first crop rotation (I.) was 4.74 species. m^{-2} and 38.00 plants. m^{-2}, in the second crop rotation (II.) was 4.62 species. m^{-2} and 38.13 plants. m^{-2} and in the third crop rotation (III.) there were 4.26 species. m^{-2} and 36.05 plants. m^{-2}.

On the variant with conventional tillage (CT 22) were found 4.75 species. m^{-2} and 16.98 plants. m^{-2}, on the variant with conventional tillage to 0.15 (CT 15) were found 3.97 species. m^{-2} and 16.06 plants. m^{-2}. On the variant with direct sowing without tillage (NoT) were found 3.50 species. m^{-2} and 52.13 plants. m^{-2}, on the variant with disk tillage (MT) were found 4.30 species. m^{-2} and 38.97 plants. m^{-2}.

Results of weed infestation from observed years were evaluated by DCA which established the length of gradient to 4.159. The length of gradient was under value 3.5 and was used for evaluation of Canonical Correspondence Analysis. Results of CCA are on the level of significance $\alpha = 0.002$ for all canonical axes.

From the data of frequency of appearance of every weed and variants of soil tillage the CCA will evaluate spatial configuration of each weed species. This is expressed in diagram (Figure 1.)

Table 1. Average number of weeds in spring barley after different variants of crop rotation and soil tillage in 2008

Weed species	Variants of crop rotation and soil tillage (ks.m^{-2})											
	I.				II.				III.			
	CT22	CT15	NoT	MT	CT22	CT15	NoT	MT	CT22	CT15	NoT	MT
Anagallis arvensis						0,08						
Arctium tomentosum	0.08						0.08					
Avena fatua												0.67
Beta vulgaris					0.08							
Cirsium arvense	0.08		0.08	0.08	0.08	0.08	0.33	0.17	0.17			0.92

Euphorbia helioscopia					0.08							
Fallopia convolvulus	0.17	0.58		0.17	0.75	0.33	0.25	0.33	0.58	0.75		
Fumaria officinalis	3.25	3.42	0.17	0.50	1.08			0.08	0.33			
Galium aparine	0.08			0.08	0.75	0.75	0.42	0.67	0.67	0.58		0.50
Chenopodium album	1.67	1.58	0.25	2.25	3.42	2.67	1.67	1.67	2.75	1.50	1.25	2.83
Lamium amplexicaule	6.00	7.00	1.00	1.67	0.75	0.17			0.08	0.17		0.08
Malva neglecta												1.42
Persicaria lapathifolia					0.25	0.08						
Phacelia tanacetifolia	6.83	19.08	95.67	77.83	16.00	16.75	84.17	68.33	12.17	13.25	97.25	59.83
Polygonum aviculare		0.08						0.75	0.25	0.08	0.33	0.58
Silene noctiflora	0.50	0.17			0.33	0.33	0.08	1.00	3.92	5.08	1.25	1.08
Sinapis arvensis									0.17			0.25
Sonchus oleraceus												0.08
Stellaria media									0.17			
Thlaspi arvense		0.33		0.08	0.67	0.08		0.25	0.17	0.08		
Veronica polita			0.25	0.17	0.25	0.25			0.33	0.17		0.67
Viola arvensis	0.42	0.75		0.08	0.67		0.08	0.42	0.50	0.42		0.25
Number of species	4.83	4.83	2.00	3.58	5.25	3.50	2.83	3.25	4.83	4.33	2.42	4.33
Number of plants	19.08	33.00	97.42	82.92	25.17	21.58	87.08	73.67	22.25	22.08	100.08	69.17

Table 1. Average number of weeds in spring barley after different variants of crop rotation and soil tillage in 2009

Weed species	Variants of crop rotation and soil tillage (ks.m^{-2})											
	I.				II.				III.			
	CT22	CT15	NoT	MT	CT22	CT15	NoT	MT	CT22	CT15	NoT	MT
Amaranthus sp.	0.08	0.08							0.08			
Avena fatua					0.92	1.00	0.50	0.25	0.42	0.17	0.50	0.75
Beta vulgaris				0.08								
Capsella bursa-pastoris	0.17											
Cirsium arvense	0.42	1.00	0.75	1.75		0.17	0.83	0.83				
Echinochloa crus-galli				1.50			0.25	1.17				
Fallopia convolvulus	0.17							0.25				
Fumaria officinalis		0.08			0.08				0.17			
Galium aparine	0.08				0.92	1.33	1.33	1.00	8.33	3.00	1.08	1.75
Chenopodium album	0.50	0.75	27.67	9.17	0.50	0.25	10.17	3.25	0.17	0.42	1.75	0.92
Lactuca serriola												0.08
Lamium amplexicaule	0.58	1.00	0.75	0.67	0.83	0.33						
Lamium purpureum	0.92	0.83	0.08									
Malva neglecta	3.33	3.75	10.08	10.92	4.75	3.17	2.17	2.00	0.17	0.33	0.25	0.42

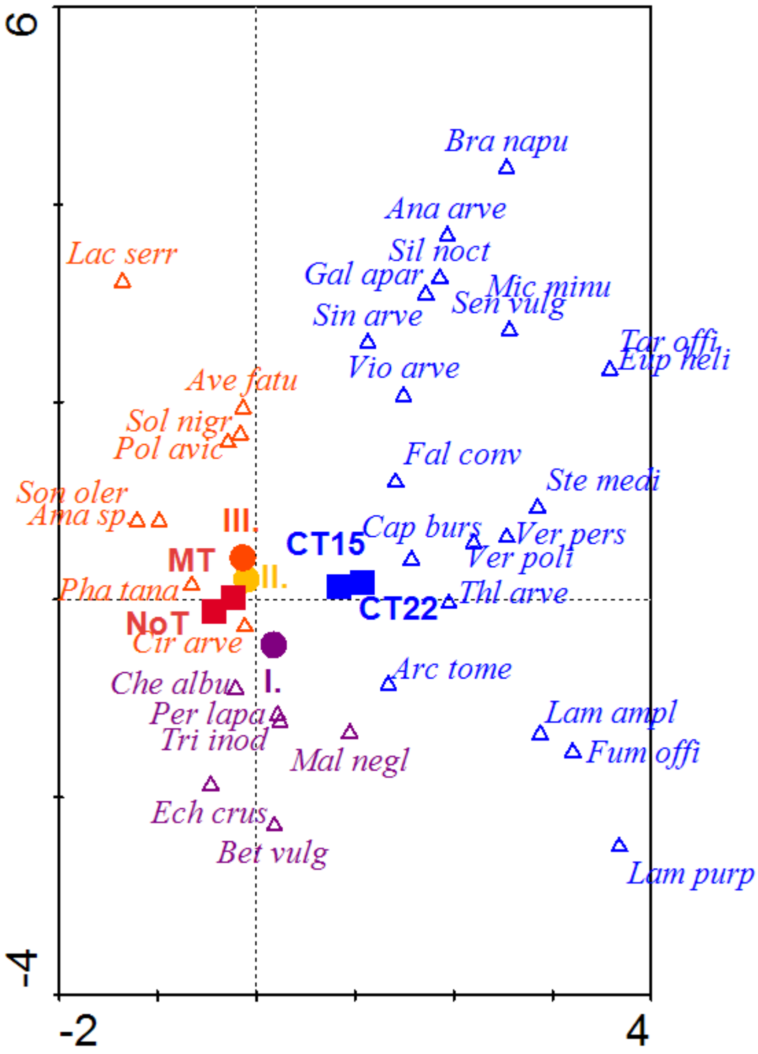
Persicaria lapathifolia	0.08	0.50					0.83			0.08	1.00	0.42
Polygonum aviculare											0.50	
Senecio vulgaris						0.08						
Silene noctiflora											0.08	
Stellaria media							0.08					
Thlaspi arvense	0.25	0.25			0.08		0.17				0.08	0.17
Tripleurospermum inodorum		0.08	0.08									
Veronica persica					0.33							
Veronica polita	0.17	0.17						0.08	0.08		0.33	
Viola arvensis					0.25				0.08	0.33		
Number of species	3.67	3.08	2.42	2.75	2.58	2.00	3.25	3.00	1.83	2.00	3.50	2.58
Number of plants	6.75	8.50	39.42	24.08	8.67	6.33	16.33	8.83	9.50	4.33	5.58	4.50

Table 1. Average number of weeds in spring barley after different variants of crop rotation and soil tillage in 2010

Weed species	Variants of crop rotation and soil tillage (ks.m^{-2})											
	I.				II.				III.			
	CT22	CT15	NoT	MT	CT22	CT15	NoT	MT	CT22	CT15	NoT	MT
Amaranthus sp.	3.58	2.25	10.50	2.58	0.67	0.58	18.50	5.00	1.00	1.33	19.08	15.92
Anagallis arvensis									0.08	0.25	0.08	
Avena fatua				0.33	0.33	0.83	3.42	1.58	0.25	0.33		0.67
Beta vulgaris			0.42			0.08						
Brassica napus subsp. napus										0.08		
Capsella bursa-pastoris			0.17						0.25		0.17	
Cirsium arvense			0.50	3.25	0.67		0.33	2.17	0.50		0.75	1.25
Echinochloa crus-galli	3.58	3.08	36.67	11.75	1.00	0.50	3.58	2.08	0.67		7.58	6.83
Fallopia convolvulus	0.42	0.33		3.33	1.25	0.25	0.08	2.58	2.00	1.58		0.92
Fumaria officinalis	1.67	2.75	1.00	1.25	0.42	0.08		0.08	0.33	0.08		0.08
Galium aparine	0.08			0.08	0.33	0.17		0.33	0.25	0.17	0.33	0.33
Chenopodium album	0.83	0.42	1.08	0.17	0.25	0.17	1.83	4.25	0.33		0.92	0.33
Lamium amplexicaule		6.42	2.42		0.33	0.17	0.08	0.67	2.00	1.00		0.17
Lamium purpureum	5.83			1.83								
Malva neglecta	1.17	0.83	0.50	1.00	0.33	0.42	0.25	0.08			0.08	0.08
Microrrhinum minus						0.25						
Persicaria lapathifolia	0.67	0.83	2.92	0.50	0.17						0.67	
Polygonum aviculare	0.08	0.25		0.25						0.08	0.17	
Silene noctiflora				0.17								
Sinapis arvensis		0.08										
Solanum nigrum					0.25	0.08	1.00	0.33	0.25	0.08		

Sonchus oleraceus				0.08							0.08	
Stellaria media	0.50	0.08		0.17	0.08	0.17		0.08	0.25	0.25		
Taraxacum officinale					0.08							
Thlaspi arvense	0.67	0.83	0.83	0.25	0.33	0.08	0.08	0.08	0.33	0.25	0.33	0.17
Tripleurospermum inodorum											0.08	
Veronica persica	2.25	2.83	1.58	1.42	3.67	2.17		0.33	2.67	1.17	0.83	0.25
Veronica polita	4.42	3.92	1.50	3.92	6.17	5.42	1.25	1.33	2.00	2.25	0.25	0.75
Viola arvensis				1.75	3.00	2.08	1.25	2.25	3.17	1.33	0.08	2.50
Number of species	7.42	6.83	7.00	8.42	6.67	5.00	4.25	6.17	5.67	4.17	3.83	4.75
Number of plants	25.75	24.92	60.08	34.08	19.33	13.50	31.67	23.25	16.33	10.25	31.50	30.25

Figure 1. Diagram expressing influent of crop rotation and soil tillage on weeds in spring barely



Explanatory notes to the diagram: **CT22** – variant with common tillage to 0.22m, **CT15** – variant with common tillage to 0.15m, **MT** – variant with disk tillage, **NoT** – variant

with direct sowing, ● **I.** – variant of crop rotation with 33.3% rate of cereals, ● **II.** – variant of crop rotation with 50.0% rate of cereals ● **III.** – variant of crop rotation with 66.6% rate of cereals.
Abbreviations of weed species: *Ama sp. – Amaranthus sp, Ana arve – Anagallis arvensis, Arc tome – Arctium tomentosum, Ave fatu – Avena fatua, Bet vulg – Beta vulgaris, Bra napu – Brassica napus subsp. napus, Cap burs – Capsella bursa-pastoris, Cir arve – Cirsium arvense, Ech crus – Echinochloa crus-galli, Eup heli – Euphorbia helioscopia, Fal conv – Fallopia convolvulus, Fum offi – Fumaria officinalis, Gal apar – Galium aparine, Che albu – Chenopodium album, Lac serr – Lactuca serriola, Lam ampl – Lamium amplexicaule, Lam purp – Lamium purpureum, Mal negl – Malva neglecta, Mic minu – Microrrhinum minus, Per lapa – Persicaria lapathifolia, Pha tana – Phacelia tanacetifolia, Pol avic – Polygonum aviculare, Sen vulg – Senecio vulgaris, Sil noct – Silene noctiflora, Sin arve – Sinapis arvensis, Sol nigr – Solanum nigrum, Son oler – Sonchus oleraceus, Ste medi – Stellaria media, Tar offi – Taraxacum officinale, Thl arve – Thlaspi arvense, Tri inod – Tripleurospermum inodorum, Ver pers – Veronica persica, Ver poli – Veronica polita, Vio arve – Viola arvensis.*

The diagram (Figrue 1.) shows that on variants with higher rate of cereals 50.00 % and 66.6 % (II., III.,) and on variants with direct sowing (NoT) and with disk tillage (MT) are conditions which enables higher appearance of these weed species: *Phacelia tanacetifolia, Amaranthus sp, Cirsium arvense, Avena fatua, Polygonum aviculare, Solanum nigrum, Sonchus oleraceus* and *Lactuca serriola*.

The diagram (Figrue 1.) shows that on variants with common tillage to 0.22 m (CT22) and to 0.15 m (CT15) are are conditions which enables higher appearance of these weed species: *Veronica polita, Lamium amplexicaule, Galium aparine, Viola arvensis, Veronica persica, Fallopia convolvulus, Fumaria officinalis, Silene noctiflora, Lamium purpureum, Thlaspi arvense, Stellaria media, Capsella bursa-pastoris, Anagallis arvensis, Sinapis arvensis, Arctium tomentosum, Microrrhinum minus, Brassica napus subsp. napus, Euphorbia helioscopia, Senecio vulgaris* and *Taraxacum officinale.*

On the variation with the lowest rate of cereals – 33.33 % (I.) were the most common species: *Chenopodium album, Echinochloa crus-galli, Malva neglecta, Persicaria lapathifolia, Beta vulgaris* and *Tripleurospermum inodorum.*

Reduced ways of soil tillage and higher concentration of cereals supported appearance mainly of late spring weeds in spring barely. On variants with common soil tillage (CT22, CT15) was higher appearance of perennial weed species. It can be supposed that reduced way of soil tillage accelerates warming-through of soil and this enable earlier germination of thermophile weed species. These species then can get an advantage in stemming stand of spring barely.

Species *Cirsium arvense* was more common on variants with minimum soil tillage and also on the variant with monoculture. Reduced soil tillage and repetition of higher concentration of cereals in crop rotation are obviously for expansion of this species more convenient. Similar results are shown also by MIKULKA (1999) who classifies *Cirsium arvense* as a perennial species which is more common on plots with limited soil tillage.
Species *Phacelia tanacetifolia* is in crop rotation used as a freezing out intercrop. In 2008 this intercrop did not froze out and also it was not liquidate in a chemical way and due to these facts its appearance was so high. In the following years its appearance in spring barley was not observed.

Conclusions

Different crop rotation in condition of different soil tillage influenced significantly species structure of weed vegetation. Weed infestation of every variant of crop rotation was relatively well-balanced. Differences were mainly in species structure of weeds. The highest weed infestation had variant with direct sowing. On the other hand the lowest weed infestation had variants with common tillage. Even there were considerable differences in species spectrum of weeds.

Reduced ways of soil tillage and higher concentration of cereals supported appearance mainly of late spring weed species in spring barely (*Chenopodium album, Echinochloa crus-galli, Amaranthus* sp, *Persicaria lapathifolia*). On variants with conventional soil tillage was higher appearance of perennial weeds (*Veronica polita, Lamium amplexicaule, Galium aparine, Viola arvensis, Veronica persica*).

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Cropping systems adaptable to acidic soils and high rainfall conditions in the north-eastern region of india

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Abstract

Potato responded significantly up to the application of 100, 44 and 50 kg ha^{-1} of N. P and K, respectively. The application of farmyard manure @ 15 t ha^{-1}, however, enhanced the response of the crop to 150, 66 and 75 kg ha^{-1} and highest tuber yield of potato was 23.23 and 22.31 t ha^{-1} in potato-cauliflower and potato-radish rotations, respectively. In the absence of P and K or farmyard manure, the curd formation in cauliflower was delayed and markedly small and loose curds were formed. The application of P, K and farmyard manure to cauliflower improved the ratio of curd to foliage from 24.3% to 34.6%. Highest uptake of N, P and K was found in potato-cauliflower rotation followed by potato-radish, rice-potato and maize-potato rotations, respectively. The study showed that benefit/cost ratio was 1.79, 1.76, 1.59 and 1.36 for potato-cauliflower, potato-radish, rice-potato and maize-potato systems, respectively.

Keywords: cropping systems, acid soils, rainfall, adaptable, northeastern region of India

Introduction

The crop production research has been reoriented as cropping systems research in the recent years. Assessment of fertilizer schedule for a system is a complex problem because of so many factors affecting availability of nutrients, their fixation and loss and residual effects (Palaniappan, 1985). The cropping systems for an area must suit the local agro-climatic and soil conditions and be superior in terms of their biological productivity with least disturbance to ecosystem. The northeastern region of India, having an area of 255 090 km^2, is predominantly hilly. The region receives about 510 km^3 of water as rainfall at an annual average of 2450 mm. The shifting cultivation is the major practice of land use. The practice was acceptable when shifting cycle used to be 25-30 years. Due to increase in population at an annual compound growth rate of 2.43%, the shifting cycle has come down to 5-7 years. The practice results in annual loss of 88.3 and 0.218 million tonnes of soil and crop nutrients, respectively, from the region. High amount and intensity of rainfall received in the region further aggravate the problem of soil erosion. More than 90% of the soils of the region are acidic in reaction and have all the the problems encountered due to soil acidity. The applied phosphorus get fixed with aluminium and iron making complex compounds and rendering it unavailable to the crop. Further, the crops grown during summer (Feb. – July) have good potential in the region due to availability of adequate moisture through rains whereas autumn and winter crops suffer from insufficient moisture and the yields are relatively poor. The results reported in this paper are from a study undertaken to evaluate four potato-based cropping systems viz. potato – cauliflower, maize – potato, rice – potato and potato – radish; in terms of their productivity, nutrient uptake and recovery and economic return.

Material and Methods

Field experiments were conducted for three consecutive years on a sandy loam soil (Typic hapludalf) to study the nutrient requirement and economics of four potato-based crop rotations. The crop rotations were, potato – cauliflower, maize – potato, rice – potato and potato – radish. The fertilizer schedule is given in Table 1. The available N, P and K content of the experimental soil at initial stage was 186, 6.8 and 201 kg ha^{-1}, respectively, with pH 5.2

CONTENT

and EC 0.156 dS m^{-1}. The treatments were replicated four times in a randomized block design. Full dose of P, K, and FYM (farmyard manure) and half of N were applied at sowing time while rest half of N was applied one month after sowing / planting of a crop. The FYM contained 0.40, 0.12 and 0.38 % of N, P and K, respectively. The crops were raised to full

Table 1. Fertilizer schedule for N, P, K (kg ha^{-1}) and FYM (t ha^{-1})

Treat-ment	Maize, rice summer potato			Cauliflower, spring potato, radish			
	N	P	K	N	P	K	FYM
F0	0	0	0	0	0	0	0
F1	50	22	25	100	0	0	15
F2	50	22	25	100	22	42	0
F3	50	22	25	100	0	0	0
F4	100	44	50	100	0	0	15
F5	100	44	50	100	22	42	0
F6	100	44	50	100	0	0	0
F7	150	66	75	100	0	0	15
F8	150	66	75	100	22	42	0
F9	150	66	75	100	0	0	0

maturity and yields of crops were recorded at harvest. The benefit/cost or economics of a cropping sequence was calculated as per prevailing market prices of different commodities. The soil and plant analysis was done as per procedures underlined by Jackson (1973) and Piper (1950).

Results and Discussion

Crop yield

Summer potato responded significantly up to the apllication of 100, 44 and 50 kg ha^{-1} of N. P and K, respectively. The application of FYM @ 15 t ha^{-1}, however, enhanced the response of the crop to 150, 66 and 75 kg ha^{-1} and highest tuber yield of potato was 23.23 and 22.31 t ha^{-1} in potato-cauliflower and potato-radish rotations, respectively. In the absence of P and K or FYM, the curd formation in cauliflower was delayed and markedly small and loose curds were formed. The application of P, K and FYM to cauliflower improved the ratio of curd to foliage from 24.3% to 34.6%. Significantly highest grain yield of maize was obtained with the F4 treatment and no further increase was found with higher level of applied nutrients (Table 2). In maize-potato crop rotation, the tuber yield of potato increased by 11.0% with the application of FYM and N over N applied alone. The increase in tuber yield may be attributed to additional supply of nutrients through FYM as well as improved soil physical condition for proper development of tubers. The results corroborate the findings of Sharma et al. (1980). The residual effect of nutrients applied to potato was observed on the subsequent maize crop

Table 2. Mean (average of 3 years) yield of different crops (t ha^{-1})

Treat-ment	System I		System II		System III		System IV	
	Summer potato	Cauliflower	Maize	Spring potato	Rice	Spring potato	Summer potato	Radish
F0	7.80	1.12	0.68	5.79	1.29	5.23	6.15	6.98
F1	16.81	8.90	1.21	10.88	2.25	9.72	14.75	10.25
F2	15.65	3.25	1.06	9.76	2.12	9.17	13.66	10.45
F3	14.71	0.99	0.95	8.45	1.92	8.27	12.25	9.56

F4	20.66	9.51	1.75	13.91	2.76	12.19	18.23	21.98
F5	19.72	4.02	1.50	11.95	2.54	12.00	18.06	20.08
F6	18.41	1.63	1.43	10.06	2.04	10.99	16.23	19.02
F7	23.23	10.24	1.71	14.81	2.75	12.75	22.31	26.86
F8	21.75	5.80	1.68	14.43	2.55	12.75	21.05	25.18
F9	20.31	2.04	1.55	12.87	2. 23	11.25	19.02	23.04
CD, p= 0.05	1.59	1.26	0.19	1.37	0.31	1.12	1.69	1.73

during the second and third year of experimentation. Similar results were reported by Singh et al. (1982). The response of rice to nutrients in rice-potato rotation was similar to maize. Maximum significant yield of radish was obtained with the highest level of applied nutrients that is 150, 66 and 75 kg ha^{-1} of N, P and K, respectively. The response of summer potato, cauliflower and radish to nutrients at highest level of applied nutrients was due to the reason that these crops are heavy feeders.

3.2 Nutrient uptake

Potato haulms (foliage) had higher concentration of N compared to tubers; however, in case of cauliflower, curd had higher concentration of N than foliage. In maize, more N and K concentration was found in stalks than grains while reverse was true for P concentration. Highest uptake of N, P and K was found in potato-cauliflower rotation followed by potato-radish, rice-potato and maize-potato rotations, respectively (Table 3). Similar trend was found

Table 3. Nutrient uptake, % recovery and benefit/cost ratio of different cropping systems

	Nutrient uptake			% recovery			Benefit/
Cropping system	N	P	K	N	P	K	cost ratio
Potato-cauliflower	185.1	17.6	175.8	89.0	20.2	140.6	1.79
Maize-potato	129.2	9.5	122.0	58.7	15.4	113.2	1.36
Rice-potato	163.1	14.6	149.9	74.3	17.4	125.5	1.59
Potato-radish	172.4	15.7	159.5	85.6	18.2	132.4	1.76

in nutrient recovery also. In the nutrient balance sheet approach, it was found that N and P had positive while K had negative balance in the soil. Removal of K was more than applied in all the cropping systems except maize. The highest depletion of K was found in potato-cauliflower rotation followed by potato-radish, rice-potato and maize-potato. The addition of nutrients to soil for a particular crop would depend on loss due to leaching, volatilisation, fixation and residual effect of of nutrients applied to the preceding crops. Since under the present condition, the possibility of leaching of N due to precipitation and fixation of P as a result of high exchangeable Al content in these light textured soils, these nutrients are required to be applied in larger quantities for good crop productivity. Of the total nutrients removed, summer potato accounted for 57.7% N, 53.4% P and 65.6% K while spring potato removed only 41.9% N, 43.1% P and 47.0 % K. The rest of the nutrients were removed by the other crop in the rotation. In general, the removal of nutrients highly correlated with the dry matter produced. Similar results were reported earlier by Bunneman and Grassia (1973).

3.3 *Residual effect and economic return*

Analysis of the soil sapmples after the completion of the experiments showed that there was a build-up of nutrients in all the cropping systems over their initial status in the soil. The available N and K content in potato-cauliflower system was significantly lower than other systems while available P varied non-significantly. This may be due to more depletion of these nutrients in this rotation. The beneficial effect of FYM on the available nutrient build-up in the soil was observed. Potato-cauliflower system was the most profitable followed by potato-radish, rice-potato and maize-potato in that order (Table 3). Maize proved to be non-profitable mainly because of high precipitation and low summer temperature (15 to 27 ^{O}C), which affected grain filling at maturity. Summer potato gave the highest net profit followed by cauliflower, radish, rice and spring potato. Since during the autumn season, the soil moisture availability is low, the yield of rainfed crops are generally poor. Due to heavy rains in the region, maize crop generally proves non-profitable except on hill slopes.

Conclusions

Shifting cultivation is the predominant land use in the northeastern region of India. This practice has become irrelevant with increase in demographic pressure over the years as due to decrease in shifting cycle from about 25 to 5 years, enough vegetation is not available for *in situ* burning and incorporating in the soil for maintenance of soil fertility. In order to replace shifting cultivation, experiments conducted to evaluate four cropping systems, showed that potato-cauliflower was the best rotation as far as economic return is concerned; followed by potato-radish, rice potato and maize-potato. Since the people of the region are mainly rice eaters, rice-potato could be the best choice for food security.

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The influence of different stand establishment and chosen biopreparations on production and health condition of winter wheat

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Abstract

In the field experiments, carried out in the period 2007-2010, the influence of different methods of crop stand establishment and application of chosen biofungicides on grain production and health state of winter wheat was evaluated. Besides conventional soil cultivation and sowing, drilling into no tilled soil covered with mulch and reduced tillage with plant biomass incorporated into soil were used. We assessed the effect of the biopreparations, used as a mixture with mineral fertilizer ANL, homogenized both with seed and as a spray. The results obtained showed grain yield increase of winter wheat, in the average of studied years, in the variant of minimum tillage technologies (+3.5%, resp.+2.2%) compared with classic technology of the stand establishment. At the same time, in the conservation tillage variants, the higher number of phytopathogenic moulds of fungi was identified in comparison with the control variant (classic tillage method). This higher health risk was significantly reduced by application of above mentioned biopreparation.

Keywords: soil management; conservation soil tillage; winter wheat; biofungicides; phytopathogenic fungi

Introduction

The effective technologies of crop stand establishment demand the use of such measures which provide not only profitable but also quality crop production. Utilization of conservation technologies of soil tillage decreases the operation number, the density of field transportation with lower risk of soil, especially subsoil over-compaction. Reduced soil tillage influences by its lower costs the whole technology of crop growing. Some time, biofungicides have been utilized for ensuring of healthy agricultural production and they are able to depressed pathogenic fungi in soil on the basis of antagonistic relationship thereby influence positively the health state of crop stands. Effective biofungicide utilization is needed especially in stands where the minimization of soil tillage is used. Especially on these plots, covered by chopped straw and post harvest residues of pre-crops, the conditions are created for higher infestation by pathogen fungi owing to higher infection pressure. To evaluate the effectiveness level of biofungicide application on the economic yield and on depression of fungal pathogens, especially of genus *Fusarium, Drechslera, Septoria and Alternaria,* in stands of winter wheat under different methods of soil tillage, is the aim of this contribution.

Materials and methods

In the field experiments of CRI in Prague, the level of economic production and health state of plants of winter wheat, var. Cubus grown under different soil tillage management and different biofungicide application, was assessed. The stands of the crop was established with use of these different tillage methods:

A - conventional, i.e. mouldboard ploughing, usual seedbed preparation and sowing
B - direct drilling into no tilled soil covered with mulch from post harvest residues of pea
C - sowing into shallowly loosened soil with chopped straw from pre-crop incorporated

Biofungicide treatments used:

1. Control treatment, fertilization by ammonium nitrate with limestone (ANL)
2. Fungi fertilizer (ANL mixed with 5 g of Supresivit per 1 kg of fertilizer)
3. Fungi fertilizer (ANL mixed with 5 g of Trianum P per 1 kg of fertilizer)
4. Fungi fertilizer (ANL mixed with 5 g of Trifender per 1 kg of fertilizer)
5. Fungi fertilizer (ANL mixed with 5 g of Koni per 1 kg of fertilizer)
6. Spraying with Supresivit (5 g of preparation per 1 litre of water)
7. Spraying with Trianum P (5 g of preparation per 1 litre of water)
8. Spraying with Trifender (5 g of preparation per 1 litre of water)
9. Spraying with Koni (5 g of preparation per 1 litre of water)
10. Seed dressing with 5 g of Supresivit per 1 kg of seed, fertilization by ANL
11. Seed dressing with 5 g of Trianum P per 1 kg of seed, fertilization by ANL

Above mentioned biofungicides were applied to winter wheat both in the mixture with mineral fertilizer, as a seed dressing before sowing and also in the form of spraying in the stage 30 BBCH. Nitrogen (ANL) fertilization was applied in all treatments in the total dose 100 kg N per ha, including 40 kg N early in spring as a regeneration dose, 30 kg N as a production dose and 30 kg N as a late fertilising.

On the plots with a different method of the stand establishment, besides grain yields, the impact of biofungicide on the health state of winter wheat plants was evaluated, i.e. pathogen fungi occurrence of the genus *Drechslera*, *Septoria and Alternaria* on the plant surface and *Fusarium* in soil. Soil samples were taken in monthly intervals and processed as soil extracts. The surface of plants of winter wheat was monthly inspected for evaluation of phytopathogenic micromycet infestation.

Results and discussions

From the Table 1, it is evident that the highest grain yields (8.52 $t.ha^{-1}$) along with the highest yield increase compared with the control variant (0.58 $t.ha^{-1}$, i.e. +7.3%) were obtained from the plots with direct drilling into no tilled soil covered with mulch from post harvest residues of the pre-crop and treated by biofungicide Trianum P applied as a seed dressing - variant No.11. A little lower average yields of grain were obtained under the same method of the stand establishment and biofungicide Trianum P application in the mixture with ANL fertilizer (var.3, +7.1%) and as a spraying (var.7, +6.7%) and also in case of use of biofungicide Supresivit in all forms of application (var. 2, 6 and 10). These grain yield values were statistically significant (tab. 2) compared with the control treatment on the basis of calculated least significant difference.

From the table of the yields data, it is evident that higher grain yields of winter wheat were achieved, on an average of evaluated years, under the use of minimization technologies (+3.5%, respectively +2.2%) comparing with classic method of soil tillage. But this status has been recorded after five-year period from the beginning of the trials when the microbial processes and soil conditions stabilized.

On an average of evaluated years, the effect of biofungicide application varied from +5.4% in classic tillage to +6.0% in the treatment of direct drilling into no-tilled soil covered with mulch. Regardless of the method of soil tillage and crop stand establishment it is evident that the effect of preparations Trianum P and Supresivit exceeded the impact of biofungicides Trifender and Koni, especially in combination with ANL fertilizer.

Tab. 1: The grain yields of winter wheat from evaluated variants (average 2007-2010)

Treatment		Winter wheat						
		A		B		C		Average
		(t.ha^{-1})	(%)	(t.ha^{-1})	(%)	(t.ha^{-1})	(%)	(t.ha^{-1})
1.	control	7.71	100.0	7.94	100.0	7.86	100.0	**7.84**
2.	fertilizer + Supresivit	8.20	106.4	8.42	106.0	8.37	106.5	**8.33**
3.	fertilizer + Trianum P	8.17	106.0	8.50	107.1	8.34	106.1	**8.34**
4.	fertilizer + Trifender	7.96	103.2	8.28	104.3	8.25	105.0	**8.16**
5.	fertilizer + Koni	8.04	104.3	8.33	104.9	8.21	104.5	**8.19**
6.	spray Supresivit	8.14	105.6	8.41	105.9	8.35	106.2	**8.30**
7.	spray Trianum P	8.23	106.7	8.47	106.7	8.41	107.0	**8.37**
8.	spray Trifender	8.11	105.2	8.38	105.5	8.32	105.9	**8.27**
9.	spray Koni	8.05	104.4	8.40	105.8	8.27	105.2	**8.24**
10.	seed + Supresivit	8.17	106.0	8.44	106.3	8.30	105.6	**8.30**
11.	seed + Trianum P	8.21	106.5	8.52	107.3	8.32	105.9	**8.35**
Mean grain yield:		**8.09**	**-**	**8.37**	**-**	**8.27**	**-**	**8.24**
Effect of biopreparations:		**-**	**105.4**	**-**	**106.0**	**-**	**105.8**	**-**
Effect of stand establishment:		**100%**		**103.5%**		**102.2%**		**-**

Notes: Methods of the stand establishment for winter wheat:
A - conventional tillage
B - no tillage - direct sowing into untilled soil, covered with mulch
C - minimum tillage- sowing into shallowly tilled soil with incorporated chopped straw from pre-crop

Tab. 2: The least significant difference

a) For grain yield, classified according to soil tillage method
The value of the least significant difference: **0.1583**

Group	Case load	Average	Conven-tional	No tillage	Minimum tillage
Conventional = control	12	8,0900		*	*
No tillage	12	8,3718	*		
Minimum tillage	12	8,2727	*		

b) For grain yield, classified according to biopreparations
The value of the least significant difference: **0.0879**

Group	Case load	Average	Control	Koni	Trifender	Supresivit	Trianum P
Control	12	7,8367		*	*	*	*
Koni	12	8,2166	*			*	*
Trifender	12	8,2167	*			*	*
Supresivit	12	8,3111	*	*	*		
Trianum P	12	8,3522	*	*	*		

Notes: The homogenous sub-groups are in the vertical columns; * indicates significantly different pairs

From the Table 3, it is evident that on an average of four experimental years, higher occurrence of disease-producing fungi was recorded in the variants with reduced soil tillage. The similar results were also published by Sturz et al. (1997). But after biofungicide use, especially Supresivit and Trianum P in combination with ANL fertilizer and also in the mixture with seeds, stronger depression (by 8 – 10 %) of pathogenic fungi in the both variants of conservation tillage compared with conventional treatment was found (in Tab. 3 the values in bold font). The use of mentioned preparations, in comparison with the variants untreated with biopreparations, causes decrease of microfungi in soil by 15 – 20 % on average. After application of biopreparations in the form of spraying, decrease of leaf disease occurrence caused by pathogens of genera *Drechslera, Septoria* or *Alternaria* was recorded (in tab. 3 the values in italic).

The similar results with the use of fungi *Trichoderma harzianum* in cereals published also Weber et al. (2001). The strains used in biological plant protection, presented in our study and in foreign literature (Omoifo, Ikotun, 2007), had increased metabolic activity, so that they react more robustly against phytopathogenic fungi.

Tab. 3: Percentage of leaf area of winter wheat infested with pathogenic fungi and CFU number of genus *Fusarium* in soil in three tillage systems (averages of period 2007-2010)

Treatment	Conventional				No-till				Minimum-till			
	a	b	c	d	a	b	c	d	a	b	c	d
1. control	17	9	18	16	21	13	21	22	21	12	19	21
2. fertilizer + Supresivit	15	7	16	**11**	18	9	18	**14**	18	10	14	13
3. fertilizer+Trianum P	14	8	15	**12**	19	11	19	**13**	17	9	16	**12**
4. fertilizer + Trifender	13	6	16	13	18	10	17	16	17	11	15	**12**
5. fertilizer + Koni	14	6	15	14	***14***	12	19	16	16	10	14	14
6. spray Supresivit	***10***	5	13	15	16	***8***	15	20	***13***	9	13	18
7. spray Trifender	13	***3***	13	14	17	10	***13***	21	15	***7***	12	19
8. spray Trianum P	***10***	***4***	***11***	14	***14***	***7***	14	19	16	***8***	***11***	17
9. spray Koni	12	5	14	15	17	10	15	20	***14***	10	12	18
10. seed + Supresivit	16	7	15	**12**	19	11	18	**13**	18	11	13	**13**
11. seed + Trianum P	13	8	16	**11**	20	9	17	**15**	16	9	14	**13**
Averages	**13**	**6**	**15**	**13**	**18**	**10**	**17**	**17**	**17**	**10**	**14**	**16**

Notes: CFU = colony forming unit

a - plant surface area infested with *Drechslera tritici-repentis* (in % of total area)

b - plant surface area infested with *Septoria tritici* (in % of total area)

c - plant surface area infested with *Alternaria triticina* (in % of total area)

d - *Fusarium graminearum* occurrence (the number of CFU) in 1gram of soil

Conclusions

It is possible to summarize that on an average of four evaluated years, higher economic yields of winter wheat were achieved on the plots with direct drilling into no-tilled soil covered with mulch from post harvest residues of pre-crop (+ 3.5%) and with sowing into shallowly tilled soil with chopped straw of pre-crop incorporated (+ 2.2%) in comparison with conventional method of stand establishment. The use of selected biofungicides in various forms of application had also positive impact on grain yields and health state of plants of winter wheat. The yield increases after biopreparation application varied on an average of the years from +5.4% to +6.0%. The highest yield effect was recorded after use of the preparations Trianum P and Supresivit. Regardless of different method of soil tillage for stand establishment, increases of grain yields after biofungicide use is possible to interpret by suppression of pathogenic organisms. In the both variants of reduced soil tillage (no- and minimum tillage) the higher infection pressure of *Fusarium* pathogens was recorded but after application of biofungicides, higher effect of their impact on pathogen reduction was found out. While the combination of biofungicides with seeds or fertilizer reduced pathogens of genus *Fusarium* in soil, the spraying of them decreased leaf disease occurrence. Besides being economically efficient, the maintenance of healthy crop stands during the vegetation period by biopreparation utilization is very important benefit for agricultural practice.

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The effect of different soil tillage and different intensity of plant nutrition and protection on the grain yield of winter wheat

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Abstract

The effect of different soil tillage and different intensity of plant nutrition and protection on the yield and grain quality of winter wheat (13 cultivars) after winter rape (2006) and pea (2007 and 2008) in the field experiments (droughter location) in Prague-Ruzyně were studied. The differences in grain yield between reduced tillage (RT) and ploughing (CT) were not statistically significant. The obtained results mainly indicated that application of reduced tillage (surface stubble ploughing to depths of 0.08-0.1 m) in combination with high input level (adequate plant nutrition and crop protection) could in these conditions result in higher grain yields than application of conventional tillage. Higher intensity and plant nutrition improved yield cultivars by average of 3 % for ploughing and 6 % for reduced tillage. Above-average yields were achieved in a cultivar Barryton and Cubus (quality group A), Meritto (B), Florett and Biscay (C).

Keywords: soil tillage, winter wheat, cultivar, nitrogen, grain yield

Introduction

Grain yield and quality are the most important quantitative traits of winter wheat and they are also under great influence of the environmental factors (Agoston, Pepó, 2005). Testing of cultivars reaction to different environments (locations and years) gives better insight in the use of its genetic yield and quality potential. In the absence of fertilizer, winter wheat grain yield is boosted by CT, but in its presence this advantage is lost (Machado et al., 2007). The main yield limiting factors under RT include slow seedling growth due to a cooler soil temperature, nutrient deficiency, toxic residues and pathogen pressure. We have previously shown that optimizing the dose and timing of fertilizer application represents a critical means of providing the best conditions for N uptake (Šíp et al., 2009), since it has a major impact on the amount of soil moisture available (Halvorson et al., 1999; Li et al., 2007; Růžek et al., 2007).

Material and method

In field experiments with winter wheat after winter rape (2006) and pea (2007-2008) the effect of different soil tillage (CT = conventional tillage with ploughing to the 0,22 m, RT = reduced tillage to the 0,1 m - since 1994 without ploughing in Ruzyně) and various intensity of plant nutrition and protection were studied on grain yield of 13 cultivars of winter wheat. Experiments were performed at Prague - Ruzyně (*sugar beet growing region, altitude: 340 m, yearly total rainfall: 472 mm, annual mean air temperature: 7,9* ^{0}C , *orthic Luvisol*). All experiments were set out as randomized complete split-plot blocks with four replicates. Two tillage systems (conventional tillage - CT and reduced tillage - RT) were assigned as main plots within each block, and the two sub-plots consisted of different input (fertilizer and other inputs) rates. Finally, each sub-plot was divided into four, within which the varieties were arranged randomly. The size of the varietal sub-subplot was 10-12m^2. The CT treatment consisted of a disc harrowing of the previous crop, followed by mouldboard ploughing to a depth of 22cm, ensuring the full incorporation of the chopped crop residues into the soil. Prior to sowing, the seed-bed was rotary harrowed. The RT treatment also consisted of a disc harrowing of the previous crop, but this was followed by stubble-ploughing to a depth of 8-

10cm. Again, the seed-bed was prepared by rotary harrowing. In this system, at least 15 % of the soil surface was covered by chopped plant residues.

Intensity of cultivation:

- CTI and RTI: lower fertilization N rates (of 2-3 doses, total dose 80-100 kg $N.ha^{-1}$ in CAN – calcium ammonium nitrate, without fungicides, without growth regulator.
- CTII and RTII: higher fertilization N rates (of 2-3 doses, total dose 130-150 kg $N.ha^{-1}$ in CAN – calcium ammonium nitrate, 2 fungicides (at the stalk shooting – DC 30-31 and in phase of heading – DC 59), growth regulator Cycocel 1-1,5 $l.ha^{-1}$ in phase DC 30-31.

At maturity, the plots were harvested with a small-plot combine (Wintersteiger). Grain yield was assessed from a harvest of the whole plot, and adjusted to 14% grain seed moisture content. Statistica CZ 8.0 programme was used for statistical evaluation of the measured data. Significant differences among average crop yields in cultivars, harvest year, soil tillage etc. (see Table 1-5) were evaluated by a method of multiple comparisons with the Tukey significant difference (HSD) test.

Results and discussion

From results in the table 1 follows that in year 2007 ploughing (CT) performed better than reduced tillage (RT) with respect to grain yield, and grain yield was particularly compromised under reduced tillage lower intensity of plant nutrition and protection (RT I). Differences in the soil's water holding capacity can provide a reasonable interpretation of this differential response, since at Ruzyně, the more reliable supply of soil moisture in a soil better able to hold water would have allowed CT-raised plants to exploit a higher availability of nutrients (especially N) and so generate faster plant growth during the spring. In year 2007 (month March, April and 2nd half of May unusually low rainfall and high temperatures during April) were higher yields by late cultivars, which used late rainfall (Biscay, Cubus, Globus, Meritto). On the contrary were at least favourable conditions for early cultivars with fast spring growth, early phase of heading and low tillering ability as cultivar Rheia.

Šíp et al. (2009), showed that in year 2007 were attained grain yields of winter wheat most influence on deficit of rainfall, in average 30 % higher by reduced tillage (RT) then by ploughing (CT). Average grain yields of winter wheat with reduced tillage were in drought year significantly greater (25 – 42 %) than grain yields using conventional tillage (Hemmat, Eskandari, 2006). Highest decrease of yield were attained by reduced tillage by cultivar Florett (55 %), Rheia (41 %), Cubus (38 %) and Banquet (37 %). Ducsay and Ložek (2004), Capouchová, Petr (2004), showed that the higher intensity of N – fertilization increased significantly yields in most experiments. Significant differences of crop yields were found in input levels ($p<0.05$) (Table 5). Table 3 shows that in season 2007 was statistically significant ($P <0.05$) reduction in grain yield compared with season 2008 and 2009. The weather conditions during 2007-2008 and 2008-2009 which were favourable for generating high yields, in the most cultivars reached 11 to 12 $t.ha^{-1}$ (Table 1). Significant differences of crop yields were found in all combinations of soil tillage and input levels ($p<0.05$) (Table 6).

Table 1. Yield of winter wheat at different soil tilllage, nitrogen fertilization and plant protection in year 2007-2009

	2007				2008				2009			
Cultivar	**RT I**	**CT I**	**RT II**	**CT II**	**RT I**	**CT I**	**RT II**	**CT II**	**RT I**	**CT I**	**RT II**	**CT II**
Akteur	7,10	8,10	7,60	8,00	10,06	10,48	10,55	10,40	10,97	10,20	11,47	11,08
Bardotka	7,26	7,72	7,59	8,05	9,12	8,97	9,06	9,22	10,53	10,18	11,43	10,93
Barroko	7,62	8,15	7,95	8,07	11,19	11,49	11,49	11,41	10,73	10,70	11,85	11,10
Barryton	7,74	8,44	8,24	8,61	11,40	11,49	11,74	11,57	10,27	10,61	11,54	11,44
Biscay	8,80	9,50	9,35	9,45	10,60	11,16	10,65	11,01	10,80	10,44	11,44	11,02
Cubus	7,77	8,47	8,45	8,76	11,51	11,48	11,69	11,61	11,51	11,38	12,41	11,97
Darwin	7,65	8,41	8,22	8,48	11,68	11,53	11,80	11,42	10,89	10,43	11,39	11,12
Eurofit	7,12	7,67	7,80	8,04	11,05	10,97	11,29	10,82	11,03	10,61	11,85	11,46
Florett	8,14	9,14	8,87	9,53	12,07	11,98	12,15	11,93	11,05	10,64	12,31	11,76
Globus	7,81	8,84	8,76	9,00	10,96	11,16	11,38	11,08	10,81	10,70	11,66	11,44
Ilias	7,57	8,40	7,98	8,42	9,91	9,97	9,77	9,94	9,98	9,36	10,62	10,23
Meritto	8,31	9,11	8,51	9,24	11,11	11,18	11,05	11,02	11,41	10,92	11,99	11,26
Rheia	6,48	7,27	6,91	7,18	11,17	10,89	11,78	11,39	10,57	10,31	11,77	11,20
Average	**7,64**	**8,40**	**8,17**	**8,53**	**10,91**	**10,98**	**11,11**	**10,99**	**10,81**	**10,50**	**11,67**	**11,23**

Table 2. Significant differences of crop yields in cultivars

Cultivar	Average Yield* ($t.ha^{-1}$)
Bardotka	9.17 a
Ilias	9.35 ab
Akteur	9.67 abc
Rheia	9.74 abcd
Eurofit	9.98 bcde
Barroko	10.15 cdef
Darwin	10.25 cdef
Barryton	10.26 cdef
Globus	10.30 cdef
Biscay	10.35 cdef
Meritto	10.43 def
Cubus	10.58 ef
Florett	10.80 f

Table 3. Significant differences of crop yields in year of harvest

Year of harvest	Average Yield * ($t.ha^{-1}$)
2007	8.19 b
2008	11.00 a
2009	11.05 a

Table 4. Significant differences of crop yields in soil tillage

Soil tillage	Average Yield * ($t.ha^{-1}$)
RT	10.05 a
CT	10.10 a

CONTENT

Table 5. Significant differences of crop yields in input levels

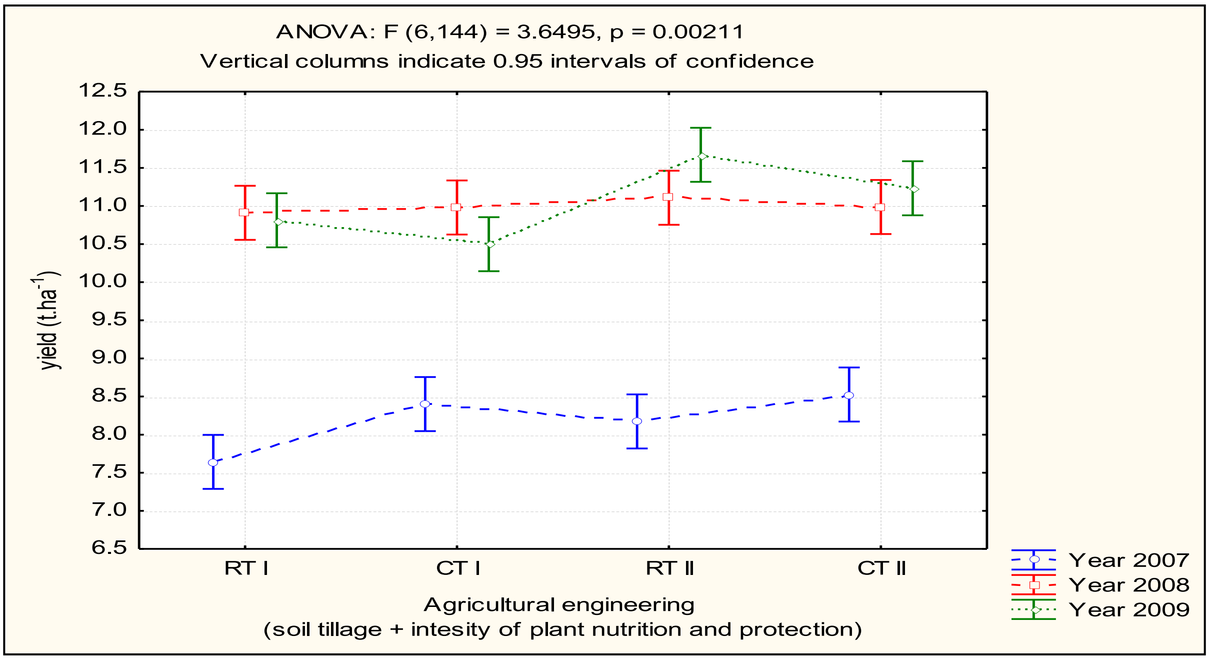
Input level	Average Yield * ($t.ha^{-1}$)
I-low	9.87 a
II- high	10.28 b

Table 6. Significant differences of crop yields in soil tillage and input levels

Soil tillage x Input level	Average Yield* ($t.ha^{-1}$)
RT I	9.79 a
CT I	9.96 ab
CT II	10.25 bc
RT II	10.32 c

*the values of average yield, with different letter combinations (a, b, c, d, e, f), are significant at p = 0.05, Tukey HSD test

Graph 1: The effect of year and cultivation practise (soil tillage, the intensity of plant nutrition and protection) on grain yield of winter wheat cultivars at the Ruzyne in 2007-2009



Conclusions

The obtained results from field experiments at Praha - Ruzyně with winter wheat in year 2007-2009 indicate no significant differences in grain yield between reduced tillage (RT) and ploughing (CT). As shown previously (Šíp et al., 2009), high input conditions (the splitting of N fertilization and the maintenance of adequate disease protection) are necessary if the higher yield potential of the RT system is to be exploited. Higher intensity and plant nutrition improves yield cultivars by average of 3 % for ploughing and 6 % for reduced tillage. Above-average yields were achieved in a cultivar Barryton and Cubus (quality group A), Meritto

(B), Florett and Biscay (C). In agreement with Deike et al. (2008), we have shown that some reduction in fertilizer application, pesticide use and tillage intensity is possible without sacrificing yield.

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