ISTRO – BRANCH CZECH REPUBLIC

(International Soil Tillage Research Organization)

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

5th International Soil Conference

SOIL TILLAGE – NEW PERSPECTIVES

Proceedings of 5th International Soil Conference

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CONTENT

PAPERS OF THE SECTION I

ISTRO

PERSPECTIVE METHODS OF SOIL TILLAGE AND CROP MANAGEMENT AND THEIR IMPACT ON SUSTAINABILITY OF CROP PRODUCTIVITY AND ENVIRONMET DUALITY

***K. Kováč[1], Z. Lehocká[2], Š. Žák[2], M. Klimeková[2], M. Macák[3]**

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Abstract

The effect of weather and different farming systems on crop productivity and soil environmental quality were studied in the field stationary trials during the years 1996-2005. The field trial was carried out at the experimental station of the RIPP Piešťany. In the first research phase 2 farming systems ecological and no – till system (integrated production) were conducted. In the second research phase 4 different systems (ecologically farming system, integrated farming system and two level of low input farming system were conducted. The higher productivity of farming system was recorded in the systems with mineral nitrogen fertilization. Productivity of farming systems, expressed by cereals unit, was highly significantly affected by the weather and significantly by farming systems. Increasing the earthworm abundance, respiration activity of the soil, the amount of microbial biomass, higher share of N_{an} in no- till systems has been noted. No-till systems increase of C_{ox} and N_{tot} in the soil, which indicate the improvement of soil properties. The amonification and nitrification activity were more active in the no-till system than in ecological one. Significant relationship between system productivity and soil inorganic nitrogen content was also noted.

Key words: No-till, ecological production, soil physical, chemical, biological properties

Introduction

The aimed tillage habitat management is crucial part of sustainable farming (Husnjak et al. 2002) and the sustainability of ecological and low input systems depends on the development of effective management practices and soil condition (Hanáčková 2000, Neudert 2002, Birkás 2006). Crops leave soil in different physical condition (Kováč and Švančárková 2003). The increasing of soil density is implemented by self-weight of soil or it is caused by intensive rainfalls during a growing season. In winter time the changes of soil bulk density (SBD) are activated by the ploughing effect of winter frosts (Franzluebbers 2002; Javůrek et al. 2004). The SBD and total porosity is considered to be an integral indicator of the soil habitat quality (Battikhi and Suleiman 1999; Logsdon and Karlen 2004).

Conservation tillage systems offer possibility cover more than 30% of soil surface by plant residues. This natural mulch reduce runoff, increase infiltration rate and decrease evaporation of soil water (Rasmussen 1999). Good soil storage water depends not only upon tillage management (Kvaternjak et al. 2008), but also upon forecrop (Kováč et al. 2005). In principle there prevails knowledge that conservation tillage technologies can be successfully used at appropriate sites (Hůla, Procházková et al. 2002).

The conservation tillage and ecological farming supported mineralization ability of the soil micro organism, abundance of earthworms by accumulation of the organic matter in topsoil layers. Conventional ploughing negatively influences the abundance of earthworms and content of the SOM (Švančárková, Lehocká 2001). Measurement of sustainable soil properties assumes the research of soil biological parameters (Filip, Berthelin 1999, In: Kováč et al. 2004) that indicate their deterioration or improvement. There is a lack of knowledge on parameters that are connected with the soil quality functions and that evaluate the environmental impact of plant growing innovation in Slovak conditions. It is a characteristics and identification of the efficiency of various functions of biological soil properties and populations of soil edafon (Messéan, 2003, In: Kováč et al. 2004). Therefore we approached the research activities regarding soil and crop management which is connected not only with indicator of production but it is connected also with ecological indicators of environmental quality.

Materials and method

The field experiment was founded in the experimental station of RIPP Piešťany in the maize growing region. The normal temperature at the experiment site is 9.2 ° C per year, 15.5° C per growing season and the rainfalls total is 595 mm per year, 338 mm per growing season. The soil is Luvi-Haplic Chernozem with loamy to clay-loamy texture with a medium humus content of 1.8 – 2%. The experiment was founded with a randomized method with four replicates (plot size 3 x 44m) of six field -course crop rotation of red clover - winter wheat - peas - winter wheat – potatoes- spring barley undersowing with red clover (EFS, LIS1) and four course rotation of peas-winter – wheat - maize for grain - spring barley (IFS, LIF2).
The particle-size distribution of the surface horizon (0-0.2m) at the site is 56 % sand, 25% silt and 14% clay. The depth of the humus horizon is 0.4 till 0.5 m and it is slightly differentiated to the alluvial and illuvial horizon. The content of humus in the tilt top soil profile is medium and low in the sub tilth top soil horizon two. The tilt top soil and the sub tilth top soil horizon have the medium compaction. The soil has a high retention of water, wilting point results in the high usability of soil moisture. At the beginning of the experiment, the average content of organic carboneum was 14g C_{ox} kg^{-1} and pH varied from 5.6 to 6.1 across the experimental area. In first phase of the experiment in the 1995 to 1999 field experiments has only 2 farming system such as ecological and integrated farming one. Paper present results from research, which came from following treatments:
Ecologically farming system (next EFS) – cultivation according to rules of the IFOAM with manuring (FYM) and incorporation all crops residues, biological crop rotation with leguminous (red clover and common peas) and biological pest management including mechanical weed regulation (tab.1) and conventional ploughing was used.
Low input farming system 1 (next LIF1) – low rate of nitrogen from mineral fertilizer, crop residues was incorporation and chemical pest management was used. Crop rotation and soil tillage were the same like in the EFS.
Integrated farming system so called “Integrated farming” (next IFS) - cultivation according “Guidelines for integrated production of arable crops in Europe (Boller, Malavolta, Jörg 1997), modified by Kováč, 1999). Its presents the no-till system, without FYM application and with crop rotation used crops typical for farming without the animal production. Four field course- cash crop rotations were used. The integrated fertilization, plant protection and growing intercrops were used. Crushed straw and applied compost remain on the soil surface after being scattered. Average of nitrogen rate from mineral fertilizers was 38 kg ha^{-1} and 72 kg ha^{-1} from the industry compost, totally 10 kg ha^{-1}.
The low-input farming system 2 (next LIS 2) presents conventional soil tillage with mouldboard ploughing to the depth 0.18–0.22, fertilization with compost and removal (export) of crop resides from the field (1999-2002) or incorporation of crop residues (2003-2005). Application of pesticides and reduced doses of nitrogen nutrients from mineral fertilizers were applied. Crop rotation was the same like in IFS. Straw was removed from the

field. Average of nitrogen rate (tab. 1) from mineral fertilizers was 58 kg ha^{-1} and 72 kg ha^{-1} from the industry compost, totally 110 kg ha^{-1}.

Table 1: The input of nitrogen from mineral and organic fertilizers (kg ha^{-1} N) and straw management during 1999-2005

Fertilizer in systems	EFS	LIS 1	IFS	LIS 2
Mineral	-	38	58	58
Manuring	72	72	62	62
Share from FYM %	100	65.5	52	52
Total	72	110	120	120
Straw management	incorporation	export	mulching	1999-2002 export/ 2003-2005 incorporation

Selected soil physical properties - soil sampling were set by the Kopecky method with cylinders with the cubic content 100 cm^3 in four replicates. Soil samples for measuring the SBD and total porosity were always taken in the spring term, after harvest and in the autumn term and for water regime in the layers from 0.05 up to 0.80 m.
Chemical and biological soil properties - pH_{KCl}, content of soil carbon and inorganic nitrogen were detected in the soil samples which were taken from the depth of 0.02-0.2 m. The biological soil properties like ammonification activity (14-days increase in ammonium nitrogen content), nitrification (14- day increase in inorganic nitrogen content only at EFS and IFS was detected), respiration activity (CO_2), abundance of earthworms were determined. The data regarding soil properties were subjected to an analysis of variance using the Statgraphics plus version 5.0.

Results and discussion

The experimental years 1999-2005 were largely different from the aspect of weather conditions. Rainfalls in the period of soil sampling from the spring to the summer (T1-T2) varied from 46.5 to 263 mm, from summer to autumn (T2-T3) varied from 102-207mm. Average dose of precipitation from spring to summer was 386. Equation of the regression line $y = 412.81x-467.18$ indicated positive correlation between the amount of rainfalls during the period from sowing to the harvest of spring crops and the reduced soil bulk density (next SBD). The SBD and porosity was highly significantly influenced by weather condition of evaluated years and SBD was significantly influenced by farming system.
The biggest difference of the SBD and soil moisture in trials was in the summer. Differences of the SBD between the systems phased down from summer to autumn. This is in accord with the information about differences of soil physical properties caused by different tillage, published by Skukla et al. (2003). These differences are balanced out at the end of the growing season. From the time point of view, i.e. the influence of years, the average SBD phased down in all systems. This proves that ecological conditions in term of physical soil habitat for the grown crops were gradually improved. Differences of the SBD in the monitored systems were observed mainly in the summer season. Hůla and Procházková (2002) introduce some information about worsening of the SBD from sowing to harvest.

Table 2: The average data (spring, summer and autumn) of physical properties (soil bulk density, total porosity) and soil moisture in summer during the years 1999-2005

	SBD t m^{-3}				Total porosity %				W (weight %)			
	EFS	LIF1	IFS	LIF2	EFS	LIF1	IFS	LIF2	EFS	LIF1	IFS	LIF2
1999	1.52	1.49	1.54	1.56	40.0	41.7	39.3	38.4	-	-	16.7	19.1
2000	1.50	1.54	1.52	1.53	40.8	40.5	40.1	39.0	15.1	14.2	14.8	16.1
2001	1.54	1.57	1.55	1.63	39.3	37.9	37.4	39.1	14.5	14.1	13.6	17.6
2002	1.59	1.59	1.45	1.52	37.3	37.6	42.6	39.7	10.4	9.4	9.6	10.3
2003	1.51	1.53	1.41	1.45	40.7	40.2	44.6	42.1	8.5	8.0	10.0	9.7
2004	1.29	1.38	1.34	1.44	49.3	45.5	47.5	42.7	10.9	10.3	10.7	11.3
2005	1.47	1.55	1.40	1.42	41.7	38.8	45.0	43.7	14.2	15.6	17.2	18.2
average	1.49	1.52	1.46	1.51	41.3	40.3	42.4	40.7	12.3	11.9	13.2	14.6
LSD	years		FS		years		FS		years		FS	
0.05	-		-		-		-		-		-	
0.01	++		+		++		-		++		++	

Our results recorded an identical tendency in the system with mouldboard tillage. From the point of view of monitored soil layers, the mellowest soil was in the upper soil layer. Results of Hůla and Procházková (2002) show that soil density can slowly be reduced by long-lasting using of protective soil tillage. The same results were achieved on medium soil and loess by Husnjak et al. (2002).The biggest differences of the SBD in term of area according the systems were between the surface and under surface soil layers. This is in accordance with results published by Javůrek et al. (2004) who mentioned that the differences of reduced SBD phase down between layers in soil protective systems of tillage. It is very likely that this was also influenced by the different crop residues management. Similarly in the experiments of Battikhi and Suleiman (1999) the implementation of the no-till system in semiarid conditions raised the production of biomass crop residue which reduced the SBD.

Significant differences in yields of productivity (by cereals unit) were found only between the ecological system and more LIS 2 (table 3). Yields of crops were more depended on soil moisture storage and rainfall during vegetation period than on SBD.

Table 3: Average data of productivity of farming systems expressed by cereals units in the years 1999-2005 (t ha^{-1})

Years/farming system	EFS	LIS1	IFS	LIS2	Average
1999	3.75	4.44	5.15	5.37	4.68bc
2000	4.24	4.24	3.45	4.08	4.01ab
2001	5.73	6.11	4.33	6.46	5.66c
2002	4.51	5.20	5.24	5.99	5.24c
2003	3.51	3.76	3.24	3.66	3.55a
2004	4.15	4.68	5.77	5.75	5.09c
2005	5.51	5.71	5.88	6.03	5.79c
Average	4.48A	4.88AB	4.73AB	5.33B	total average 4.86

The means within columns or rows followed by the same letter are not significantly different at the 0.05 probability level

Soil properties were directly managed by farming systems via its components (crop rotation, tillage and target fertilization of nitrogen from mineral fertilizers) and indirectly by affecting soil environmental processes. The content of SOM, N_{tot} and the amount of microbial biomass were significantly higher in no-till production (table 4).

Table 4: Average soil chemical properties in a soil layer 0.02-0.2 m as affected by years and farming systems (FS) in the years 1999-2005

	C_{ox}				N_{tot}				N_{an}			
	EFS	LIF1	IFS	LIF2	EFS	LIF1	IFS	LIF2	EFS	LIF1	IFS	LIF2
1999	1.130	1.230	1.400	1.29	0.122	0.126	0.141	0.131	14.1	17.5	22.1	18.6
2000	1.260	1.170	1.440	1.18	0.126	0.126	0.155	0.130	11.8	9.0	23.3	11.9
2001	1.160	1.150	1.220	1.100	0.126	0.124	0.144	0.119	17.1	12.0	29.4	18.9
2002	1.250	1.260	1.880	1.280	0.127	0.128	0.192	0.129	7.4	6.1	20.7	7.2
2003	1.253	1.235	1.391	1.192	0.118	0.115	0.130	0.114	8.3	9.1	26.8	19.4
2004	1.278	1.238	1.432	1.214	0.116	0.113	0.129	0.110	6.6	11.1	10.5	18.2
2005	1.266	1.161	1.548	1.178	0.112	0.137	0.137	0.102	8.1	9.0	8.0	12.5
average	1.232	1.206	1.489	1.205	0.121	0.124	0.147	0.119	10.5	10.5	20.1	15.2
LSD	years		FS		years		FS		years		FS	
0.05	-		-		+		-		+		-	
0.01	-		++		-		++		-		++	

The respiration activity reflects ability of the soil micro organism to decompose the organic matter in optimized conditions (table 5). The no-till and ecological production increased earthworm's abundance in soil contrast to the conventional way of soil management. Maintaining a favourable habitat for earthworms there is one of the recommended applications for mitigation of plant sensitivity to climate-stress (Birkás et al., 2008).
Higher content of organic material, active and numerous soil biota indicate the improvement of qualitative soil properties in the conservation and ecological regime of soil management.

Table 5: Soil biological indicators in a layer 0.02-0.2 as average from sampling in each year 1999-2005

	Soil microbial biomass carbon				Flux of CO_2 (basal respiration)				Earthworms abundance			
	EFS	LIF1	IFS	LIF2	EFS	LIF1	IFS	LIF2	EFS	LIF1	IFS	LIF2
1999	530.1	529.9	572.0	623.1	4.00	4.02	7.52	5.03	40	68	137	86
2000	495.7	505.9	512.1	576.8	4.84	4.71	8.43	5.08	0	5	16	0
2001	549.2	360.3	596.6	582.5	3.24	3.19	7.37	5.61	16	11	53	13
2002	372.4	530.2	590.9	528.9	4.92	5.06	7.17	4.75	78	43	41	5
2003	832.7	801.9	582.0	730.8	4.25	6.31	6.67	3.59	12	18	36	4
2004	570.5	528.3	676.0	626.6	5.57	4.82	6.68	4.99	30	20	40	4
2005	759.6	651.1	783.6	767.9	4.05	4.18	6.13	3.94	32	20	24	6
average	587.2	557.7	654.7	633.8	4.41	4.61	7.17	4.71	29.7	26.4	49.6	16.8
LSD	years		FS		years		FS		years		FS	
0.05	-		-		-		-		+		-	
0.01	++		+		-		++		-		++	

It is connected with information which was publishing by Rasmussen (1999); Tebrugge and During (1999), that conservation tillage technologies offer suitable condition for better development of earthworms population by better accumulation of SOM. The balance of SOM was calculated form 1999 up to 2005. As for the active balance of soil carbon the positive one was at EFS and IFS (table 6).

Table 6: Balance of soil organic carbon (kg ha^{-1} C) of evaluated farming systems in the soil layer 0.02-0.2 m in the years 1995, 2005

Year	EFS	LIS1	IFS	LIS2	Average
1995	35 264	36 654	43 120	40 248	38 822
2005	37 220	35 991	43 344	33 455	37 503
Difference	+1 956	-663	+224	-6 793	-1 319

From the obtained results we can confirm, that the average of inorganic nitrogen in soil were affected by farming system (highly significantly) and weather (significantly). Average content of inorganic nitrogen in soil (layer 0.02 -0.2 m) in the whole research period (by order EFS, LIF1, IFS, LIF2) was 31-32-59 and 46 kg N_{an} ha^{-1}. It present the 1st up to 3rd potential intensity of water resource pollution by NO_3 which came from agriculture ((Bielek 1998)
From results can be seen that higher content of N_{an} in the soil were found in systems with higher rate of nitrogen (58 kg N ha^{-1}) from industrial fertilizers (IFS or LIS 2) (table 4). Between crop productivity and soil inorganic nitrogen content the significant relationship was noted. From the point of view of soil quality environment the best results gave ecological system without mineral fertilizers and pesticides. As for the N_{an} our results showed that highest content of inorganic nitrogen were found in no-till production and in systems with mineral fertilizers. The “long term tillage” field site for this study has undergone identical agronomic practices and crop rotation for more than 10 years. Historical yields trend for plant cultivation at this site generally reflect those observed our research focused on farming system on ecological farming and no-till production and biological and cash crop rotation. On average ecological farming yielded lower than IFS with inputs of nitrogen from mineral fertilizers. Our results demonstrate that relationship between chemical and biological soil properties and conducted farming systems have time and space limitation (table 7).

Table 7: Relationship between productivity, nitrification activity and selected soil properties in the ecological and integrated farming systems in the years 1996-2005

Y	X	EFS		IFS (no till)	
		R^2	ir	R^2	ir
Productivity	Amonification	0.9565	0.97++	0.3250	0.57 NS
Productivity	Nitrification	0.5024	0.71+	0.5369	0.73+
Productivity	N_{an}	0.5611	0.74+	0.7583	0.87++
Productivity	CO_2	0.8507	0.92++	0.8957	0.94++
Productivity	C_{ox}	0.4948	0.70+	0.4998	0.70+
Productivity	N_{tot}	0.4525	0.67 NS	0.2832	0.53 NS
Productivity	Porosity	0.7829	0.88++	0.8848	0.94++
Productivity	Sum of temperature	0.7836	0.88++	0.7836	0.88++
Productivity	Sum of rainfall	0.9959	0.99++	0.9599	0.97++
Nitrification	CO_2	0.5758	0.75+	0.5919	0.76+
Nitrification	pH	0.9750	0.98++	0.9760	0.98++
Nitrification	Porosity	0.8154	0.90++	0.5132	0.71+
Nitrification	Sum of temperature	0.7922	0.89++	0.5194	0.71+
Nitrification	Sum of rainfall	0.6415	0.80+	0.7397	0.85++

Results present characteristics which are binding with soil genetic type and climate conditions. The pressure of the reform of CAP EÚ on water and soil environment protection will lead to more intensive implementation of ecological and conservation soil management which can be qualified as having favourable (sustainable) effect on environment quality.

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STRUCTURAL STRENGTH ANALYSIS OF A SUBSOILER WITH FINITE ELEMENT METHOD

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Abstract

Soil compaction is an important issue that is necessary to solve as a problem. Soil compaction is defined as reduction of air volume in soil zone due to external forces. This compaction in soil effects growing plant diffusing, and limits the movement of water and air in the soil. It also makes seed to become grassy slowdown. As a result, decreasing on yield is seen. One of the useful methods, which has been using for preventing to yield decrease is deep tillage with subsoiler. Subsoiler is a tillage tool that can work 45-75 cm soil depth. Subsoiler works under the reaction forces of soil because of deep tillage. In this study, working condition was simulated for a standard subsoiler as three-dimensional. To investigate stress distributions on subsoiler constructions because of tillage effect, Ansys Workbench commercial finite elements code was used. Based on the results from the simulation and experimental study, it was determined that the subsoiler's tines have plastic deformation under the operating condition. In addition, according to obtained results, conclusions were presented to prevent failure of subsoiler construction.

Keywords: Subsoiler, Strength analysis, Finite element method

1. Introduction

In agricultural production, one of the problems is soil compaction. It acts on plant diffusing directly in the soil. Because growing plants needs enough space and water permeability in the soil. Same tillage procedure and wheel traffic increase soil compaction every year. They cause a hard layer about 25 cm soil depth and that layer is called as hardpan or plow pan. This layer must be broken in order to for provide to healthy plant diffusing area [1]. Therefore, subsoiling has become an essential tillage operation [2]. The effect of soil compaction on a sample plant's root can be seen in Fig.1 [3].

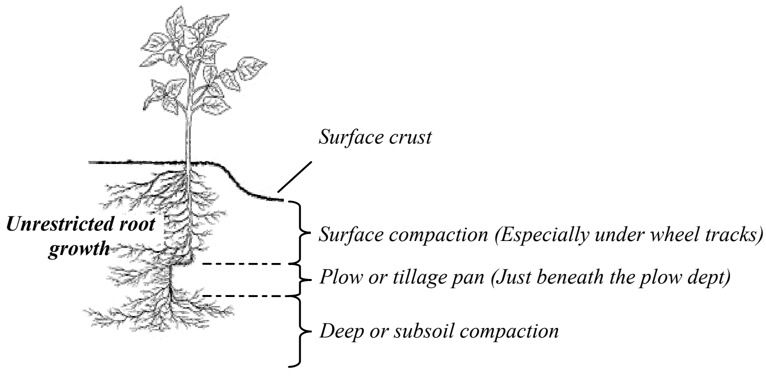

Figure 1. Soil compaction effect on a root of plant

One of the useful methods is deep tillage with subsoiler to avoid undesired soil compaction [4]. Subsoiler is a tillage tool that can work at 45-75 cm soil depth. Although there are many kind of different designs of subsoilers, each of them is used for same purpose in agricultural fields. Usually, a subsoiler has a main framework, support parts, tine and a narrow share and they are manufactured as steel construction.

Subsoiler has high magnitude reaction forces from the soil during deep tillage. For these reaction forces affect construction elements of subsoiler directly or indirectly. If the construction elements cannot compensate the reaction forces, they become useless due to plastic deformation or fracture. Therefore, structure of subsoiler must have been designed as stable and durable enough to avoid undesired failure cases. Usually, machine manufacturers uses materials, which have high safety coefficient or high weight machine members to avoid unappreciated case and operating conditions. However, this is not an optimum way. Actually, stress distribution should be well known to generate design, optimum material shape and durability of elements according to defined operating conditions. In fact, not all of the factors (non-linear and dynamic) can be described exactly in real working condition of subsoiler on field. Therefore, some assumptions are generated to define these factors for developing approaches to reality like all engineering problems.

In engineering applications, computers have been used for a long time and the applications calls as Computer Aided Engineering (CAE). Three-dimensional (3D) solid modeling and numerical applications help engineers for designing products in visual screen. So the engineers can evaluate and re-change their design parameters before prototype procedure without time and cost losing.

Numerical methods have been used to solve complicated problems in different engineering disciplines. In mechanical design process, one of the most used numerical methods is Finite Element Method (FEM). This method has been developed at the beginning of 1950's in order to computing stress distribution of complicated structure in aeronautic industry. Today, the method can be used nearly all kind of different engineering field together with developing technologies and computers. In addition, using these applications are so important in agricultural mechanization system design. The FEM is also being used to study soil cutting and tillage [5]. In this article, a three-tine subsoiler was modeled together with all construction elements as 3D. Draft force of subsoiler was measured from experimental study. Obtained data were defined in Finite Element Analysis (FEA) and FEA carried out to investigate stress distribution of a three-tine subsoiler under the boundary condition. Experimental investigation and simulation results were evaluated and conclusions were presented.

2. Experimental study

Two-tractor method and a dynamometer were used to measure draft force of subsoiler in the experimental study. The study was carried out in BATEM (Batı Akdeniz Agriculture Research Institute) agricultural field at the unit of Aksu/Antalya is located in the West-Mediterranean region of Turkey. In agricultural field, where the experimental study was realized, soil structure has sand 15%, clay 30%, silt 55%, and $CaCO_3$ is 30.4% and, tractor working speed at tillage was 4 km/h. Subsoiler-tractor connections and dynamometers can be seen in Fig.2. According to dynamometers data, maximum draft force obtained as 38.32 kN (Fig.3).

Figure 2. Subsoiler-tractor connections, dynamometer and experimental study

Draft Force	Average	Min.	Max.
[kN]	20.94	8.11	38.32

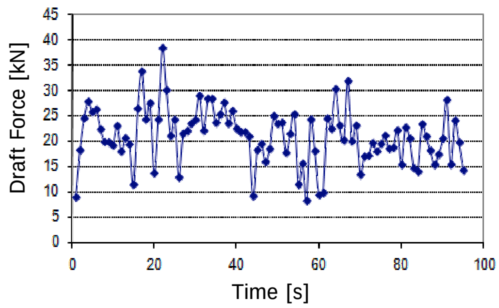

Figure 3. Draft force

3. Three Dimensional Solid Modeling and Finite Element Analysis of Subsoiler

Subsoiler with three-tine, which has been manufactured by a local manufacturer company, was modeled as 3D. Solidworks 3D parametric design software was used in solid modeling process. All elements of the subsoiler were used in assembled model, depended to original structure dimensions, in Solidworks. Original dimensions and 3D solid model of subsoiler are shown in Fig. 4.

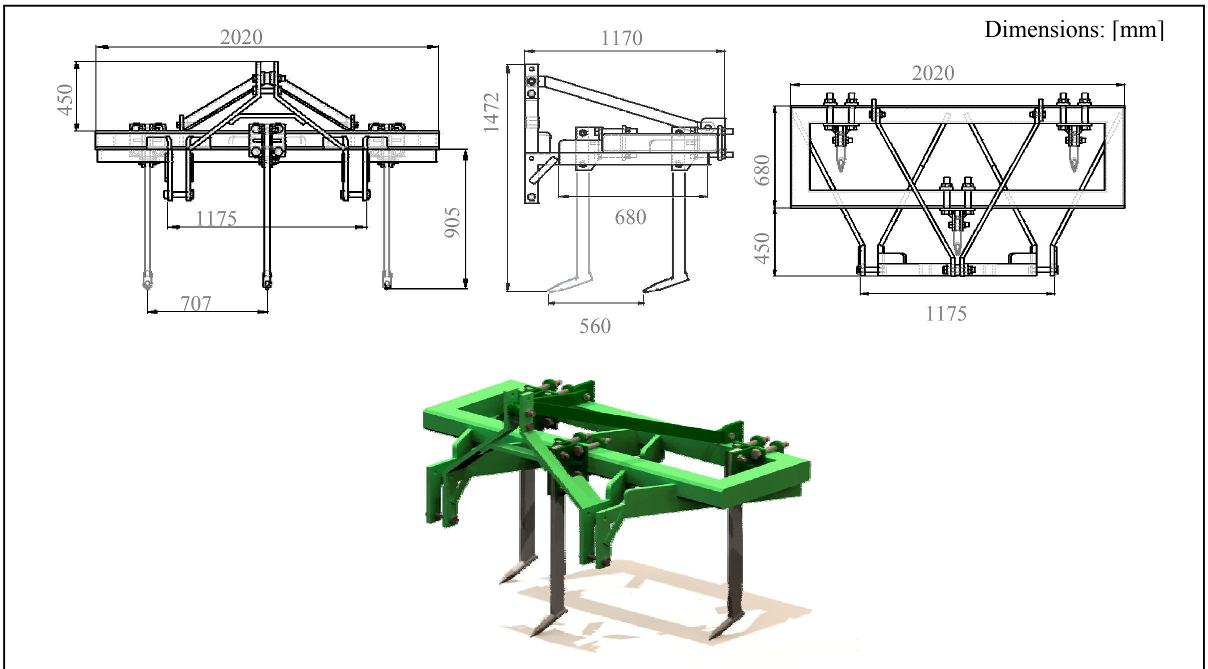

Figure 4. 3D solid model of subsoiler

After solid modeling process, FEA simulation was carried out to investigate stress distribution on elements of subsoiler. Ansys Workbench FEM code was used to obtain stress results and deformations. The FEA was set up in 3D, static, linear and isotropic material model assumptions. St52 construction steel is used for material of subsoiler elements in the analysis (Table 1) [6]. Bonded contact type was used between all assembled elements. According to operating condition of subsoiler, boundary condition was defined. Cylindrical supports were applied on tractor-linkage connections of subsoiler. Maximum draft force, which was obtained from the experimental study, applied on surface of narrow share of each tine as 12.773 kN. In meshing process, 10-Node Tetrahedral Structural Solid (Solid187) and 20-Node Hexahedral Structural Solid (Solid186) were used and in totally 108082 nodes and, 75943 elements were obtained [7]. Meshing construction and defined boundary conditions are presented in Fig. 5.

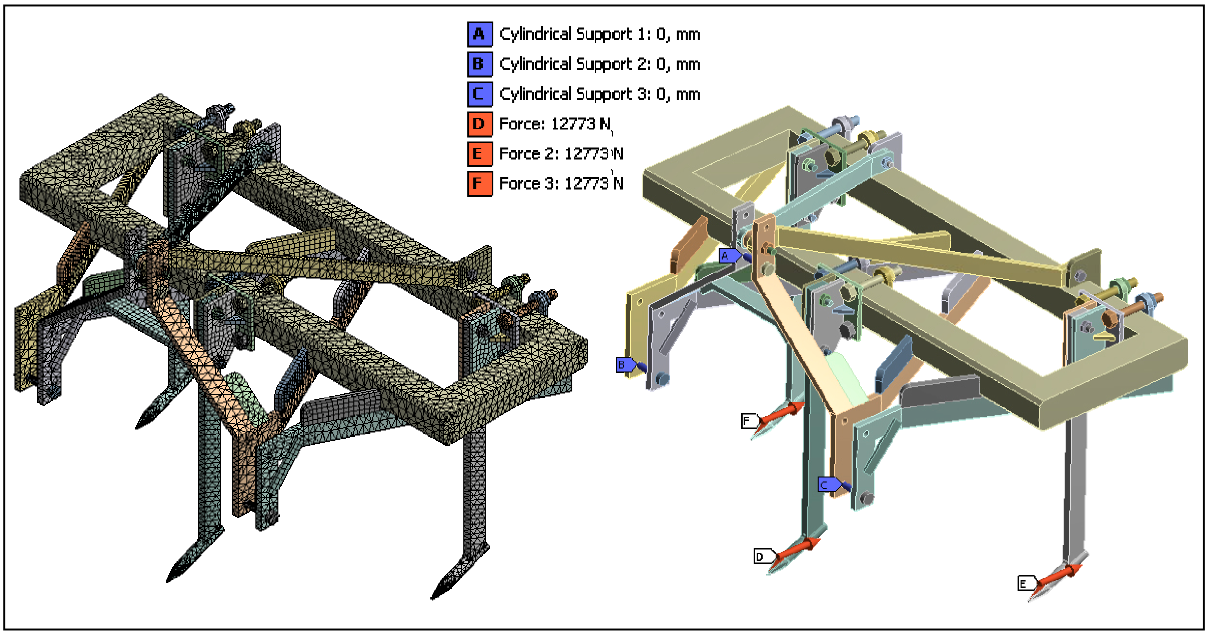

Figure 5. Meshing construction and boundary conditions of the subsoiler

Table 1. Mechanical properties of subsoiler elements (St52)

Young's Modulus	[GPa]	205
Tensile Ultimate Strength	[MPa]	520
Yield Strength	[MPa]	355
Poisson Ratio	[-]	0.29
Density	[kg/m^3]	7870
Bolt Connections	[Standards]	8.8

At the post process of FEA, equivalent (Von Misses) stress and displacement results were obtained for subsoiler construction. A maximum stress of 535.76 MPa was occurred on connection element of tine (on bolt) and maximum deflection was measured on tine as 19.463 mm for all construction. The equivalent stress distributions and, deformation behavior of subsoiler and some of its elements are presented in Fig.6 and, Fig.7 respectively.

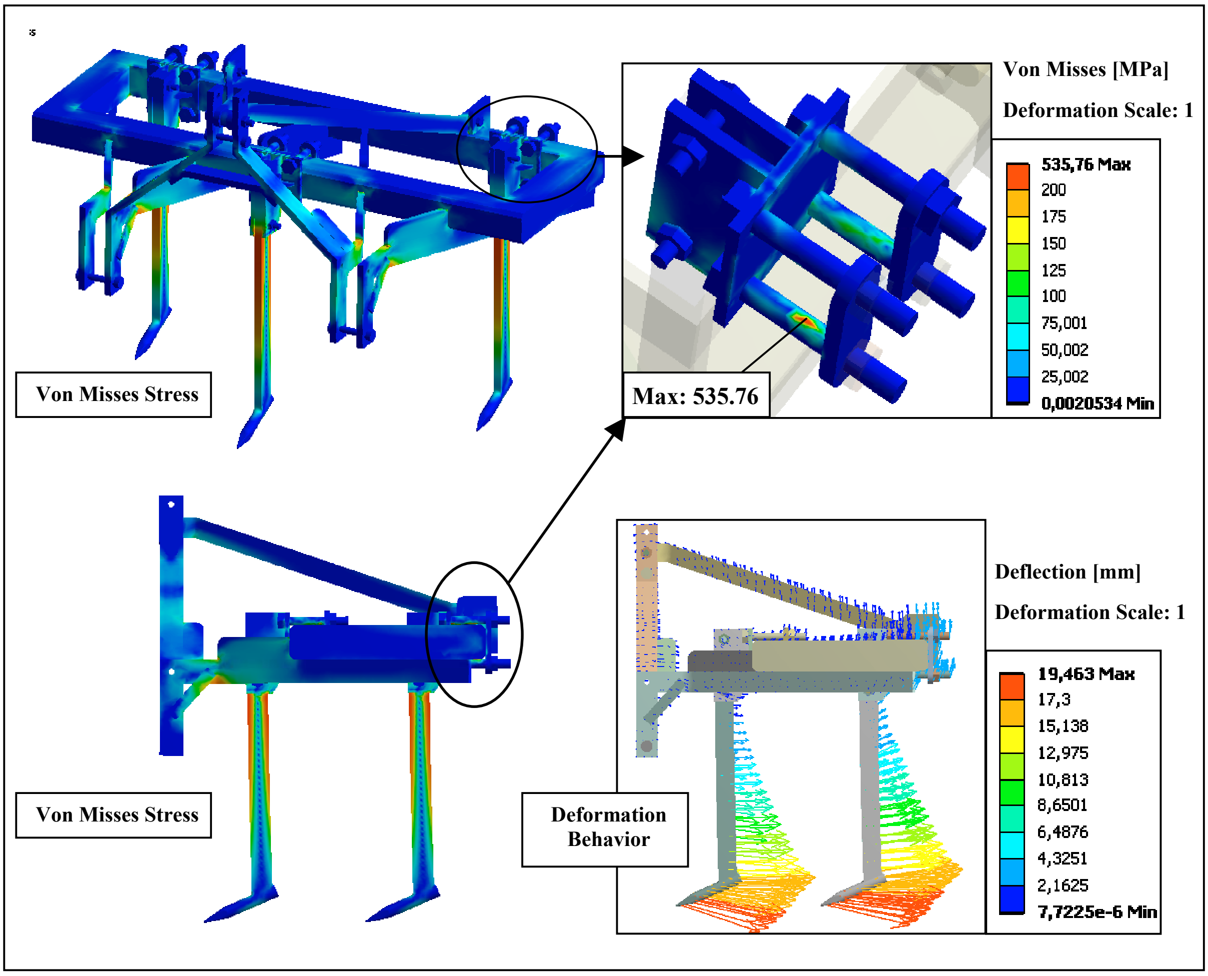

Figure 6. Equivalent stresses and deformation results of FEA

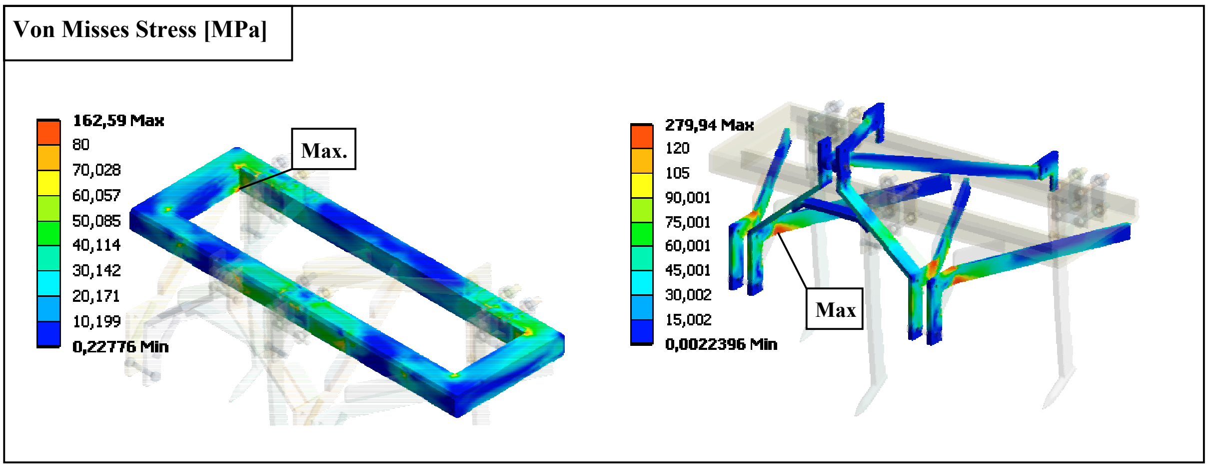

Figure 7. Equivalent stress distribution of framework and support Equivalents, respectively.

The stress values were evaluated for all elements of subsoiler, according to yield strength of construction material. Evaluation results show that all members of subsoiler are working without any failure except tines. Stress magnitude of tines was over the yield point of material. It means that tines have plastic deformation. When evaluated all results from this experimental study for subsoiler, plastic deformation of tines was corrected. Comparing points, simulation results and tine deformation are presented in Fig. 8.

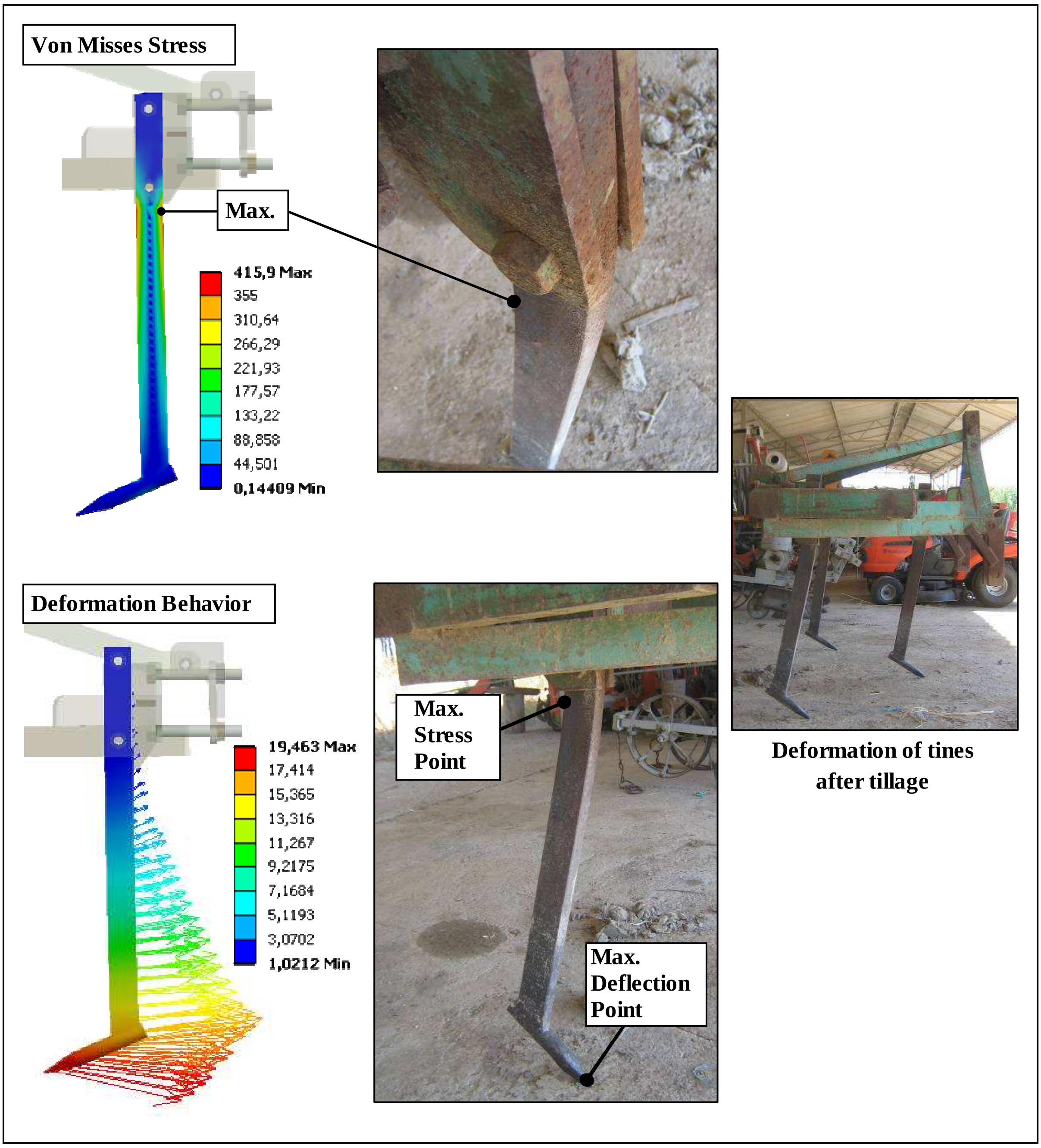

Figure 8. Comparing of simulation results and deformation of subsoiler's tine

Conclusions

In this study, it was focused that 3D solid modeling and FEM application on a three-tine subsoiler. FEA input data were obtained from the experimental study, which is performed to determine draft force of three-tine subsoiler. As a result, some important points can be summarized as;

1. Two-tractor method with a dynamometers was used in experimental study. Maximum draft force was measured as 38.32 kN.
2. For the FEA simulation, maximum stress was measured as 535.76 MPa on bolt in all elements of subsoiler. In addition, maximum stress was occurred as 162.59 MPa and 279.94 MPa on framework and support elements of subsoiler respectively.
3. Maximum displacement was measured as 19.73 mm on tine in totally.
4. According to yield stress of material, just tines have plastic deformation. Its maximum stress value was measured as 415.9 MPa. It was above the elastic region of material and it has plastic deformation.

Using CAE application it is possible to increase the quality and capacity of optimum machinery and tool design in agricultural field. In addition, these numeric applications can be used to prevent probable failures, design-material errors, time and cost losing. On the other hand, this study can be called as a preliminary work for shape optimization of subsoiler construction elements.

This study was focused on using 3D solid modeling and simulation techniques on agricultural mechanization systems. As result of the study, although failure was detected, failure analysis study was not conducted exactly. This can be investigated as another study subject.

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ROLE OF AGRICULTURAL MECHANIZATION IN PERSPECTIVE SOIL TILLAGE SYSTEMS

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Abstract

Development in the sphere of navigation systems allows using GPS for new organization of machines travelling across the plots. The controlled traffic farming systems principle will enable to concentrate the traffic trajectories in such way to protect effectively the production area against the unfavourable soil compaction. Monitoring of machines passages on the surveyed field showed high load of the soil by heavy agricultural machines and other traffic crossing the field. The achieved accuracy related to the machines working width keeping during GPS navigation in direction of straight line and within the chosen curve indicates effectivity of the new navigation systems in soil cultivation systems. In proper application of strip cropping principle it is possible to expect none negative impact on the machines exploitation indicators.

Key words: machinery passages across fields; GPS navigation; machines exploitation indicators

Machines current assortment for soil treatment and seeding enables to realize technologies of soil cultivation and crop covers establishing in variants corresponding with soil and ecological conditions of agricultural enterprises and cultivated crops structure. A significant positive change has occurred in both work quality and machines performance utilized in minimizing and soil protecting technologies. Nowadays technical solutions bringing new quality in soil treatment and seeding technologies are more applied as well as in other working operations in cultivation technologies and processes of soil care.

Reduction of undesirable soil compaction

Agricultural land is exposed to pressures of different intensity caused by tractors, harvest machines and transport means travelling mechanisms. The land has different resistance against compaction – important factors are soil texture composition, instantaneous soil moisture, organic matter content and soil structure. One of the options possible to reduce undesirable soil compaction is the concentration of machines travelling across the land into permanent rail traces. As early as before 15-25 years the experience was obtained by indication of prospective application of these traces across the field. The maximum machines travelling should be concentrated in those traces, while production area would be saved against compaction. Moreover, the positive argument is that the permanent traces enable to reach lower values of rolling resistance. This is a positive argument. But no means were available to secure reliable navigation of machine sets during movement across the field at the mentioned time. Current GPS system of navigation enables to solve a need of soil undesirable compaction reduction with qualitative new process.

Agricultural guidance systems

Evaluation of new technologies in agricultural machinery driving is very important and can help producers to choose the right equipment for their applications.

Beside operating and supervising the implements, the driving of the machine demands a high level of concentration from the driver. Driving can be tiring and monotonous especially in large fields. Glare or darkness can cause additional deterioration of working conditions. Automatic steering supports the driver so that he can keep his attention to the main functions of the machinery. Due to this reason, automatic control of agricultural machines gains importance, especially automation of machines driving (Stoll et Kutzbach 2000).
The guidance system GPS can be used and applied in many field operations. Dunn et al. (2006), Han et al. (2004), Stoll and Kutzbach (2000), Debain et al. (2000), Cordesses (2000) state main benefits of the guidance systems:

- reducing driver tiredness: guidance system reduces the effort associated with maintaining accurate machine paths;
- reducing costs: accuracy is increased by reducing overlapping and omissions of operating passages by machines on the field;
- increasing productivity: higher operating speeds are possible;
- improving quality: driver can focus his attention to ensure better quality;
- improving safety;
- less negative impact on the environment;
- enabling work when visibility is poor (i.e., in the night).

Many different types of technologies such as ground based sensing systems (Hague et al. 2000), laser systems (Chateau 2000), vision-based machine guidance systems (Han et al. 2004, Debain et al. 2000), and GPS (Ehsani et al. 2004, Karimi 2006) have been attempted to use in navigation of agricultural machines. GPS-based navigation systems are the only navigation technologies that have become commercially available for navigation of farm machines (Batte et Ehsani 2006). DGPS technology has introduced many possibilities for better input management by enabling growers and farmers to apply the right amount of inputs at the right location. As a result, DGPS technology has made the precision agriculture concept more appealing to the agricultural community (Ehsani et al. 2004). Nowadays comparison between different guidance systems has typically been based on the amount of guidance error (i.e., the deviation of the machine from the desired path). Possibilities of applying these steering systems are prospective in anti-erosion control measurements and against soil compaction.

Controlled traffic farming (CTF)

Nowadays passages of heavy agriculture machinery across a field are a common practice but they are mainly random. As a result of this fact, soil is exposed very often to repeated passages and thus to the irreversible structural changes connected with soil compaction. Soil compaction caused by traffic reduces soil infiltration, hydraulic conductivity, porosity, and aeration; and increases bulk density and impedance for root exploration (Gan-Mor et Clark 2001, Radford et al. 2006). The use of a technology called controlled traffic may minimize or eliminate the need for deep tillage or subsoiling, since CT is based on maintaining the same wheel lines for several years (Hadas et al 1990). The CT was primarily suggested since soil compaction caused by heavy agricultural machinery has become an acknowledged problem in reducing agricultural yields.

Erosion control measures

The most expansive technique for preventing water runoff and resulting soil erosion is construction of long benches along contour lines, which are lines of certain altitude. This practice is called terracing, contour or strip farming and it helps to retain the excessive water (Gan-Mor a Clark 2001, Morgan 2005).

Contour farming, controlled traffic and sub-surface drip-irrigation are technologies where centimeter accuracy is essential for commercial application and high investment is thus clearly justified (Gan-Mor et Clark 2001).

Materials and methods

In order to gain enter data for further CT systems observation, several measurements concerning frequency and total area of machinery passages in a field were done in the year 2007. DGPS receivers were placed into the machines for monitoring of all machinery passages across observed fields with 2 s logging time for position data saving. All field operations in the particular field were observed for 3 variants of tillage systems during one year. Conventional system with ploughing, conservation tillage and direct seeding systems were evaluated. The total area covered by all machine's tyres crossing was calculated with help of the software ArcGIS 9. Also repeatedly run-over areas were detected.
For evaluation of achieved accuracy related to the machines operating width keeping during GPS navigation was used the GPS steering system Trimble AgGPS Autopilot HP in modification for receiving of differential signal OmniStar HP. The measured values were obtained at the seeding by drilling machine JD-NT 2000 (operating width 6 metres) in set CASE MX270.
The method of machines operation monitoring, worked-up at the RIAE, was used for data recording of machines utilization assessment during their operations in agricultural enterprise and investigation of Diesel fuel consumption. The appropriate device with microcomputer was used for data recording. This device enables to record geographical coordinates, to set working speed and time from the GPS receiver and has been built-in the GSM module for data sending and function adjustment of the recorder. Besides the GPS data also Diesel fuel consumption is recorded. From soil texture point of view mostly loamy soil and less sandy-loam soil dominate in the surveyed area.

Results

The results of machinery passages across field monitoring showed that 96 % of the field area (square cut out 1 ha) was run-over by machines at least once during a year when conventional tillage was used, and 65 % and 43 % of the field area were run-over when respectively conservation tillage and direct seeding were used. It was calculated that 144 % of area covered by all machine's tires crossing was run-over repeatedly for conventional tillage, 31 % for conservation tillage and only 9 % for direct seeding. The results show considerable high number of tyres passage on the field. (Fig. 1).
Results of achieved accuracy of machines operating width continuity for seeding are demonstrated in Fig. 2 and Fig. 3. These results showed high accuracy in keeping of operating passages by the machines on the field governed by automatic satellite navigation. This accuracy is higher than in the situation when the disk markers are used. Automatic satellite navigation minimizes overlapping and omissions of operating passages by machines on the field, which has a significant role in quality of seeding and consequently in growth quality of the crops. The next advantage is obvious in possibility to set up accurate system of track rows, which provides accurate operating of machines on the field in all agricultural processes.
The results of the Diesel fuel consumption monitoring showed, that Diesel fuel consumption decreases with increasing area size. The important result is determined dependence of Diesel fuel consumption on average length of operation drive through the plots, which is positive argument for application of row crops change in steep land areas (Fig. 4). If the area length in

the contour lines direction assumes to be not decreased then it is possible to apply the row crops change principle without any negative impact on machines exploitation indicators.

Conclusion

Current GPS navigation allows increasing the quality of soil care in some aspects. The CTF (Controlled Traffic Farming) system could be considered as prospective particularly due to increased soil protection against undesirable compaction. The travelling concentration into the given travel traces is real with the GPS navigators utilization in sufficient accuracy. Nevertheless the increased costs represent machines adaptation with aim to unify the wheels spacing.

The GPS navigators can be successfully applied in steep fields' cultivation. The GPS navigation also can facilitate the machine sets travel in contour lines direction and makes good conditions for contour cultivation of steep fields including strip cropping principle. The current GPS navigator accuracy is sufficient for these purposes. It is possible to expect that application of strip cropping principle on steep land areas does not need to have any negative impact on machines exploitation indicators.

Results presented in this paper were obtained during solution of the research projects 1G57042 and MSM6046070905.

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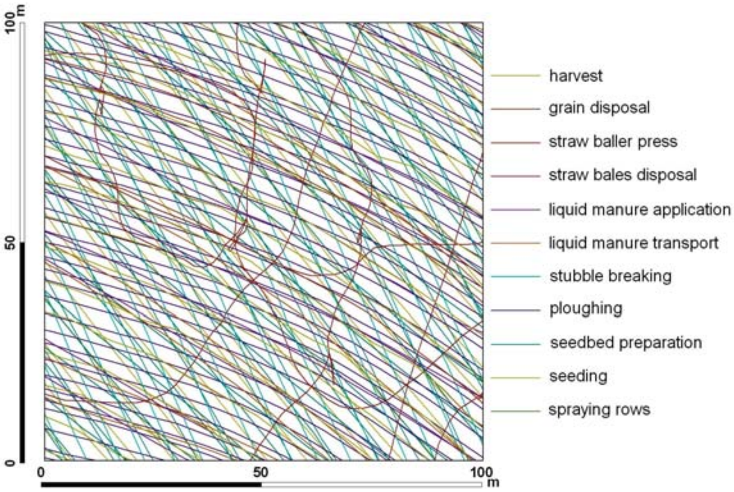


Fig 1. Map of the passage trajectories on the field – winter wheat, conventional soil tillage

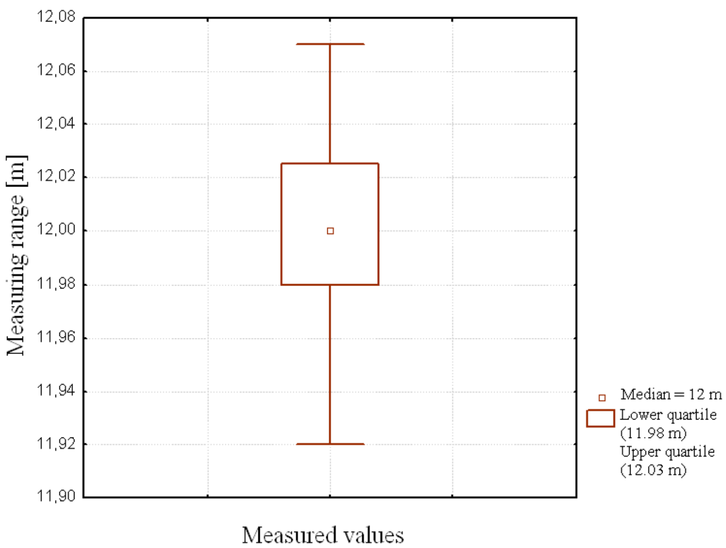
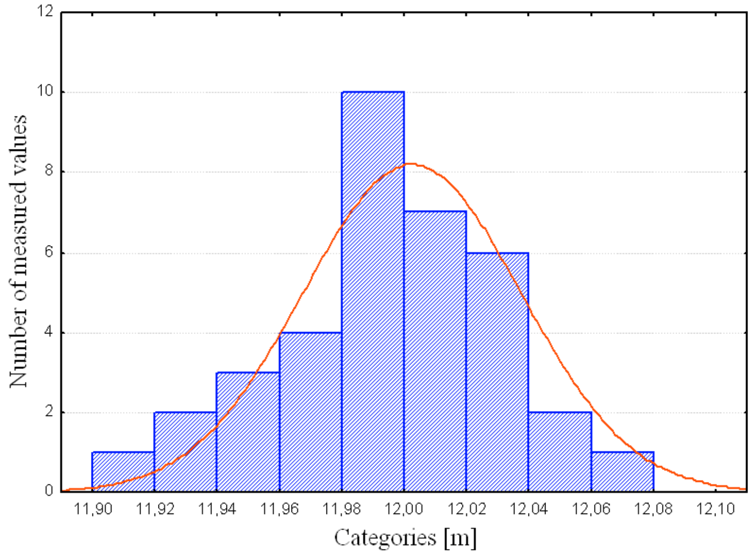


Fig. 2. Keeping operating width at seeding by drilling machine JD-NT 2000 (operating width 6 metres) in set with tractor CASE MX270 – deviations from double operating width



3. Number of measured values histogram - seeding by drilling machine JD-NT 2000 in set with tractor CASE MX270

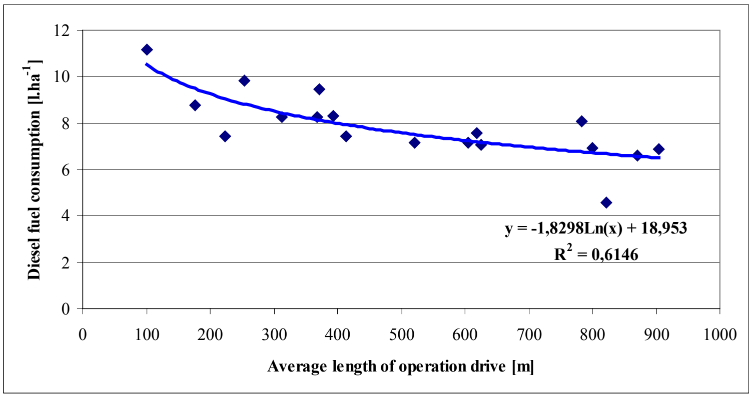


Fig. 4. Dependence of Diesel fuel consumption on average length of operation drive through the plots – skimming by disc tiller DOWLANDS 4500 in set with tractor JOHN DEERE 8200

CONSERVATION-AGRICULTURE (CA) MECHANIZATION

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Abstract
Conservation-Agriculture (CA) is the new "revolution" in agricultural crop production systems that is being developed for many global regions and crops. Because general tillage is not used with CA, special mechanization implements and management are needed to successfully crop in non-tilled, residue-covered soils. CA Concept, Principles, Technical Alternatives, Crops, and suggested Mechanization Implements are described.
Keywords: Conservation, Mechanization, Cropping, Agricultural-Revolution, CA

CA *Concept*:

"Conservation-Agriculture" (CA) is the umbrella under which the best of what we know from use of "zero-till", "ridge-till", "zone-till", "strip-till", "chisel-till", "minimum-tillage", and "no-till" are combined. These best aspects have been selected from global experiences with those technologies and put together into cropping management and technology schemes which really work on the long-term, achieving both profits and conservation. This has been done to separate out the "junk-technologies" that should not be recommended, from "good-technologies", so that with CA, farm-producers can have the support that they need for success.

What is CA? ***CA is a set of managerial and technical alternatives which will, in both the short-term and long-term, accomplish the "3-Ws": to store Water in the soil, to save the Water stored in the soil, and to efficiently utilize stored soil Water for beneficial crop production.*** The active part or focus of "conservation" in CA is the conservation of available water. In the process of applying technologies for conserving and managing the use of rainfall water, the conservation of soil, environment, agricultural inputs, farm labor, health, and rural community resources automatically occur. The focus on water conservation is very helpful, for it provides the following criteria: Any proposed component of CA must be evaluated relative to its potential impact on any or all of the 3-Ws. CA approaches to cropping seem to have the best chances for long-term successful cropping relative to water availability and management (Hobbs, 2007).

CA *Principles* (IIRR and ACT, 2005):

#1. Provide year-around protective coverage of the soil; to do this, we do not use the plow, chisel plow, field cultivator, bedder, or disc harrow. Use of such implements cut and mix the residues into the soil and we need all of the produced residues to be kept on the surface, year-around, for soil protection and water conservation

#2. Disturb the soil only the minimum amount to insert seed, fertilizers, and beneficial materials into the soil below the protective soil-covering materials or vegetation; all CA field operations are shallow operations, not much deeper than seeding depth.

#3. Leave the soil uncompacted (untrafficed) where the crop plants are to be grown; keep all field wheel-traffic in the same lanes and do not plant in those lanes; this is necessary because if we are not plowing, then we need to keep the fields from becoming compacted. Also, do not use dual tractor tires because they compact lanes that are too wide, and duals are not needed with low-draft CA implements.

#4. Mix and rotate crops to minimize weed, insect, and disease problems; use good pest management as part of CA.

#5. Control weeds so that soil fertility and water resources are not diverted from crop growth; just like in no-till farming, year-around weed control and management is a key element in CA.

#6. Select, plant, and rotate crops to most effectively utilize available soil water; after maximizing the catching and retention of rainfall water by following the above CA Principles, this water resource can be used for profitable crop production.

There are workable Technical Alternatives for CA that can be used to reap the benefits of CA; Alternatives include the following list, but others may also apply:

CA *Technical Alternatives*:

1. Leave the bulk of the soil undisturbed year-after-year by elimination of broadcast plowing, cultivation, and tillage;
2. Use old-crop residues for soil coverage by leaving all residues in-place in the field during harvest;
3. Spread manures (FYM) on the soil surface to add to the protective soil cover; do not disturb the soil to incorporate this material;
4. Spread calcium/lime soil additive (as needed to decrease soil acidity) on the soil surface; do not disturb the soil to incorporate this material;
5. Conduct year-around weed control;
6. Destroy weed plants when they are juvenile; do not let weeds develop seed or spread in fields;
7. Use herbicidal (and in some cases shallow low-disturbance cultivation) weed controls;
8. Seed N-fixing legume crops in crop rotations or intercropping to supply some fertilizer-N for subsequent crops and to improve soil structure (see #10, below, for a limitation);
9. Seed grass, legume, or other "cover crops" to increase soil coverage for increased soil protection between main crops, i.e.; during the fallow period between main crops; (see #10, below, for a limitation);
10. Seed grass, legume, or other "cover crops" (see #8 & 9, above) only when soil-stored rain-water is in excess to the amount required for the principal crop;
11. Apply supplemental chemical fertilizers during the seeding operation as "starter fertilizer" in the soil; under, beside, near, or in the seed furrow where the seed is placed; apply at non-toxic rates of N- and K-fertilizers; apply all of P- fertilizer and trace minerals here;
12. Apply chemical insecticides in the seed furrow or over the closed furrow, as needed by the crop and in response to local insect-pest control situations;
13. Apply additional supplemental organic or chemical fertilizers as "side-dress fertilizer" in lines along the crop rows, on the surface or cut into the soil at a shallow depth beside the crop rows; apply needed N- and K-fertilizers here when the crop plants are small to allow enough time for rains to leach nutrients into the soil root zone;
14. Apply high-enough rates of supplemental organic or chemical fertilizers (see application method in #13, above) to, a) support the growth and yield of crops to pay for off-farm inputs for crop production, b) to grow enough crop residues to continue

protecting the soil, and c) to support extra yield to provide a final profit; [an example recommendation might be: for monocrop-maize, apply 1 kg of active N-fertilizer for each expected yield of 60 kg of dry grain];

15. When intercropping, adjust seeding rates lower and crop yield expectations lower for each of the intercrops than if they were being grown as a monocrop (only crop during that cropping-season);
16. Seed subsequent crops into the old-crop rows to take advantage of utilization of any residual fertilizers, lack of soil compaction, and the improved soil structure from the roots of the previous crop;
17. When harvesting a crop, leave as much as possible of the crop plant attached to the soil to keep the protective soil cover in-place in the field;
18. Maintain tractor and other wheel traffic in the same lanes in the fields, between crop rows, to prevent soil compaction from being a problem without plowing; usually, do not seed in these compacted lanes, even for broadcast or drilled crops.
19. Rotate or sequence crops to minimize crop pest infestations;
20. Drilled and row crops may be sequenced to produce different types and amounts of soil-protecting crop residues;
21. Keep CA crop production simple by the choice of easy-to-use methods.

CA *Crops*:

Target crops are both drilled and row-crops, including beans, maize, wheat/rye/barley/oats, sorghum, cotton, canola, upland-rice, and whatever, except perhaps sugar cane, sugar beets, groundnuts, and potatoes.

CA *Mechanization Implements*:

When we elect to do CA cropping, we leave all of the stalk, straw, and stubble residues in-place on the field surface. Therefore, we must have CA implements which will operate in soils with sometimes-heavy residue-cover without functional problems. Because of the residue cover, the soil under the residues will be at higher water content closer to the surface, so that not only is the surface covered, but the soil will be in a different condition than if we were doing conventional plowed-chiseled-disked-cultivated tillage.

Also, the soil may not be compacted (because we are going to keep all wheel traffic in designated lanes), but it will not be pre-loosened by tillage (and that is a good thing because we do not want our CA implements to be high-draft, deep-tilling implements). Therefore, CA implements must be designed to operate in firm and higher-moisture soils.

Conservationists now understand that if we keep the surface covered all year and do not compact the seeding areas, that we can limit our implement operations to just where we need to open the soil to place seed, fertilizers, and other supplements. And, we only need to open the soil to seeding depth or slightly deeper. This means that no CA field operation needs to be deeper than approximately 10cm!

For CA cropping we do not use implements which plow/chisel/disk/cultivate; therefore, CA field operations will be one of two basic systems:

A) "no-till" or "strip-till" for row crops;
B) "no-till" for drilled crops (because "strip-till" is not used for drilled crops).

But, CA is "enhanced" no-till or "enhanced" strip-till because we are adding improved residue management, weed-control management, and soil-compaction management, along with more emphasis on crop rotations to conduct integrated pest management and best management practices (see, CA *Technical Alternatives,* above).

The following selection of implements for CA are from a composite of experiences, trials, and evaluations, as seen to be the current best implement schemes to successfully conduct CA cropping. Many currently available implements are almost CA-ready; but, they may lack the inclusion of one or more desirable components or attachments to operate in full CA field conditions.

<u>Available conventional implements for CA:</u>
I) Available <u>field sprayers</u> and <u>fertilizer-spreaders</u> are almost-O.K., if they are mounted on narrow wheels allowing them to travel in the designated traffic lanes (compacted drive lanes), or on low-pressure floater tires. The spreaders are needed for broadcast "top-dressing" fertilizer on drilled crops (because we currently do not have an available technology to sidedress-fertilize drilled crops for more efficient fertilizer placement).

II) Conventional <u>row-crop planters can be used with strip-till</u>, so that the frequent "planting problem" with no-till is avoided with the use of strip-till.

III) If residue stalks are to be cut (may not be necessary or desirable), then conventional <u>stalk cutters/shredders</u> can be used, but remember that all wheels should be traveling in the traffic lanes!

<u>Specialized implements for CA:</u>
IV) We need CA implements for <u>strip-till ripping,</u> <u>direct no-till seed planting and drilling,</u> <u>fertilizer applications,</u> and <u>low-disturbance cultivating*</u> to produce short-term and long-term CA field conditions and benefits.

*A <u>low-disturbance cultivator for row crops</u> would only be used in those years when herbicide applications do not control weeds in the row middles; this implement may be owned as an optional implement and not used in most years.

For these specialized CA implements, the author suggests the following designs and management:

A) Set all tractor, harvester, and implement wheels to the <u>same track width</u>.

B) All implements should be of the same or multiples of the <u>same working width</u> (Morrison, 1985).

C) Use <u>rolling residue-rake wheels ahead of each row unit</u> opener to initially clear a path through heavy or bunched/piled residues that can not be cut with a coulter blade; free-floating wheels are best.

D) Use a <u>rolling coulter blade</u> that is lightly spring loaded (~70 kg) to cut what the residue-rake wheel misses; it only needs to run about 3-4 cm deep, so it does not need 180 kg (as typically recommended for coulters on no-till implements); the rolling coulter free-floats.

E) Use a vertical shank knife-type furrow opener (vertical shanks throw less soil) behind the coulter; at least 18 cm behind for residue-clearance.

F) Have a replaceable tool point on the bottom of the vertical shank to rip for strip-till, open a furrow for seeding, place fertilizer, or cultivate with a wide low-disturbance sweep.

G) Follow the shank with berming discs for strip-till, a presswheel for seeding, or nothing for sidedress-fertilizer application or low-disturbance cultivating.

H) Provide positive depth control on each row unit to obtain uniform results.

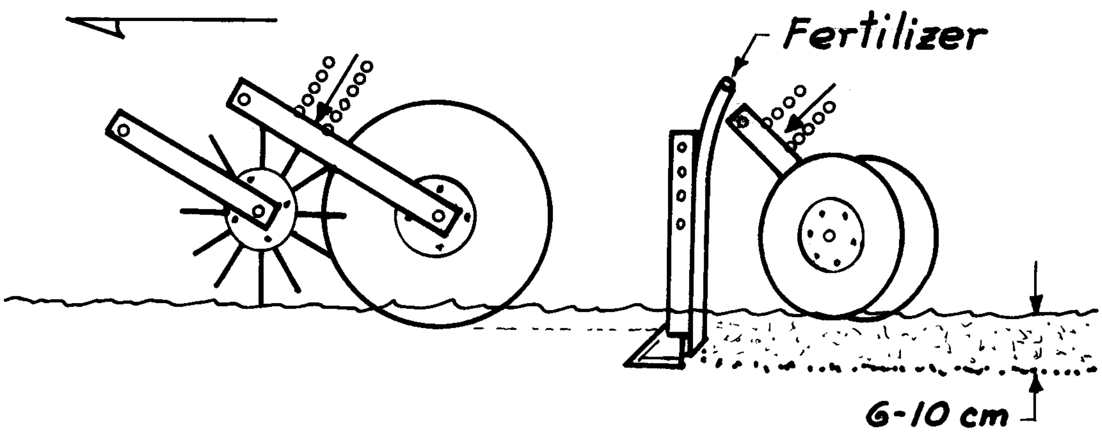
I) Use parallel or similar linkage for individual row-unit flotation.

Note: From the above specifications, you will notice that these CA implements have very similar row units. That is because they have similar functions, i.e., to clear and cut a path for a shallow low-disturbance tool to open the soil.

Note: You have also noticed that disc-type furrow openers are not specified. We have tried to utilize disc-type soil openers for many years, but those openers tend to roll over problems and not solve problems. Disc-type furrow openers were not designed to be operated in firm soils. Row-crop planters with shank openers are not widely available. Optional types of furrow openers may have to be used; staggered double-disc openers successfully operate in many CA-planting situations and are an alternative to shank furrow openers on planter and drill seeders. Also, optional disc-and-knife fertilizer applicator units may be satisfactory for sidedress-fertilizing of row crops, but selected units should also have residue-rake wheels and depth control.

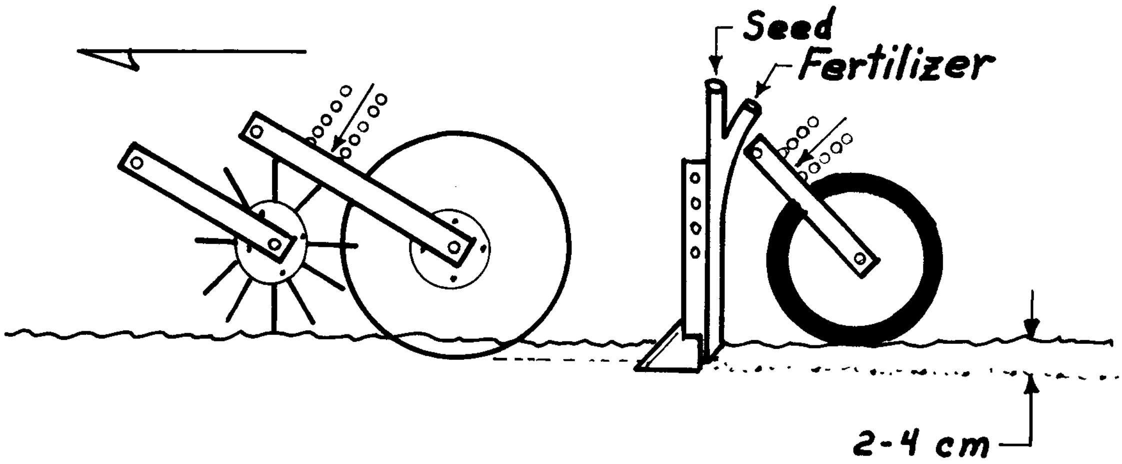
The following proposed CA implement designs include the features (C) – (I) from above [examples of available implements will also be shown during the oral presentation, but there is not space to include them in this Conference Proceedings document]:

V) Strip-till rippers



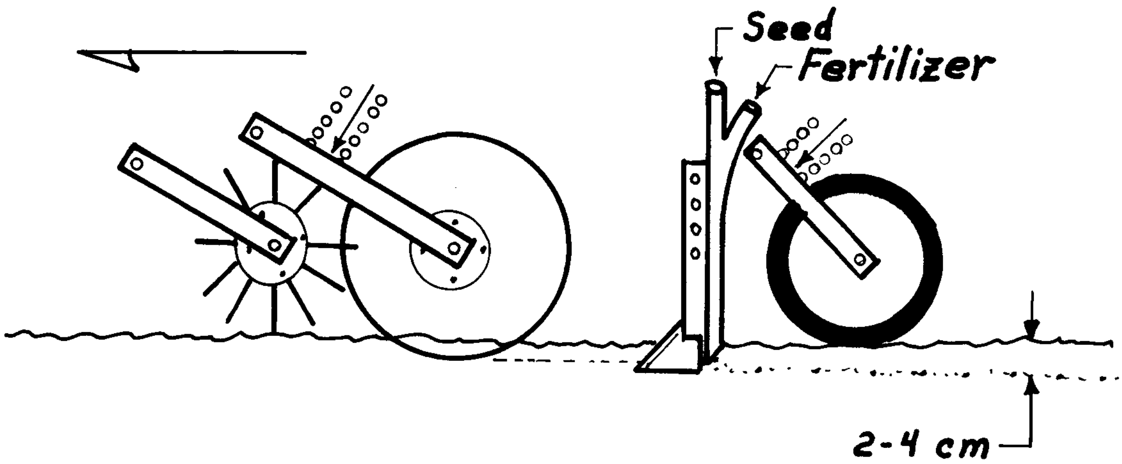
Concept design for CA Strip-till ripper row units; depth control is accomplished with the dual berming discs behind the ripper shank; starter-fertilizer may be applied with the ripper.

VIa) Direct No-till row-crop seeder/planter



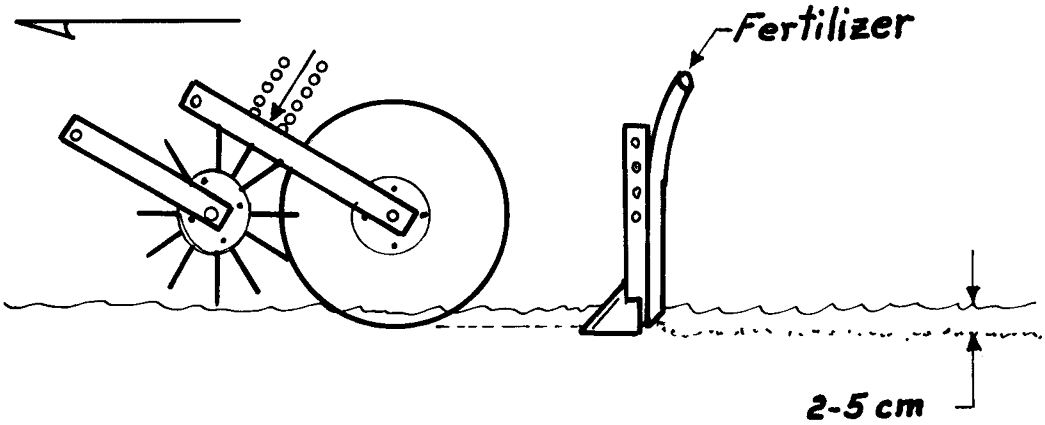
Concept design for CA direct No-till row-crop seeded/planter row units; units are typically spaced 40-100 cm apart for row-crops; non-toxic rates of starter fertilizer, trace minerals, and other needed supplements are applied into the seed furrow; seeding depth is controlled with the rear presswheel.

VIb) Direct no-till drill seeder/planter



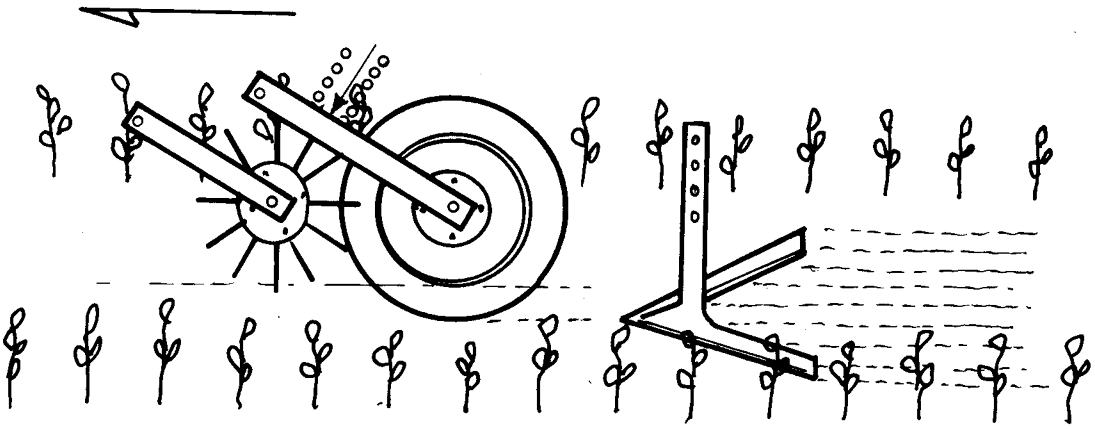
Concept design for CA direct No-till drill-type seeded/planter row units; units are typically spaced 15-30 cm apart for drilled-crops; design of row units is functionally identical to row units for row-crop seeding; (optional design) each row unit may be fitted with an appropriate shank tool and application tubes to seed two paired-rows, depositing the starter fertilizer between the two rows.

VII) Fertilizer applicator



Concept design for CA sidedress-fertilizer applicator for row-crops; this implement is for application of a band of high-rate fertilizer beside rows of small plants and below the surface residues and soil surface; each applicator row unit must have individual depth control (not shown).

VIII) Low-disturbance cultivator



Concept design for CA low-disturbance cultivator for row-crops; shallow v-blade is used to undercut surface residues and soil surface to cut weed roots; depth control is accomplished with a depth-band on rolling coulter blade or other device.

Summary:
Conservation-agriculture adoption is awaiting the availability of CA implements to accomplish the critical field operations for which conventional implements are not adequate. The above design specifications and management suggestions may be useful to those who wish to support the next revolution in agricultural cropping, namely “CA”.

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RESEARCHES REGARDING THE INFLUENCE OF MINIMUM TILLAGE SYSTEMS UPON THE SOIL PROPERTIES, YIELD AND ENERGY EFFICIENCY IN THE CASE OF MAIZE, SOYA-BEAN AND WINTER WHEAT CROPS

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Abstract

The paper presents the influence of the conventional ploughing tillage technology in comparison with the minimum tillage, upon the soil properties, weed control, yield and energy efficiency in the case of maize, soya-bean and winter wheat in a three years crop rotation. Human action upon soil by tillage determines important morphological, physical-chemical and biological changes, with different intensities and evaluative directions. Basic characteristics as: structure, humus content, physical indexes in the case of haplic luvisol are changing function of type and intensity of tillage and crop. The use of minimum soil tillage systems within a three years rotation: maize, soya-bean, wheat favorites the rise of the aggregates hydro stability with 5.6-7.5% on a 0-20 cm depth and 5-11% on 20-30 cm depth.

The soil tillage system influences the productivity elements of cultivated species and finally the productions thus obtained. Two elements are considered worthy being analysed taking into account the influence they have on production: plants density and weeding rate.

For all cultures within the crop rotation, the weed encroachment is maximum for the disc harrow and rotary harrow soil tillage, followed by the chisel and paraplow. The weed encroachment is minimum for the conventional ploughing tillage technology. The results of investigations showed that the yield is a conclusion soil tillage systems influence on soil properties, plant density assurance and on weed control.

The fuel consumption is reduced to 12.4-25.3 litters of gasoline / ha by applying the minimum soil tillage systems of haplic luvisol and also by reducing the power input to 23.6-42.8%.

Key words: *minimum tillage, yield, energy efficiency*

Introduction

The cultures respond to the system of soil tillage in a way that is hard to predict. The results depend on one hand on the soil characteristics and microclimate and on the other hand, on the association of different practices, such as: the rank of soil preparation, the sowing dates, the equipment used, the cultures rotation, the species or the hybrid used, the way in which it is fertilized (the time and the way it is applied) the weed control etc. (Gus, 1997; Rusu, 2001; Jitareanu et al., 2006). The relation between the production – its profit and the systems of soil tillage is mostly influenced by the previous management of the soil and by the weather. Consequently, the applying of the new systems of soil tillage must be done together with the managerial input, with the results acquired by research and the creation of new species and hybrids.

The alternative systems look for the sustainability of the agricultural system, to increase the actual soil fertility and ensure – as research proves - productions close in number to those obtained by classical ploughing. Another fact that must be specified is that the equal productions or the reductions up to 90 – 95% in the case of unconventional systems of soil tillage in opposition to the classic systems are considered more profitable. This is explained by the reduction of the expenditures when eliminating the ploughing in case of new systems

of soil tillage and by the increasing of optimum tilled and traffic ability as result of the improving the soil characteristics.
The production differences between the alternative systems and the classic one can be the result of a variant choice that can be used in certain pedoclimate conditions (Dick et al., 1994; Moiroizumi and Horino, 2002; Mark and Mahdi, 2004; Feiza et al., 2005; Riley et al., 2005; Ulrich et al., 2006). The efficiency of the alternative systems is ensured only in the case of a crop rotation, case in which cultures rotation alternates with the systems of tillage.

Material and Method

The tests were organized at the University of Agricultural Sciences and Veterinary Medicine of Cluj Napoca, Romania, on a moderately inclined northern slope, on haplic luvisol (MESP, 1987; SRTS, 2003), with medium fertility, content of 2.7-3.29% humus, slightly-moderate acid reaction (pH = 5.17-6.06), clay texture (40-42% clay in Ap), medium content of nitrogen and potassium, small content of phosphorus. These areas were was our research presents a medium multi annual temperature of 8.2^0C medium of multi annual rain drowns: 613 mm**.**
The soil profile is the following: Ap–A/Bw-Btyw-Bty-B/C-C, the 3rd quality class with 47 points of fertility potential of using arable.
Stationary testing with 6 variants:

a. *The classic systems*: V_1 –classic plough + disc –2x
V_2 – reversible plough + rotary harrow
b. *Minimum tillage*: V_3 – disc + rotary harrow
V_4 – rotary harrow –2x
V_5 – paraplow + rotary harrow
V_6 – chisel + rotary harrow

The several variants were tested three times in a row. In one variant the area of a land was 300 m^2. The results were statistically analysed by ANOVA test (PoliFact, 2002).
The cultures resulted from rotation were: maize, soya-bean, and winter-wheat. The biological material was represented by the 200 Turda – hybrid maize, S2254RR – a variety of soya-bean resistant to Roundup Ready and the Ariesan – species for the winter-wheat. Except for the soil tillage, all the other technological sequences of sowing, fertilizing, weed control, are identical in all the variants. The weed control for maize was accomplished by a preemergent – ppi (pre planting incorporated) treatment with the Guardian CE herbicide (acetochlor 820-860 g/l + antidote) 2.5 l/ha; 2 treatments postemergent – on vegetation with Roundup Ready (glifosat acid 360 g/l) 2.5-2 l/ha for soya-bean; a postemergent treatment with Icedin Super (dicamba 100 g/l + 2.4D 280g/l) 1.0 l/ha for winter-wheat.

Results and Discussions

<u>The influence of soil tillage system upon the yield in the case of maize, soya-bean and winter-wheat.</u> The soil tillage system influences the productivity elements of cultivated species and finally the productions thus obtained. Two elements are considered worthy being analyzed taking into account the influence they have on production: plants density and weeding rate.
The results show in all years of experimentation the change of culture density when applying the minimum system (table 1). When this applied on such type of soil it is imperious to differentiate the conventional system considering the aspect of optimum density by the quantity of seed that is used.
Taking into consideration the aspect of weeding, one con register different ranks of weeding influenced by yield and soil tillage system. Maximum weeding is when rotary harrow-2x is used, followed by disc harrow, chisel and paraplow. Weeding is minimum for conventional tillage technology with ploughing.

Table 1

The influence of different soil tillage systems upon the plants density, weeding and yield in the case of maize, soya-bean and winter-wheat crops cultivated on haplic luvisol

Variant / Characteristic	Plough + disc – 2x	Plough + rotary harrow	Disc + rotary harrow	Rotary harrow - 2x	Paraplow + rotary harrow	Chisel + rotary harrow
Plants/m^2 M	3.5	3.8	3.3	3.3	3.5	3.5
Plants/m^2 S	24.3	24.7	18.5	19.4	17.8	16.4
Plants/m^2 W	480	500	460	475	465	440
Weeding M^1	65.9	54.4	86.2	110.2	78.3	85.3
Weeds/m^2 S^2	63.8	62.6	87.9	92.2	88.1	87.7
S^1	2.3	1.7	1.7	2.1	1.8	2.0
W^1	24.1	18.7	27.7	36.3	26.1	30.5
Production M	4860(wt)	5849(***)	4314($_{000}$)	4583($_{000}$)	4730($_0$)	4710($_0$)
kg/ha S	3025(wt)	3546(***)	3146(ns)	3313(**)	3385(**)	3113(ns)
W	3730(wt)	3986(*)	3683(ns)	3612(ns)	3615(ns)	3486($_0$)

Note: wt – witness, ns – not significant, * signification positives, ^{0} signification negatives; M - maize, S - Soya-bean, W - winter-wheat, ^{1}Determination acquired when yielding, ^{2} Determination acquired before the first treatment

The different soil tillage systems influence the productions obtained. One thing that con be noticed is that when using the ploughing + rotary harrow for the preparation of the germinal layer (for all the three rotating cultures) the greatest yield was obtained. The productions are lower at maize yield in opposition to the classic soil tillage systems with significant differences, in all variants worked by the minimum tillage system. The soya-bean culture reacts surprisingly well when the minimum tillage systems are applied, the productions obtained being even greater, with disting positive significance when working with paraplow + rotary harrow and rotary harrow –2x. The winter-wheat culture, the productions obtained at the minimum tillage systems are without statistic differences, except when using chisel + rotary harrow, case in which the production differences are significantly negative.

One thing that weeds to be mentioned is that when applying the minimum tillage systems of working the land the results are both in immediate effects, satisfactory productions and also the preserving and the increasing of soil fertility which has profitable effects in time. The applying of any variant can be taken into consideration, regarding culture, climate conditions, available agricultural equipment and the measures of protecting the plants (especially the weed control).

The influence of soil tillage system upon efficiency and gasoline consuming. The necessary power quantified for accomplishing the basic tillage and the preparation of seeds layer is different for each soil tillage system. In what concerns the classic plough and disc-2x for the preparation of seeds layer is of 30.9-41.8% energy input reduction and disc + rotary harrow, rotary harrow-2x and of 23.6-27.3%, to paraplow + rotary harrow and chisel + rotary harrow (table 2).

The power balance shows us that the decreasing of energy input with soil tillage with conservative purpose, does not diminish the efficiency of energy used. When the variants with minimum tillage are used, the indicator shows us that the best values for maize yield when the paraplow + rotary harrow are used and chisel + rotary harrow, for winter-wheat when worked with the disc + rotary harrow, and all variants for the soya-bean culture.

The efficiency of the energy utilization shows, us firstly, that starting from a power consuming on a total culture, in general, alt all 3 cultures of 22000-24000 MJ/ha, the energy resulted at 1 MJ/ha invested is almost double at maize, apposed to soya-bean and winter-wheat. Starting from the fact that in all variants worked by the minimum tillage system the productions were smaller at maize culture, as apposed to the variants where the plough is applied; we can safely say that when - by the yield potential - the best results on this type of soil are acquired by the intensely processed mobilization. We can notice that the efficiency of the energy utilization is practically very close or even equal at maize, and equal or even greater at winter-wheat and soya-bean when related to the classic plough + disc.

Table 2

The influence of soil tillage system in a haplic luvisol upon the efficiency of the energy utilization at maize, winter-wheat and soya-bean

Variant / Characteristic		Plough + disc –2x	Plough + rotary harrow	Disc + rotary harrow	Rotary harrow –2x	Paraplow + rotary harrow	Chisel + rotary harrow
Soil tillage	MJ/ha	1956.9	1672.26	1138.56	1352.04	1494.36	1423.2
	%	100	85.4	58.2	69.1	76.4	72.7
Power balance efficiency, %	M	100.0	102.0	99.3	99.5	100.3	100.2
	S	100.0	103.7	101.6	102.5	102.9	101.1
	W	100.0	101.6	100.5	99.9	99.7	99.0
Energy utilization, MJ	M	9.54	11.54	9.01	9.17	9.83	9.76
	S	5.23	6.02	5.69	5.53	5.50	5.32
	W	5.56	6.21	5.63	5.88	5.97	5.51

M - maize, S - Soya-bean, W - winter-wheat

The gasoline consuming. It is known the fact that on of the technological operations with the highest rate of gasoline consuming is classical ploughing with the use of which the soil is turned. This that the soils are of medium smoath or smoath texture and the processed is done deeper. Its replacement, at least partial, is a solution to decrease the fuel consumption especially if the productions are not significantly reduced. The replacement of ploughing and the preparation of germinal layer by disc-2x with tillage paraplow + rotary harrow or chisel + rotary harrow accomplisher an economy of fuel of 12.4-15.2 l/ha, and in the case of processing only with the help of the disc + rotary harrow or rotary harrow-2x the decrease is of 19.3-25.3 l/ha.

The evolution of agrophysical properties on haplic luvisol depending on the soil tillage system. The effect of soil tillage systems' action over the structure provokes a special theoretical and practical interest. Hydro stability of structural aggregates (H.S.) determined at every yield show firstly for the minimum tillage systems a growth in stability in the soil's surface towards its depth. At the end of the 3 rd year of tests the results acquired set the stability rate in a variation domains of 62.4-74.5% hydro stabile macro-aggregates. As opposed to the witness classic plough + disc-2x variation of the stability rate was higher within the minimum systems: 1.6-5.6%, on 0-10 cm depth, 1.1-7.5% on 10-20 cm depth and 5-11% on 20-30 cm depth (Table 3).

The state of physical settlement of the soil expressed through the apparent density (A.D.) calculated annually as an average of the determinations on phenophase shows that in all years of experimenting a better mellow on the 0-20 cm depth at variants were the plough is used (A.D. = 1.0 – 1.38 g/cm^3). Beneath the depth of 20 cm the soil remains slightly ram with medium values (A.D. = 1.4 – 1.45 g/cm^3). Thus it is shown stratification on the soil's profile from the point of view of settlement state, through the existence of a layer that can be ploughed (trough the energetic tillage). The tillage without turning off the soil with paraplow and chisel respectively leads to a apparent density value raising and slightly decreasing in underploughing level. But the values remain on a variation domain slightly mellow-ram, and respectively medium-low on the layers of haplic luvisol one can practically differentiate the following (table 4): 0-10 cm depth, there are no differences as opposed to the ploughing variation, the soil being slightly mellow with low values for this type of soil (texture) under

1.31 g/cm^3 at A.D.; 10-20 cm depth, the soil remains more ram in comparison to the variant where it was ploughed (A.D. in general 1.33-1.36 g/cm^3); 20-30 cm depth the soil is slightly ram and much more in the ploughing variant (A.D. = 1.4 – 1.45 g/cm^3) and more reduced for chisel and paraplow (A.D. = 1.35 – 1.41 g/cm^3) thus being much more closer to the specific values of this type of soil, for this depth; 30-40 cm depth and respectively 40-50 cm there are no differences between variants, the values determined being in general medium among and tendency to improve.

Table 3

The evolution of stability rate (H.S.,%) on a haplic luvisol depending on the soil tillage system

Rotation	Soil tillage system						
	Depth cm	Plough + disc-2x	Plough + rotary harrow	Disc + rotary harrow	Rotary harrow - 2 x	Paraplow + rotary harrow	Chisel + rotary harrow
Maize	0-10	58.2	59.1	58.7	59.4	59.6	59.0
	10-20	60.2	65.0	61.5	69.2	69.0	69.5
	20-30	61.6	64.2	62.4	68.5	69.4	69.6
Soya-bean	0-10	63.8	64.1	65.3	66.8	67.4	67.4
	10-20	64.4	65.3	68.2	70.4	70.6	70.6
	20-30	65.5	66.4	70.4	73.5	71.5	72.4
Winter-wheat	0-10	62.4	63.0	64.5	68.0	67.5	64.0
	10-20	66.0	66.8	67.2	73.5	68.0	67.1
	20-30	63.5	70.0	71.5	74.5	69.2	68.5

Our tests confirm that the haplic luvisol has the tendency to return to its initial setting state that is specific to be stable of relatively balance with the environment, a state given by the relation: pedogenetic factors – environment – properties and soil characteristics if the degrading factor is discarded and the phenomenon does not exceed bearable limits.

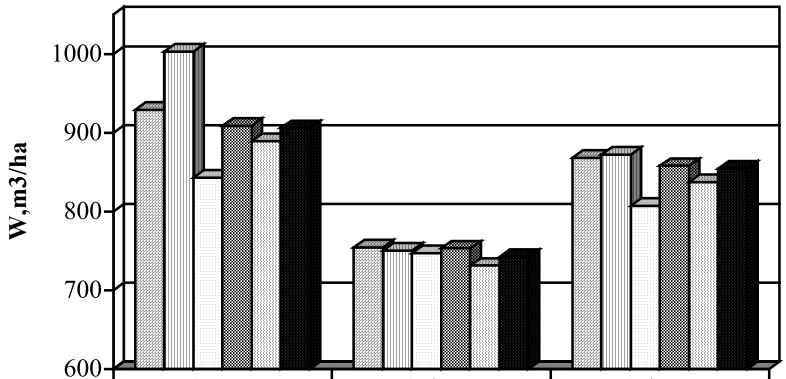
The annual soil tillage system with disc and rotary harrow without further deep mellows leads to registering some A.D. values practically equal to the other values of other variants on 0-10 cm depth. Beneath this depth, 10-20 cm for these variants, we have the highest values of apparent density: A.D. = 1.38 – 1.4 g/cm^3.

Table 4

The evolution of apparent density (A.D., g/cm^3) on haplic luvisol depending on soil tillage

Rotation	Soil tillage system						
	Depth -cm-	Plough + disc-2x	Plough+ rotary harrow	Disc + rotary harrow	Rotary harrow - 2 x	Paraplow + rotary harrow	Chisel + rotary harrow
Maize	0-10	1.30	1.14	1.30	1.24	1.22	1.27
	10-20	1.38	1.21	1.38	1.40	1.36	1.34
	20-30	1.45	1.41	1.39	1.39	1.41	1.41
	30-40	1.45	1.38	1.40	1.38	1.41	1.41
	40-50	1.47	1.47	1.46	1.45	1.46	1.46
Soya-bean	0-10	1.17	1.00	1.18	1.10	1.11	1.12
	10-20	1.27	1.18	1.33	1.35	1.26	1.32
	20-30	1.40	1.40	1.39	1.38	1.36	1.35
	30-40	1.40	1.40	1.40	1.39	1.39	1.39
	40-50	1.47	1.47	1.46	1.46	1.46	1.46
Winter wheat	0-10	1.20	1.13	1.11	1.08	1.18	1.18
	10-20	1.26	1.23	1.38	1.36	1.35	1.33
	20-30	1.40	1.40	1.42	1.40	1.39	1.39
	30-40	1.41	1.40	1.41	1.40	1.39	1.41
	40-50	1.43	1.43	1.45	1.44	1.44	1.44

The water supply (W, m^3/ha) of the soil calculated annually and a 0-50 cm depth as an average of the phenophase determinations is greater in the ploughing variants in all years of experimenting. As opposed to the witness variant – classic plough + disc-2x the value are more reduced for the minimum tillage variants with 20-86 m^3 /ha for maize, with 23 m^3 /ha for soya-bean, with 10-61 m^3 /ha for winter-wheat (figure 1).
After three years of applying the same soil tillage system, one can notice with the help of determinations that the soil's capacity to retain water is better when working with rotary harrow-2x and chisel + rotary harrow variant, the values being 5.54 and respectively 5.08 l/m^2/min. For witness classic plough + disc-2x the water quantity tickled in was of 4.25 l/m^2/min. The lowest amount was registered for rotary harrow – 2x variant with 3.21 l/m^2/min.



	1st year	2nd year	3rd year
plough+2disc	929	754	868
plough+r.harrow	1003	750	872
disc+r.harrow	843	747	807
rotary harrow-2x	909	753	858
paraplow+r.harrow	889	731	837
chisel+r.harrow	906	742	854

Figure 1. The water suppy of the haplic luvisol, and a 0-50 cm depth, depending on soil tillage sistem

The evolution of agrochemical properties on haplic luvisol depending on the soil tillage system. The soil's content of humus depending on the variant used of tillage has at the end of three years of experimenting limits that very between 2.28-3.29% and the depth 0-20 cm with obvious tendency to grow if the minimum system with paraplow + rotary harrow and chisel + rotary harrow is used (table 5). The increasing of organic matter and even of humus is due to the vegetal remainders partially incorporated and to an adequate biological activity.
The soil's content of phosphorus and mobile potassium change significantly under the influence of soil tillage system in the way that the administered fertilizers are located at different depots. Thus working with disc harrow or rotary harrow locates large quantities of mobile phosphorus in the first 10 cm of tillage soil. The paraplow and chisel do the exact same thing but we have to mention that phosphorus reaches 10-20 cm deep in practically equal quantities with the classic tillage system that involves ploughing. The intensity of aeration and the thickness of plants motivate the lower contents of mobile phosphorus in the variant where the classic ploughing is used.

The soil's reaction and the rate of saturation in bases, remain practically unchanged regardless of the way in which the soil was tillage except for the variants where the paraplow and chisel were used and pH (H_2O) tendencies is to drop and the soil to acidify as a result of hydrogen status growing and base status dropping.

Table 5

The influence of soil tillage system upon certain agrochemical properties of haplic luvisol

Soil tillage system	Depth, cm	$pH_{(H2O)}$	Humus %	N total %	P mobil ppm	K mobil ppm	V %
Plough+ disc-2x	0-10	6.06	2.55	0.220	12	155	79
	10-20	6.08	2.28	0.217	15	134	80
	20-30	6.30	2.70	0.242	4	117	83
Disc+ rotary harrow	0-10	5.90	2.72	0.195	34	211	78
	10-20	5.79	2.68	0.217	12	122	79
	20-30	6.13	2.11	0.200	7	125	84
Rotary harrow -2x	0-10	5.81	2.70	0.226	33	196	79
	10-20	6.03	2.59	0.241	9	131	80
	20-30	5.95	2.32	0.235	3	125	79
Paraplow + rotary harrow	0-10	5.62	3.00	0.252	25	158	74
	10-20	5.72	3.06	0.239	10	117	74
	20-30	5.80	2.53	0.224	8	128	75
Chisel+ rotary harrow	0-10	5.77	3.29	0.280	27	207	75
	10-20	5.73	3.16	0.263	12	151	73
	20-30	5.80	2.62	0.240	7	122	79

Conclusions

The soil tillage system influences the productivity elements that derive from the different thickness of plants and the influence of weed upon the vegetation factors, mostly upon water and nourishing substances.
By applying the unconventional soil tillage systems one can obtain productions comparable to the classical variant with ploaghing as for the maize, soya-bean and winter-wheat yield. The productions are equal or even greater for the minimum soil tillage system in the case of soya-bean crop and for the disc + rotary harrow, rotary harrow-2x and paraplow + rotary harrow variants for the winter-wheat crop.
The fuel consumption is reduced to 12.4-25.3 liters of gasoline / ha by applying the minimum soil tillage systems of haplic luvisol and also by reducing the power input to 23.6-42.8%. The power efficiency is greater in the case of minimum soil tillage variants when the production differences are not significaly negative as apposed to classical soil tillage systems.
The use of minimum soil tillage systems within a three years rotation: maize, soya-bean, wheat favorites the rise of the aggregates hydro stability with 5.6-7.5% on a 0-20 cm depth and 5-11% on 20-30 cm depth.
Under the influence of tillage system the main thing that is modified is the accumulation of phosphorus and potassium in the soil. Tillage with disc harrow or rotary harrow locates large quantities of phosphorus in the first 10 cm beneath the soil. The paraplow and the chisel do the same thing but we have to mention the phosphorus can go beneath 10-20 cm deep.
The soil's reaction and the saturation rate of base status remain practically unchanged, no matter how the soil was tillage. What is registered is the soil reaction in water (pH) tendency to drop and a slight acidify of the soil for the paraplow and chisel variants.
The water supply accumulated in the soil correlates with the tillage system and is maximum for the ploughing variant. The speed at which the water infiltrates in the superior side of the soil's profile is maximum for the paraplow and chisel tillage variants.

CONTENT

The advantages of unconventional soil tillage systems can be turned into account as improving methods in weak productive soils with reduced structure stability on slope fields and as measures of preserving the soils on the rest of the surfaces.

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CONTINUOUS SOIL DRAFT MEASUREMENT – NEW DEVELOPMENTS

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Abstract

It is well known that the high tillage force values influence plant yield notably. Thus, tillage force mapping can be an effective tool for site-specific management. To receive proper amount of data we need to measure with an on-line method. According to earlier developments that were carried out in our institute the authors are presenting new results. The main differences between two investigations are in materials and methods.The system is based on the electro-hydraulic system (EHS) of a Steyer 9078/A tractor. Load cells are installed in the EHS, which provide electric signals with the forces affecting the hydraulic system. The induced voltages from the load cells using an RS232-ADC module were fed to the DellAxim x50v PDA throughout Quatech DSCF-100 two port RS232 serial Compact Flash Card. A software developed by the institute records and displays the digitized summarized signals of the load cells and writes to the main memory of the PDA together with the position (GPS) information in *.txt format. This file format is available for every GIS software for later processes. This new innovation makes the earlier development more accurate and provides the system to use in practical field-works. In addition all the accessories are simple and available at relatively low cost rate. Using today's technical development state makes the whole process user friendly.

Keywords: tillage force, soil strength, site specific tillage, continuous measurements

Introduction

The aim of the sustainable development is to preserve the land, water, plant and animal genetic variability, which is technically implementing, economically viable and socially acceptable. Sustainability from soil tillage viewpoint can evolve towards great efficiency of resource use, can develop and maintain a harmony between crop production technologies and soil environment (Birkás et al., 2007). To reach these goals we need to know the soil – as one of the main renewable energy resource (Várallyay, 2007) – detailed parameters. In our days, within precision agriculture the *precision tillage* plays much bigger role than ever. To decrease the high energy requirements of the loosening as well as to increase the estimated yield we have to know the in-filed conditions accurately. The cone penetrometer is a widely used practical tool to provide information about the soil strength. The soil strength estimates in kPa, often referred to as cone index C_i is a composite soil parameter, strongly influenced by soil type, soil structural state and soil water content. The cone penetration resistance has often been used to predict the draught requirement of soil tillage implements (Desboilles et al., 1999). According to Neményi et al. (2006) the biggest problem of a vertical penetrometer is that the measured values are available only from the measured point, and areas among these points are described with calculated data, the penetrometer records vertical resistance, however dynamical forces are affecting the tillage tool, just as the measurements require many hand work and provide only few spatial information. Adamchuck et al. (2004) lists several on-to go soil sensors for precision agriculture. These sensors give valuable information about soil differences and similarities, which make it possible to divide the field into relatively homogeneous management zones. Godwin (2006) enlists the major effects, which are getting on implement geometry on soil failure and implement forces. Specific draught can be identified with the following expression: $S = \frac{D}{4wd}[kPa]$ where *D*- is the draught force [kN], *w*- working with [mm], *d*- working depth [mm] (Watts et al., 2006). One of the main aims of a good farm management is to prepare the soil for planting in the shortest possible speed (Onwualu et al., 1998). According to their statement the relationship between tillage force and speed must be known. Therefore, knowing tractors speed is a key factor in precision tillage management. Velocity measurements are important to convert the specific draught data to a standard velocity in order to compare data sets from different years or from different fields (Bergejik et al., 2001). The result of Wheeler et al. (1996) investigation confirms that the inertial forces are insignificant at speeds less than $\sqrt{5gw}$ (4.36 km h^{-1}). Modifying this expression to accommodate the effect of soil failure on the sides of narrow tines to $\sqrt{5g(w+0.6d)}$ produces a critical speed of 10.7 km h^{-1} for 30 mm wide and 250 mm deep tines. At this speed the average horizontal force increased by 19% and 14% in frictional and cohesive soils respectively. Al-Jahil et al. (2001) and Kheiralla et al. (2003) are presenting results, measured by a three-point hitch dynamometer. Their development can measure the horizontal and vertical forces affecting the tillage tool. Despite of all no position recording is mentioned, the recorded data can not be used to determine the spatial heterogeneity. Sirjabos et al. (2002) presents a dynamometer with a whole measurement chain. With his tool he can record a site-specific data what is a promising perspective for an on-line characterization of a soil physical state. This new information for precision agriculture may be used for the real time regulation of soil tillage or sowing functional parameters according to the site specific soil physical state. Accurate tillage depth measurement is also an essential parameter for site-specific draught calculations. Mouazen et al. (2005) also highlights on an importance of depth control system. It is a useful parameter for controlling the depth of the tillage tool during online measurement of soil compaction indicated a dry bulk density. However, Mouazen et al. (2006) concluded that there is no clear correlation between soil properties and measured draught, and therefore the field measurement is not the best procedure to correlate draught with the other influencing parameters (depth, water content, bulk density) and theoretical modeling is still an alternative option, Neményi et al. (2006) and Whalley et al. (2008) founded a significant impact between high tillage force and yield. In Desboilles et al. (1999) study we can find a comparison between C*i* vs. soil strength factor (*S*), where is no specific correlation and between *Pe* (the area enclosed under the curve of the C*i* versus depth relationship down to the depth of work) and *S*, where is definitely a tight connection. After the listing of the scientific references it is still an outstanding question, how to solve the on-line soil draft measurement for practical use, because no acceptable solution exits, however soil draft is one of the key parameter for site specific soil tillage. The aim of this study was to evaluate the soil strength continuously in a modern, cost effective way, that can be used easily in everyday practice.

Materials and methods

The system is based on the electro-hydraulic system (EHS) of a Steyer 9078/A tractor. Load cells are installed in the EHS, which provide electric signals with the ratio of the force affecting the hydraulic system. The hydraulic system was loaded with different forces exerted by a hydraulic lever. For reference values we used a max. 10 kN chargeable load cell, combined with an Almemo universal measuring unit. The induced voltages from the load cells were fed to the DellAxim x50v PDA (Personal Digital Assistant) using an RS232-ADC module throughout a Quatech DSCF-100 two port RS232 serial Compact Flash Card. Software developed at the institute – with a simple programming environment Zeus - records and displays the digitized summarized signals of the load cells and writes to the main memory of the PDA together with the position (GPS) information – recorded by CSI Wireless DGPS Max - in *.txt format. This file format is available for every GIS software for later processes, so the results can be displayed spatially. The working speed is obtained from a GPRMC - recommended minimum specific GPS/Transit data - line of the NMEA sentence information:

*$GPRMC,101337.00,A,4753.48819,N,01716.29480,E,**0.17**,335.72,131207,,,A*56*

The highlighted and underlined number is the speed in knots. The conversion is: 1 knot = 0.5144 m sec^{-1}. Above all our on-field investigations were carried out at a relatively low speed (e.g. 3.5 km h^{-1}). To set up the appropriate working depth we calibrated the hydraulic controlling switch of the tractor (Table 1.) and we used it in switch pos. **5** during the measurement.

Table 1.: Calibration of the hydraulic control switch

switch position	depth [cm]	depth [cm]	depth [cm]	depth [cm]	depth [cm]	mean depth
	up	up	down	up	down	
0	29.0	30.0	30.0	29.0	29.0	29
1	9.0	14.0	14.0	8.5	12.5	12
2	-5.5	-2.5	2.5	-6.0	-3.0	-3
3	-16.0	-16.0	-13.5	-16.5	-14.0	-15
4	-28.5	-27.0	-25.0	-29.0	-29.5	-28
5	-40.0	-41.0	-37.0	-39.5	-37.0	-39
6	-49.5	-	-48.0	-50.0	-50.5	-50
7	-59.5	-59.0	-59.0	-59.5	-59.5	-59

In order to moderate or even eliminate the fluctuation which may be caused by the not perfectly constant working depth and the direction of load 3 sec alleviation was applied (with a condenser built in to the controlling panel). For the post process of the measured data we used Microsoft Excel 2003 (Microsoft Corp.) and Arc View 9.1 to demonstrate the spatial distribution.

Results and discussion

Fig. 1. represents the correlation between the draft force and the EHS voltage change. The high R^2 values shows that there is a strong connection between the listed parameters, so we can declare that the draft force can be determined continuously with the voltage change of EHS. Using the PDA with in-house software (Fig. 2.) we can easily display the actual draft force with the coordinates and we are also able to record them. These raw data after a post process are capable to provide valuable site-specific information for precision agricultural management (Fig. 3.).

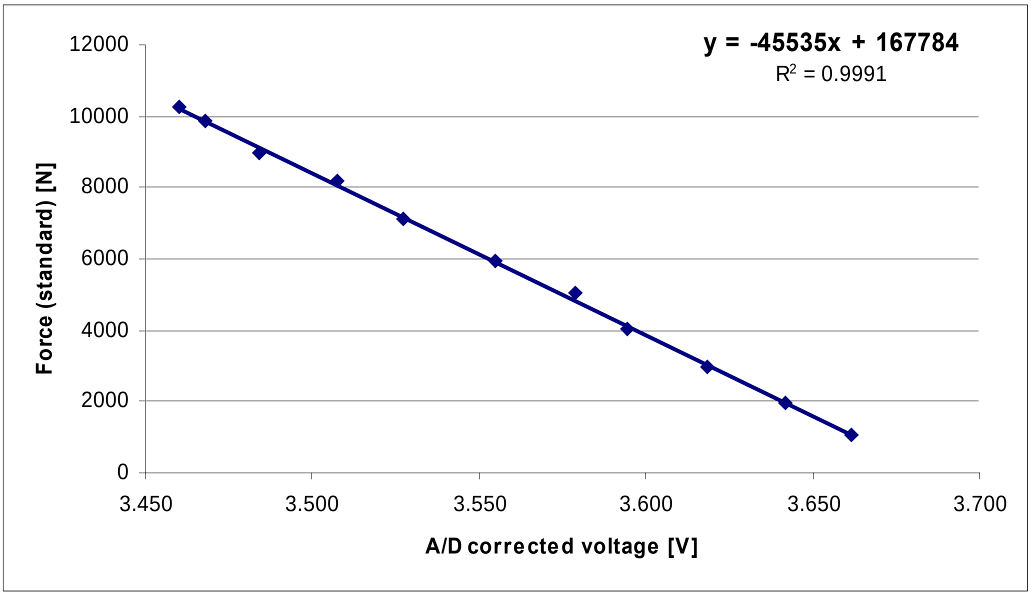

Figure 1. The combined signals of the load cells corresponding to different loads

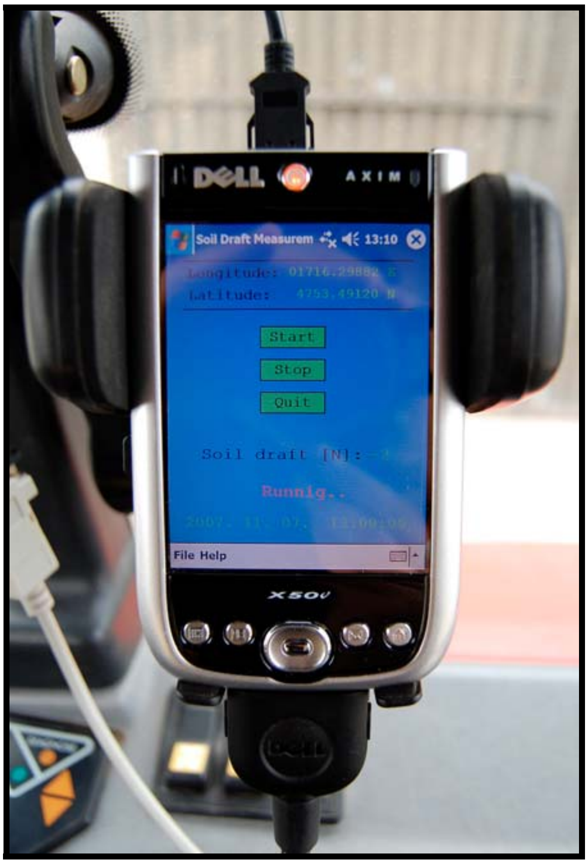

Figure 2. The in-house software is running on the PDA

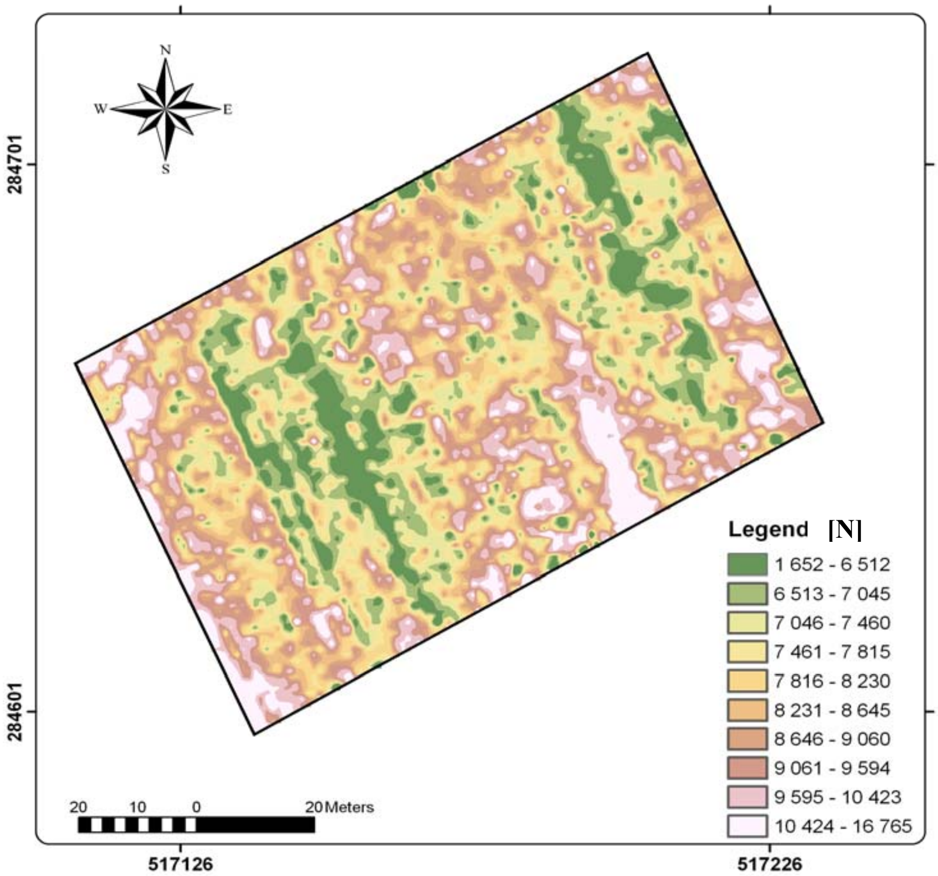

Figure 3. Tillage force map of the experimental field

Conclusions

Based on the presented results, we can declare that the load cells provide electric signals with the ratio of the forces affecting the hydraulic system, which we can convert to on-line force using above mentioned system. The recorded spatial data are easily attachable to GIS systems, so we can map and compare to other parameters e.g. yield to increase the efficiency of our production. This new innovation makes the earlier development more accurate (with the similar efficiency) and provides the system to use in practical field-works. In addition to all the accessories are simple and available at relatively low cost rate. Using today's technical development state makes the whole process user friendly.

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CONTENT

PAPERS OF THE SECTION II

THE CHANGE OF SOIL PHYSICAL PROPERTIES DUE TO MECHANICAL, BIOLOGICAL AND BIOCHEMICAL FACTORS

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Introduction

The main factors influencing the destructive change of the soil physical properties:

1. Destruction of soil structure is related in a broad sense to soil degradation. Desaggregation in A horizon is caused mainly by the combination of mechanical action of agricultural machinery and by the decrease of C org. especial by the decrease of components of stabile soil humus (e.g. humic acids) after tens of years of intensive agricultural use of soils. The desaggregation in deeper horizons is related partly to the degradation of the whole soil profile, partly it is the result of the use of heavy machinery.
2. Soil compaction is the result of the weight and dynamic action of agricultural machinery and tillage operations. The compaction may be limited just to the surface horizon, but after a long term use of heavy machinery it may reach up to the depth of 60 or 70 cm. This deep layers compaction is not simply ameliorated, in some instances the compaction is nearly irrreversible.
3. The substantial change of the chemical composition of the soil solution may cause a change of the ζ potential. The fine soil particles are peptized, the soil aggregation is not possible and the soil hydraulic conductivity is then substantially reduced, as it was shown in Lecture Notes on Saturated and Unsaturated Flow. The change of the soil solution is either due to deposition of wastes or due to the inappropriate irrigational practices in arid zones.

I am using the following tools for characterizing soil physical properties and the soil porous system (SPS) dominantly influencing them:

(i) Empirical soil water retention curve SWRC *S(h)*, or $\theta(h)$ and its derivative curve with $r = a/h$ as the empirical estimate of the pore size distribution.

(ii) The minimum minimorum on the derivative curve to empirical soil water retention curve h_A separates the matrix (indexed by 1) from the structural domain (indexed by 2).

(iii) Model of lognormal pore size distribution *g(r)*

$$g(r) = \frac{\theta_S - \theta_R}{\sigma r\sqrt{2\pi}} \exp\left\{ -\frac{[\ln(r/r_m)]^2}{2\sigma^2} \right\} \tag{1}$$

(iv) SWRC of bi-modal soils with pore size distribution modeled by (1)

$$S_i = \frac{1}{2} erfc\left[\frac{\ln(h_i / h_{mi})}{\sigma_i\sqrt{2}} \right] \tag{2}$$

$$S_i = \frac{\theta_i - \theta_{Ri}}{\theta_{Si} - \theta_{Ri}} \tag{3}$$

and $\theta = \theta_1, \theta_2$ when $i = 1$ is for matrix pores and $i = 2$ for structural pores.

(v) Unsaturated hydraulic conductivity function of bi-modal soils with pore size distribution modeled by (1)

$$K_{R_i} = S_i^{\alpha_i} \left\{ \frac{1}{2} erfc \left[(\ln \frac{h_i}{h_{mi}}) \frac{1}{\sigma_i \sqrt{2}} + \frac{\beta_i \sigma_i}{\sqrt{2}} \right] \right\}^{\gamma_i} \tag{4}$$

$K_R = K/K_S$ and when $i = 1$ is for matrix pores and $i = 2$ for structural pores. And $K = K_1 + K_2$.

K_S is saturated hydraulic conductivity and h is the pressure head (potential), θ is the volumetric soil water content, r is the pore radius, r_m is the geometric mean radius, σ is the standard deviation, θ_R is the residual soil water content when the liquid flow is essentially zero, θ_S is the soil water content at saturation, i.e. at $h = 0$, S is the relative saturation, or parametric soil water content [dimensionless], h_m is the pressure head related to r_m, and *erfc* is the complementary error function. Parameters α, β, γ in (4) are assumable tortuosity and pore connectivity characteristics in Childs-Fatt-Burdin-Mualem equation

$$K_R = S^{\alpha} \left[\frac{\int_0^r r^{\beta} g(r) dr}{\int_0^{\infty} r^{\beta} g(r) dr} \right]^{\gamma} \tag{5}$$

1. THE ROLE OF SOIL STRUCTURE

The role of soil structure was studied on Gleyic Hapludalf loamy soil developed on fluvial loess deposits. The measurements were performed on two locations at a depth of 15 cm in the Ap-horizon. One was with a moderately developed structure, denoted by S15 and the other one was on a compacted path by the wheel track with distinctly destroyed structure, denoted by D15. At the first location, the measurements were also performed in the B-horizon at the depth 60 cm (S60).

The retention curve for each of the soil horizon was plotted and the derivative curve to the retention curve was used in order to separate the two domains of matrix (indexed by 1) and of structural pores (indexed by 2), Fig. 1. At the minimum of the derivative curve, the value h_A was estimated. It separates the two domains. Physically, it is the air entry value of the matrix domain. For each domain a separate retention curve was reconstructed. Fig. 2. Parameters of Eq. (2) and (3) were obtained by a fitting procedure to the measured data. They are together with h_A in the Table 1, where SPS1 denotes matrix pores, SPS2 the structural pores.

Table 1. Physical parameters of the soil water retention curves

Soil	SPS	h_m	σ	θ_S	θ_R	h_A
S15	1	2460	1.5	0.318	0	60
	2	9.8	1.1	0.147	0	
S60	1	1000	1.52	0.35	0	30
	2	13.8	0.84	0.079	0	
D15	Mono	1450	2.03	0.405	0.08	0

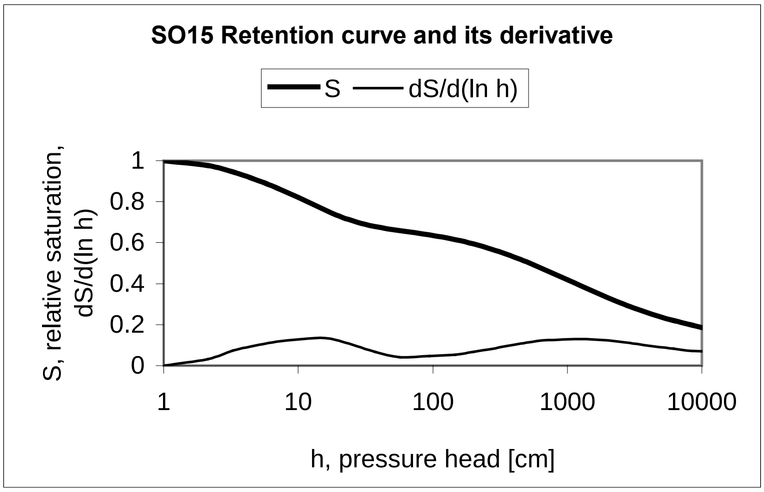

Fig.1. Soil water retention curve *S(h)* of a well aggregated soil. Structural domain of pores is on the left side from the minimum of the derivative curve $h_A = 60$ cm, and the matrix domain of pores is on the right side of h_A.

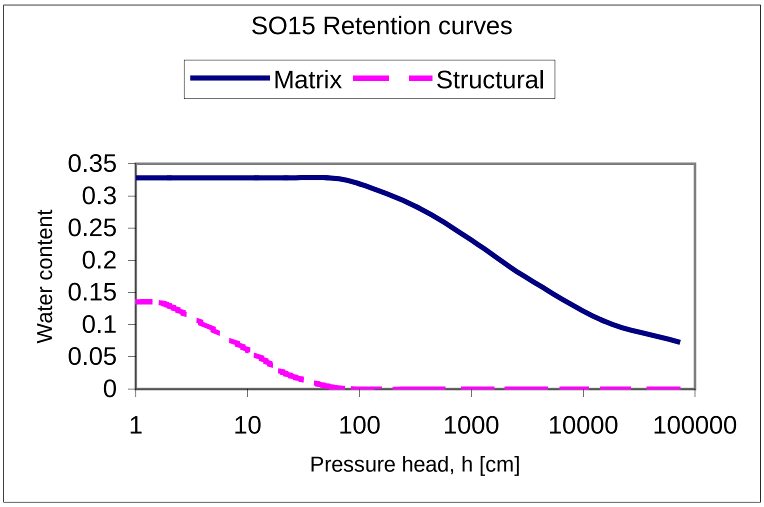

Fig. 2. Separation of two domains of soil water retention cur-ves (SWRC): Matrix SWRC and structu-ral SWRC in a well aggregated soil.

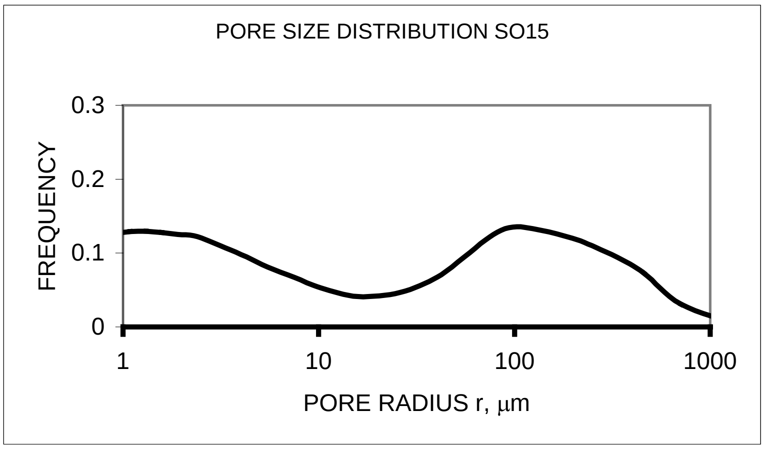

Fig.3. Pore size distribution in a well aggregated soil, derived from Fig. 1.. The separation of the two domains is at the pore radius $r = 40$ µm.

If the structure is destroyed, the bi-modal system approaches the monomodal system and in this studied case, $h_A = 0$ and the structural domain disappeared totally, see Fig. 4 and Table 1. The absence of the structural domain reduces the saturated as well as unsaturated hydraulic conductivity, when the values are compared to the original well aggregated soil, see the Figs. 5 and 6.

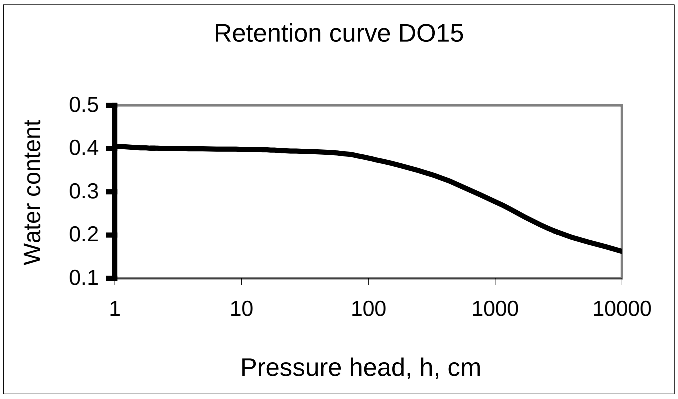

Fig. 4.Retention curve of the same soil as SO15, but the aggregates were mechanically destroyed. There is no indi-cation of a separation of two domains. The structural do-main is absent due to the loss of structure.

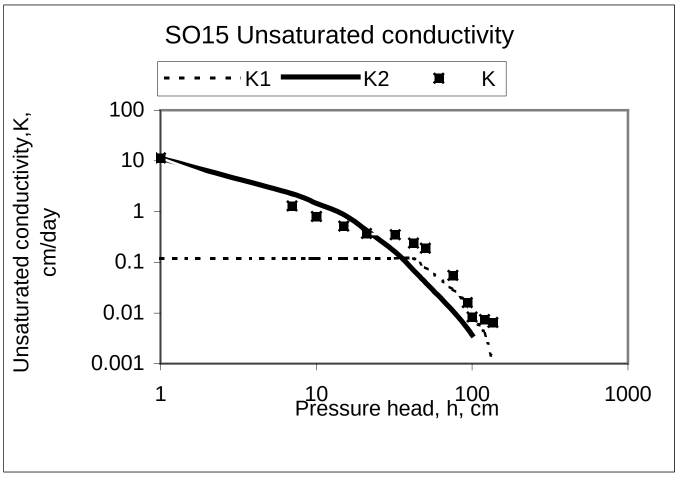

Fig. 5. The measured ■ unsa-turated hydraulic conductivity of the well aggregated soil was transformed into conductivities of the structural domain and matrix domain by eq.(4). Preferential flow is realized in the structural domain and the structural conductivity function is indispensable for the solution of the preferential flow.

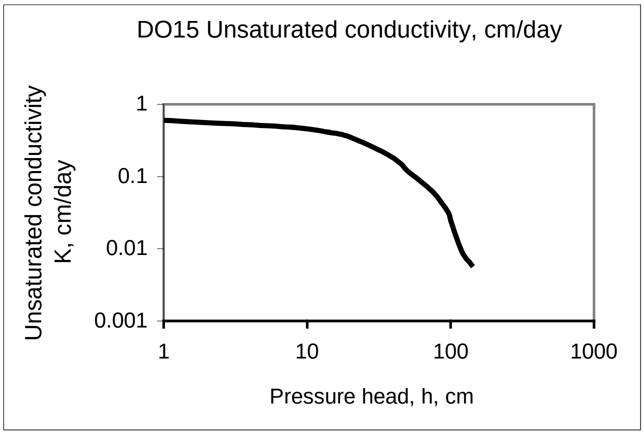

Fig. 6. Unsaturated condutivity of the same soil as SO15, but the aggregates were mecha-nically destroyed. Conductivity is by about one and half order of magnitude smaller than in aggregated soil in the wet domain, since the structural domain is absent.

Similar results were obtained when the Corg content decreased substantially by intensive long term agricultural use under classical tillage. As the resulting aggregate stability was very poor, the SWRC was similar to that one in Fig. 4 and the pore size distribution lost its bi-modal pattern. The *K(h)* function ressambled the curve of *K(h)* in matrix domain.

2. THE CHANGE OF THE SOIL POROUS SYSTEM DUE TO COMPACTION

Undisturbed soil samples (100 cm^3) were taken from the A or Ap horizon in five locations of Greece with Mediterranean climate (Panayiotopoulos et al., 2003). In order to demonstarte the role of aggregation and precompression, two soils will be demonstrated in details, see Figs 7 and 8.

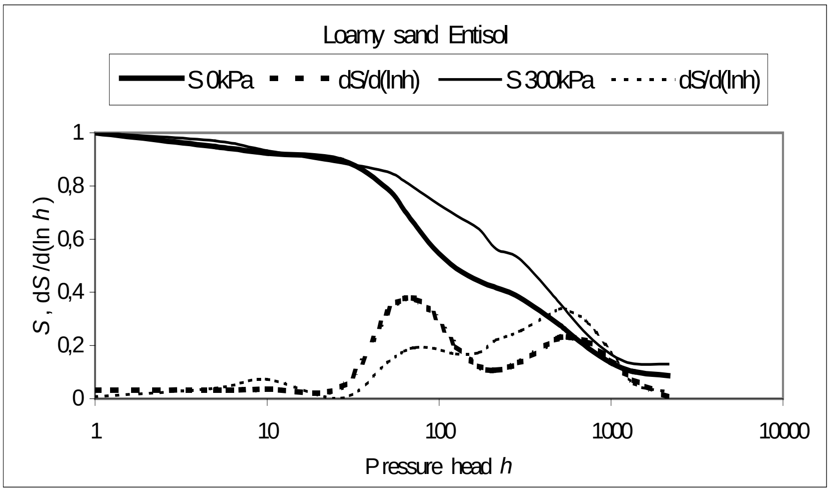

Fig. 7. Retention curves and their derivative curves for poorly aggregated Entisol without compression (0 kP) and after compression by 300 kPa.

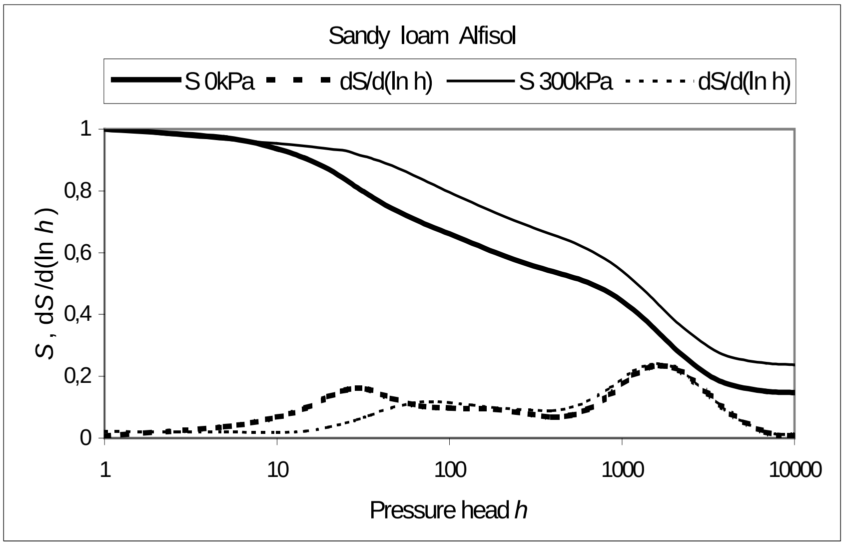

Fig. 8. Retention curves and their derivative curves for well aggre-gated Alfisol without compre-ssion (0 kP) and after compressi-on by 300 kPa.

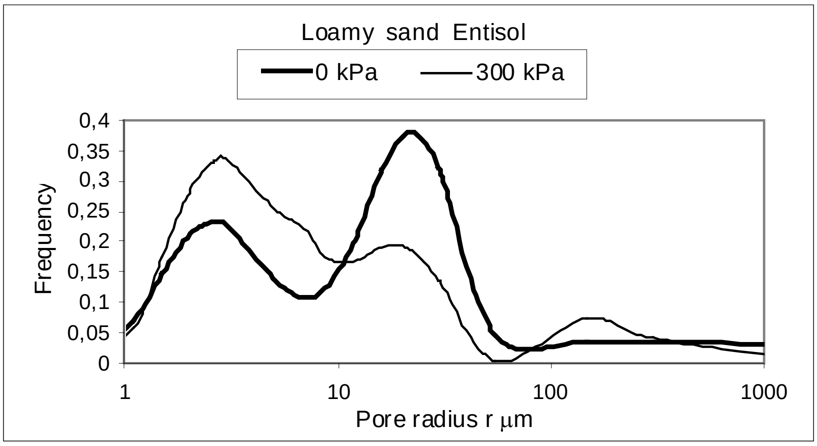

Fig. 9. Pore size distribution in poorly aggrega-ted soil due to compression, estimated from Fig.7. The volu-me of structural pores was sub-stantially redu-ced due to the compression, while the matrix pores volume increased.

Soil water retention curves are significantly changed due to compression in soils of low aggregate stability. The change is substantially smaller in soils of high aggregate stability.

The value of pressure head h_A separating the structural pores from the matrix pores is in very broad ranges for various soil taxons and the applied compression. The boundary between soil pore categories can not be taken as a fixed value for all soils and all types of soil use.
The parameters of the pore size distribution in structural and matrix domains do not react in the same direction of increase or decrease due to the compression when individual soils are compared. The pore size distribution is changed substantially in structural as well in matrix domains of soils characterized by low aggregate stability. The change in the structural domain is relatively small in soils with well developed structure and high aggregate stability, while the change is more expressed in the matrix domain.

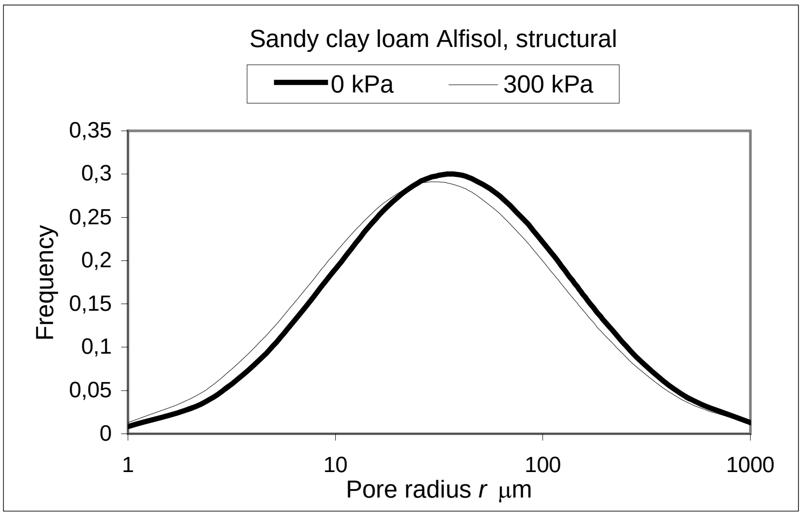

Fig. 10. Pore size distribution in the structural domain of a well aggrega-ted soil before and after the compre-ssion. The compre-ssion influences only slightly the pore size distri-bution.

The change of pore size distribution influences the saturated K_S as well as unsaturated conductivity *K(h)*. The stability of soil structure plays an important role, see the change due to compression in Figs 11 and 12. *K(h)* was computed for SWRC directly measured. Both figures were computed for the poorly aggregated soil in order to demonstrate a strong influence of compression upon *K* unsaturated mainly in the originally structural domain, i.e. for soil water content roughly between saturation and fielkd capacity. In this range the change of *K* is extreme due to compression. On the other hand side, the well aggregated soil does not show such an extreme reduction of unsaturated conductivity in the range near the saturation.

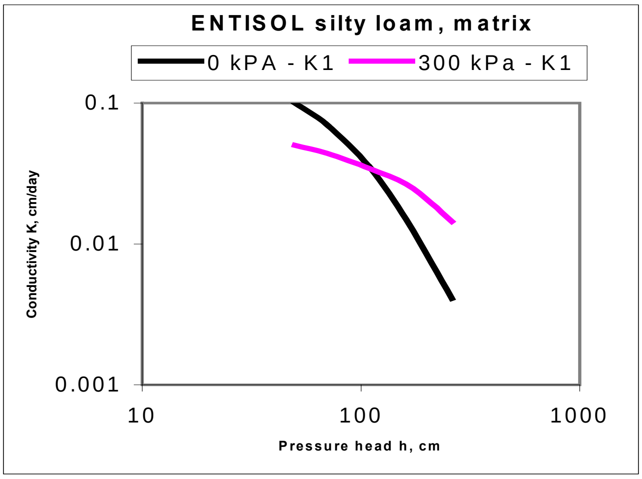

Fig 11. Unsaturated hydraulic conductivity *K* in matrix domain is not significantly influenced by compression and for water content related approximately to field capacity and to a lower water content *K* is even higher due to compression.

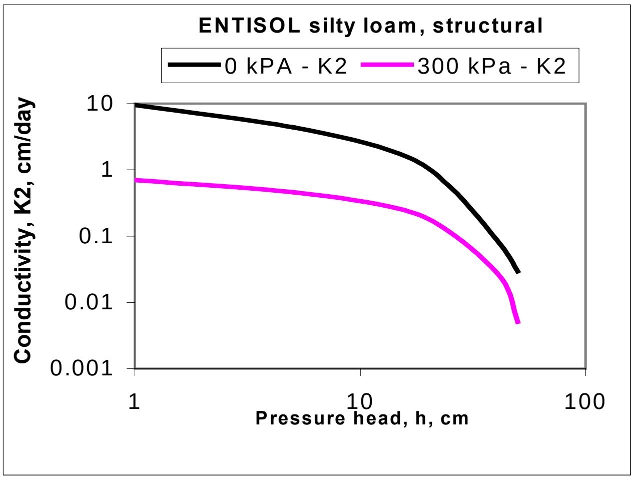

Fig. 12. Unsaturated conductivity of the structural domain of a soil of poor aggregation is by about one order of magnitude lower due to the applied compression. The reduction of K decreases when h decreases, i.e. with the decrease of soil water content.

3. THE CHANGE OF THE SOIL POROUS SYSTEM DUE TO THE CHANGE OF THE SOIL SOLUTION

We distinguish between principally two scenarios:

a/ The nature of the prevalent inorganic cation in the solution plays an important role relative to pore size distribution and to the value of K_S and $K(h)$. The increase of the percentage of exchangeable sodium (ESP) is accompanied by the increase of ζ potential provided that the soluble salt content of the soil water is small. If the electrical conductivity of the soil paste EC is about 1 $mS.cm^{-1}$ or less, the loss of soil structure is accompanied by the complete disappearance of structural porosity, if ESP is above about 20%. The consequence is decrease of K_S two or three orders of magnitude and the functional relationship $K(h)$ is changed, when compared to the same soil with negligible value of ESP.

b/ Large organic cations as e.g. pyridinium cause a flocculation of clay particles and even if the structural porosity may reach small values, the matrix porosity is characterized by high percentage of coarse pores and thus the K_S value is increased substantially. Let us note that big organic cations appear during the transformation of raw organic material into humic substances when the enzymes function mainly catalytically, usually with the contribution of root exudates.

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USE OF SOIL PHYSICAL QUALITY INDEX FOR ASSESSEMENT OF EFFECTS OF TILLAGE AT DIFFERENT DEPTHS

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Abstract

The investigations were performed in the Experimental Station Baborówko in Poland in the years 2004 - 2006. The experiment has started in 2002, when three fields for rape/lupin – winter wheat – spring barley crop rotation were separated. Additionally two fallow fields with no mechanical interference into soil: successive fallow and green cut fallow were set up. Soil samples were collected from the fields of wheat cultivated at three different soil depths: 30 cm – traditional plough system, 8 cm – reduced system with cultivator utilization and no tillage – direct sowings and from fields of both fallow grounds: 2-times cut green fallow and the successive fallow without any treatments, which soils were not examined with any mechanical measures. The purpose of this study was to investigate the effect of tillage at different soil depths on the index of soil physical quality in comparison to both successive and cut fallow. The research showed that the soils of both fallow fields were characterized by poor soil physical quality in comparison to three conventional, reduced and direct sowings soil tillage depths. Soil of cut fallow were distinguished from other tillage systems in 0-30 cm soil layer by significantly highest bulk density. Increasing bulk density lowered values of index S. Soils at cultivated fields were characterized by smaller bulk density and better soil physical quality.

Keywords: soil water retention characteristics, index S, bulk density, soil tillage systems, long-term-fallow

Introduction

Developing the concept of soil quality determination may help to identify the soil and crop management practices required for environmentally, socially, and economically sustainable agriculture. The relative importance of anthropogenic or management factors compared to non-anthropogenic physical, chemical and biological factors will generally be determined by the function or application for which a soil quality assessment is made.

Biological, chemical and physical processes influencing soil quality affect nutrient cycling by influencing two basic soil structure components, the formation of water stable aggregates and biopores. The primary process linking nutrient cycling and soil structure, and therefore, influencing soil quality, appears to be soil organic matter transformations.

Many of soil properties such as: physical, chemical and biological can be change by frequency and intensity of tillage management.

The most common soil properties influencing soil physical quality are: bulk density or degree of compaction, saturated and unsaturated hydraulic conductivity, water retention characteristics, soil structure, stability of soil aggregates, pore size distribution organic matter content (Karlen et. al. 1997, Niedźwiecki et. al. 2006, Shukla et. al. 2006, Pranagal 2007) and soil strength. Canarache (1990) determined „agrophysical index" on the base of weighted mean of 10 soil physical properties. The big numbers of soil parameters influencing the physical state of soil cause that quantification soil physical quality is very difficult. Recently developed in the Institute of Soil Science and Plant Cultivation in Pulawy, Poland by Dexter (Dexter 2004 a,b,c) index of soil physical quality S gives possibility of such quantification. A

soil physical index S is already defined it is equal to the slope of the soil water retention curve at its inflection point. The curve must be plotted as the logarithm (to base e) of the water potential against the gravimetric water content (kg kg^{-1}). The value of S index is indicative in the extent to which the soil porosity is concentrated into a narrow range of pore sizes. In the most soils larger values of S index are consistent with the presence of a better-defined microstructure. Some previous work have shown that this microstructure is responsible for most of the soil physical properties that are necessary for the proper functioning of soil in agriculture and the environment. The use of S index is illustrated with examples of soils with different texture, bulk density, and organic matter content. It is suggested that S index can be used as an indicator of soil physical quality that enables different soils and the effects of different management treatments and conditions to be compared directly.
The bigger values of S index showed better soil microstructure i.e. better soil physical quality. The following categories of the index of soil physical quality have been suggested: S<0,020 very poor, 0,020<S<0,035 poor; 0,035<S<0,050 good S>0,050 very good (Dexter Czyż 2007).
Dexter and Czyż (2007) found that different management practices can result from a number of agricultural and environmental problems related from degradation of soil structure. Processes of soil physical degradation, such as compaction, can destroy soil micro-structure, and one of the best indicators showing these changes is the distribution of pore sizes as quantified by S index. Increasing values of soil bulk density, such as produced by compaction, are found to give smaller values of S index. It is proposed that S index can be used as an indicator for characterization of soil physical quality that enables the effects of different soil management practices on soil physical quality to be quantified and compared. This approach using S can help to select appropriate management practices to protect our soils and the environment.
Reduced tillage usually leads to limited penetration of deeper layers of the soil which may affect soil physical parameters. The effects of various soil tillage systems on soil physical status were already determined. According to our knowledge it is a first attempt worldwide to compare the index of soil physical quality between regularly tilled land, an successive and a cut fallow. The purpose of this study was to investigate the effect of tillage at different soil depths on the index of soil physical quality S in comparison to both successive and cut fallow.

Material and Methods
The investigations were performed in the Experimental Station Baborówko in Poland in the years 2004 - 2006. The experiment has started in 2002, when three fields for rape/lupin – winter wheat – spring barley crop rotation were separated. Additionally two fallow fields with no mechanical interference into soil: successive fallow and green cut fallow were set up. Soil samples were collected to 100 cm^3 metal cylinders from the cultivated fields of wheat at three different soil depths: 30 cm – traditional plough system, 8 cm – reduced system with cultivator utilization and no tillage – direct sowings. The results of tillage at different soil depths were compared to fields of both fallow grounds: 2-times cut green fallow and the successive fallow without any treatments, which soils were not examined with any mechanical measures. The particle size distribution of the arable layer of this soils was as follows: 1,0-0,1mm fraction – 56%, 0,1-0,02mm fraction – 27%, <0,02mm fraction - 17% and clay <0,002mm fraction 4%. Total organic carbon content TOC = 1,3 %.

Measurements of soil physical properties:

- Bulk density was determined by method described by Blake and Hartge (1986),
- Water retention characteristics of the soil were measured using conventional methods at water potentials of -10, -20, -40 and -80 hPa on a sand-table apparatus and at -250, -500, -1000, -2000, -4000, -8000, -15000 hPa on ceramic pressure plate extractors.

The water retention curves were fitted to the van Genuchten (1980) equation (1):

$$\theta = (\theta s - \theta r)\,[1+ (\alpha h)^{n}]^{-m} + \theta r \qquad (1)$$

with the Mualem (1976) restriction: m = 1-1/n
where:
θs – water content at saturation [$kg \cdot kg^{-1}$],
θr – residual water content [$kg \cdot kg^{-1}$],
h – pressure head [hPa],
α - adjustable scaling factor [hPa^{-1}],
n – adjustable shape factor.

Index of soil physical quality S was defined by Dexter (2004 a,b,c). It is equal to the slope of the soil water retention curve at its inflection point (Eq. 2). The equation was developed by Dexter (2004a,b,c) from Eq. 1.

$$S = -n \cdot (\theta s - \theta r) \cdot \left[\frac{2n-1}{n-1}\right]^{\left[\frac{1}{n}-2\right]} \qquad (2)$$

Results of the measurements and laboratory analyses were statistically analyzed by ANOVA. Means were compared by Tukey test and considered significant at P=0.05. Calculations were performed using statistical program Statgraphics Centurion v.15.

Results and Discussion

After three years since tillage depth has been differentiated showed better physical quality in 0-25cm depth soils examined by tillage than soils of both cut and successive fallows. The mean values of S index in the 0-25cm depth were as following: conventional tillage - 0,059, reduced tillage - 0,054, direct sowing - 0,048, cut fallow - 0,041 and successive fallow - 0,031 (tab. 1).

Table 1. Values of soil physical quality index S of investigated soils

Treatment	depth cm	year			mean from 3 yr	mean 0-25 cm
		2004	2005	2006		
Cut fallow	0-5	0,070	0,030	0,054	0,051	
Cut fallow	10-15	0,048	0,032	0,047	0,042	
Cut fallow	20-25	0,030	0,029	0,029	0,029	0,041
Successive fallow	0-5	0,038	0,027	0,045	0,037	
Successive fallow	10-15	0,020	0,021	0,033	0,025	
Successive fallow	20-25	0,029	0,030	0,033	0,031	0,031
Direct sowing	0-5	0,063	0,051	0,041	0,052	
Direct sowing	10-15	0,063	0,039	0,033	0,045	
Direct sowing	20-25	0,076	0,036	0,029	0,047	0,048
Reduced tillage	0-5	0,068	0,075	0,051	0,065	
Reduced tillage	10-15	0,055	0,046	0,036	0,046	
Reduced tillage	20-25	0,066	0,047	0,040	0,051	0,054
Conventional tillage	0-5	0,073	0,059	0,045	0,059	
Conventional tillage	10-15	0,089	0,076	0,044	0,070	
Conventional tillage	20-25	0,070	0,035	0,042	0,049	0,059

It should noticed that small statistical differences of values of soil physical quality index between tillage treatments resulted probably from short duration (3 years) of this experiment. The research showed that the soils of both fallow fields were characterized by poor soil physical quality in comparison to three: conventional and reduced and direct sowings soil tillage systems. Soil of cut fallow distinguished by significantly highest bulk density in 0-25 cm soil layer. Increasing bulk density lowered values of index S. Soils at cultivated fields were characterized by smaller bulk density and better soil physical quality (tab 2).

Table 2. Values of bulk density of investigated soils

Treatment	depth cm	year 2004	2005	2006	mean from 3 yr	mean 0-25cm
Cut fallow	0-5	1,55	1,65	1,58	1,59	
Cut fallow	10-15	1,62	1,68	1,76	1,69	
Cut fallow	20-25	1,72	1,70	1,77	1,73	1,67
Successive fallow	0-5	1,65	1,66	1,59	1,63	
Successive fallow	10-15	1,83	1,81	1,67	1,77	
Successive fallow	20-25	1,79	1,78	1,58	1,71	1,71
Direct sowing	0-5	1,55	1,52	1,63	1,57	
Direct sowing	10-15	1,51	1,72	1,69	1,64	
Direct sowing	20-25	1,57	1,68	1,65	1,63	1,61
Reduced tillage	0-5	1,57	1,40	1,54	1,50	
Reduced tillage	10-15	1,68	1,63	1,68	1,66	
Reduced tillage	20-25	1,67	1,69	1,58	1,64	1,60
Conventional tillage	0-5	1,51	1,53	1,56	1,53	
Conventional tillage	10-15	1,59	1,52	1,48	1,53	
Conventional tillage	20-25	1,64	1,76	1,66	1,69	1,58

Soils of both fallow fields were characterized by poorer soil physical quality. Increasing bulk density lowered values of S index . It was discovered that the coefficient of determination for relationship between bulk density and S index equalled to $R^2 = 0.82$ (fig.1).

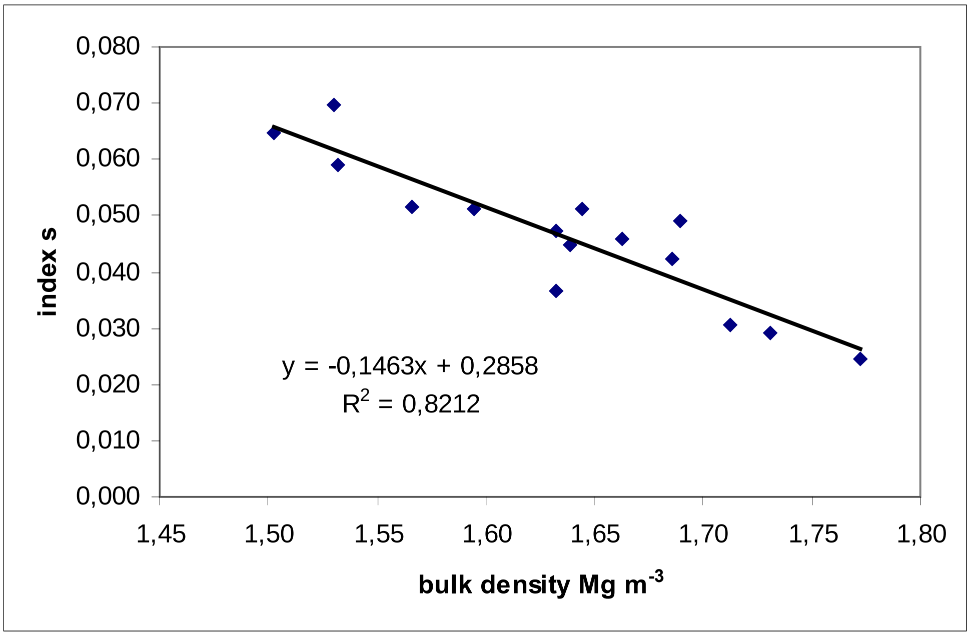

Figure 1. Effect of bulk density on soil quality index S

Soils at cultivated fields were characterized by smaller bulk density and better soil physical quality.

Dexter (2004 a,b,c) showed that several important soil physical properties can be estimated from the slope of the water retention curve at its inflection point. Soil physical degradation occurs when soil is compacted, and this reduces the slope of the water retention curve at the inflection point, i.e. S index decreases with increasing bulk density (Dexter, 2004a).

Hill and Cruse (1985) compared bulk density and penetration resistance between no-till, reduced tillage, and conventional tillage operations under two Mollisols. Their results showed that soil bulk density increased with depth for all systems. Although they found greater soil strength in the conservation methods, they did not observe enough compaction to hinder root growth to an appreciable level. Moreno et al. (1997) also compared conservation tillage and conventional tillage. They reported that bulk density and penetration resistance were always higher in the conservation tillage than in the conventional tillage systems. Similar result was reported for a comparison of no-till and conventional tillage system on a silt loam (Wilkens et al. 2002). During the conversion from a tilled to no-till system, soil strength significantly increases. However, after 17 years of no-till, the penetration resistance levels were near that of intensive tillage levels. The authors also noted that the tillage pan located between 15 and 30 cm was began to disappear in the 17th year of no tillage. It might suggest that soil structure improves after the conversion of intensive tillage to a no-till system with time.

In summary, no-till, conservation tillage will result in increases of bulk density and penetration resistance compared to traditional tillage, but after an undesignated time, the soil strength may reduce to traditional tillage levels (Green et al., 2003). Although the results show that more than 15 to 30 years of no-till were needed to see levels decrease, the increase in soil strength may not have a negative impact on crops (Fuentes et al., 2004; Green et al. 2003).

Our research showed that S index can be used as an index of soil physical quality that enable the differentiation of soils and the effects of different management treatments and conditions to be compared directly. This would be helpful in protection of rural ecosystems and proper management of the production capacity.

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EFFECT OF LONG TERM ORGANIC AND CONVENTIONAL FERTILIZATION METHOD ON CHOSEN SOIL CHEMICAL PROPERTIES

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Abstract
Soil samples to analyze soil chemical properties from 65 organic and conventional farms distributed all over Poland were collected. Organic management resulted in slightly higher soil pH. Bigger differences were found in case of C and N content. Thanks to organic fertilization method in loamy and clay soils C content was higher by 13.5% and N content was higher by 20.3%. The same tendency, although not so marked, was found on sandy soils.
Conventional fertilization resulted in higher content of exchangeable P, especially on sandy soils. Almost the same content of exchangeable K was found on both farm types. Higher amounts of exchangeable Mg were found on organic farms on each soil type: sandy, loamy and clay. In the same time bigger disproportions of Mg content were found on organic farms (30 – 112mg Mg kg^{-1}) than on conventional farms (30 – 87mg Mg kg^{-1}).

Key words: farming systems, soil pH, C_{org}, N_{tot}, exchangeable P,K,Mg.

Introduction
Productivity of Polish soils is low. Above all their humus content is insufficient. When assuming the standard of the European Soil Office of 2% C_{org} as a critical value, then 89% of the acreage of Polish soils would belong to the category of those of low content of organic matter [GONET, 2004]. Humus has a significant influence on the physical and chemical stability of soil properties, as well as its biological parameters. Moreover in the context of global climate changes, it should be kept in mind that the biggest reserves of carbon are hidden in soils. Proper use can increase significantly the accumulation of carbon in soil, as presently its historic potential in this sphere is utilized only in 50-60% [LAL, 2004].
Soil acidity is a second problem. Organic farmers are sure that the starting point in a long-term process of soil improvement should be checking and optional regulation of its pH [TYBURSKI, ŻAKOWKA-BIEMANS, 2007]. At the same time the researches of the Institute of Soil Science and Plant Cultivation in Puławy show that at present 28% of agricultural land in Poland has high acidity (pH in KCl lower than 4.5), and 31% is acid (pH in KCl from 4.5 to 5.5). The biggest part of very acid and acid soils (65 - 85%) occurs in central eastern and south eastern Poland, while lower share (30 – 50%) occupies western and south western Poland.
Unbalanced or insufficient fertilization leads as consequence to soil depravation from nutritive elements and its impoverishment [KĘSIK 2000, FOTYMA 2000]. The cited authors claim as alarming the impoverishment of Polish soils in exchangeable nutrients. According to the researches of the Institute of Soil Science and Plant Cultivation in Puławy, the very low and low content of K has 49%, of P 38% and of Mg 35% of soils [IGRAS et al. 2003]. In this situation good effects in crop production can be obtained only after a pH correction and soil nutrient status. In creating the soil content of nutritive elements and its fertility, the increasingly bigger significance plays the usage of mineral and organic fertilizers [MATTSON

1999, MAZUR 1999, CWOJDZIŃSKI, NOWAK 2000]. Unbalanced fertilization can lead to soil degradation and greatly lowers its productivity – mainly as a result of acidity and disturbance of the ion equilibrium in soil environment [MERCIK et al. 2000a, MERCIK et al. 2000b, RICHTER et al. 2000]. The biggest changes influenced by fertilization are observed in soil acidity and in the content of exchangeable forms of P, K and Mg, and to a lesser extent in the content of organic carbon and total nitrogen.
In this context, a question can be asked whether the change of farming system for organic might improve the situation. In fundamental principles of organic farming by International Federation of Organic Farming [IFOAM 2005], the second principle is that of environment protection, which emphasizes recycling and predominantly that of fertilizers. Does organic farming really affect favorably soil fertility in Poland? The aim of the present researches was examination of the content of exchangeable form of P, K, Mg and C_{org} and N_{tot} as well as soil's pH after several years of cultivation in the systems of organic and conventional farming.

Methods

In order to determine the influence of conventional and organic farming systems on chemical properties of soils, in the years of 2005-2007 there were samples taken on 65 farms situated in all regions of Poland. Researched were only those organic farms, which had been run in this system for at least 10 years. While the conventional farms were always situated in close neighborhood of the organic farms in order to ensure the possibility of taking soil samples which did not differ significantly in basic properties (parent rock, content of particles Ø ≤ 0.02 mm, etc.)
The representative soil samples were obtained from the ploughing layer (0-20 cm) by aid of Egner's cane. The taken material was dried to the state of air dry, ground and sieved by a sieve of 1mm mesh. Such prepared samples of soil underwent a chemical analysis and there were measured:

- potentiometically pH in suspension of 1 mol $KCl \cdot dcm^{-3}$ solution,
- content of form of P and K were determined by method of Egner-Riehm,
- content of exchangeable Mg by Schachtschabel's method,
- content of organic carbon by Turin's method,
- content of N_{tot} after mineralization by distillation.

The obtained research results were worked out statistically by *Statistica* computer programme.

Results and discussion

The researches done proved that the organic farming system affects more favorably than the conventional one the amount of organic carbon in soil (tab. 1). The favorable influence of organic farming on C_{org} was stronger in soils containing more than 20% colloidal fraction. Probably to lighter soils (less than 20% of colloidal fraction) came less organic matter because of their smaller productivity. It can be also assumed that in light soils mineralization was more intensive than in heavy soils. The histograms of the C_{org} content show clearly different conditions of cultivation (Fig. 2).
In literature of the problem there are majority of reports affirming the favorable influence of organic farming methods on the content of humus in soil. It was reported among others by HEPPERLY et al. [2006] in a relation of many years' researches conducted in Pennsylvania, USA. Also from the USA comes a paper summarizing the results of many experiments conducted in different regions of that country that also indicate more favorable influence of organic methods than conventional ones on amount of humus in soil [MARRIOTT, WANDER, 2006]. Similar relationships were obtained by SOKOŁOWSKA et al. [1998] in researches made in Poland. In the oldest and the most known DOK trial in Therwil in Switzerland started in

1978, it was concluded that the most advantageous for the content of humus is the biodynamic system, followed by organic and conventional with manure fertilizing, whereas definitely negative impact had mineral fertilizing [MÄDER et al. 2002].
Yet in many years' researches conducted in Minnesota, USA, by Porter and co-authors [2006] and in Poland by MEYSNER and co-authors [2006] no relation was found between the system of farming and the amount of humus.
Similarly to the content of C_{org} also the concentration of N_{tot} was on a bit higher level in soils cultivated in the organic system, and in heavier soils (Tab. 1). It is worth noticing the bigger disparity of N_{tot} in heavier soils of organic farming system than in the same category of soils in conventional system. It could be caused by the agro-technological differences on organic farms e.g. by crop rotation and influx of organic matter to soil. In the case of light soils such a big disparity of N_{tot} content as influenced by the system of farming was not reported. The distribution of N_{tot} concentration in soils fertilized organically and conventionally to the high degree was identical to that of C_{org} (Fig. 2). Similarly to our own researches, more N in organically cultivated soils was reported in many years' researches in the USA by HEPPERLY and co-workers [2006], whereas in researches conducted in Poland MEYSNER et al. [2006] did not report a favorable influence of this system on accumulation of N in soil.
One of the most important factors of soils quality is their pH reaction, which influences directly assimilation of nutritive elements. In conditions of the conducted researches there was stated a very strong diversity of soils' pH as fixed in suspension of the solution of 1 mol $KCl \cdot dm^{-3}$ (Tab. 1). The lowest pH values both for light and heavy soils occurred in the case of conventional system and the highest ones in the organic system. The changeability of pH of the examined soils was also significantly bigger for the soils fertilized conventionally.
We think that soils fertilized in organic system are less prone to acidity due to elimination of acidifying mineral fertilizers (esp. N and K), and thanks to generally and often used organic fertilizers as well as to use of crop rotation with legumes. The proof of this thesis are histograms of the distribution of pH of soils fertilized organically and conventionally (Fig. 2). Acidity of soils often grows up along with the increase of mineral fertilization, whereas organic fertilizers, which form the base of fertilization in organic farming, can prevent to a high degree that disadvantageous phenomenon [SIENKIEWICZ 2003]. Data obtained in the researches prove the above stated thesis.
Analyses showed a very strong changeability of the content of exchangeable forms of P, K and Mg in light and heavy soils regardless the farming system (Tab. 1). Bigger differences of concentration of available P for plants occurred in soils cultivated in conventional system as compared to those cultivated in organic one. It can indicate a bigger stability of this P form in soils which were cultivated organically for many years. In this context it is worth citing the results of MÄDER'S et al. researches [2006], who in the framework of Therwil DOK experiments reported a higher degree of mycorrhiza occurrence on crop roots grown in organic system. It should be emphasized though that in the conventional system accumulation of exchangeable P in soils was significantly higher than in the organic system. This relation was stronger in the case of light soils. Definitely more P available to plants was to be found in heavier soils as compared to light ones. The variability of the discussed P form in soils fertilized conventionally was less marked and closer to the normal distribution (Fig. 1).
Generally it is believed that P is an element which does not limit production in organic farming. In nutrients balances this element sometimes gets slightly negative values (-2 ÷ -3 kg per ha per year), but it comes quite often that it shows positive values. It was proved among others by the researches of GRANSTEDT et al. [2004], GRANSTEDT [2006], HÜLSBERGER et al. [1997], GRANSTEDT et al. [2007]. Yet the tendency to mining of soil abundance in P was recorded among others in Therwil in Switzerland [MÄDER et al. 2006] and in POTE'S et al. researches [2006] in the USA.

As for the content of exchangeable K in soil a bit different relations occurred. The strongest disparity was observed in the case of heavy soils fertilized ecologically (Tab. 1). – the soils were slightly less rich in the discussed element than comparable soils fertilized conventionally. Inversely though there was the case with light soils – slightly more exchangeable K was found in condition of organic farming and a stronger difference occurred on soils fertilized conventionally. Taking into account the distribution of the content of K available for plants in soils, it should be stated that similarly to the P case it was more favorable in the conventional system – more soils lay in the ranges of higher abundance (Fig. 10). Generally K can be an element in organic farming with a negative balance, because crops bring with yield the most of this element. Thus it depends a lot on a specialization of an organic farm – if it sells more crops, among them vegetables, then the mining of K in soils will be greater [GRANDSTEDT et al. 2007].

The content of exchangeable Mg in turn was the most different in heavy soils cultivated in the organic system (Tab. 1). Regardless the farming system in soils containing more than 20% of particles content of particles Ø ≤ 0.02 mm there was also more exchangeable K. Both in heavy and light soils fertilized ecologically more available forms of Mg was recorded than in soils of the same category fertilized conventionally. It can be supposed that farmers running conventional farms fertilized their fields insufficiently in Mg. On the other hand, soils fertilized ecologically, due to input of organic fertilizers, can get Mg in this way. Contrary to the case of exchangeable K, definitely more soils fertilized ecologically lay in the groups of increased content of Mg – more than 70 $mg \cdot kg^{-1}$ (Fig.1)

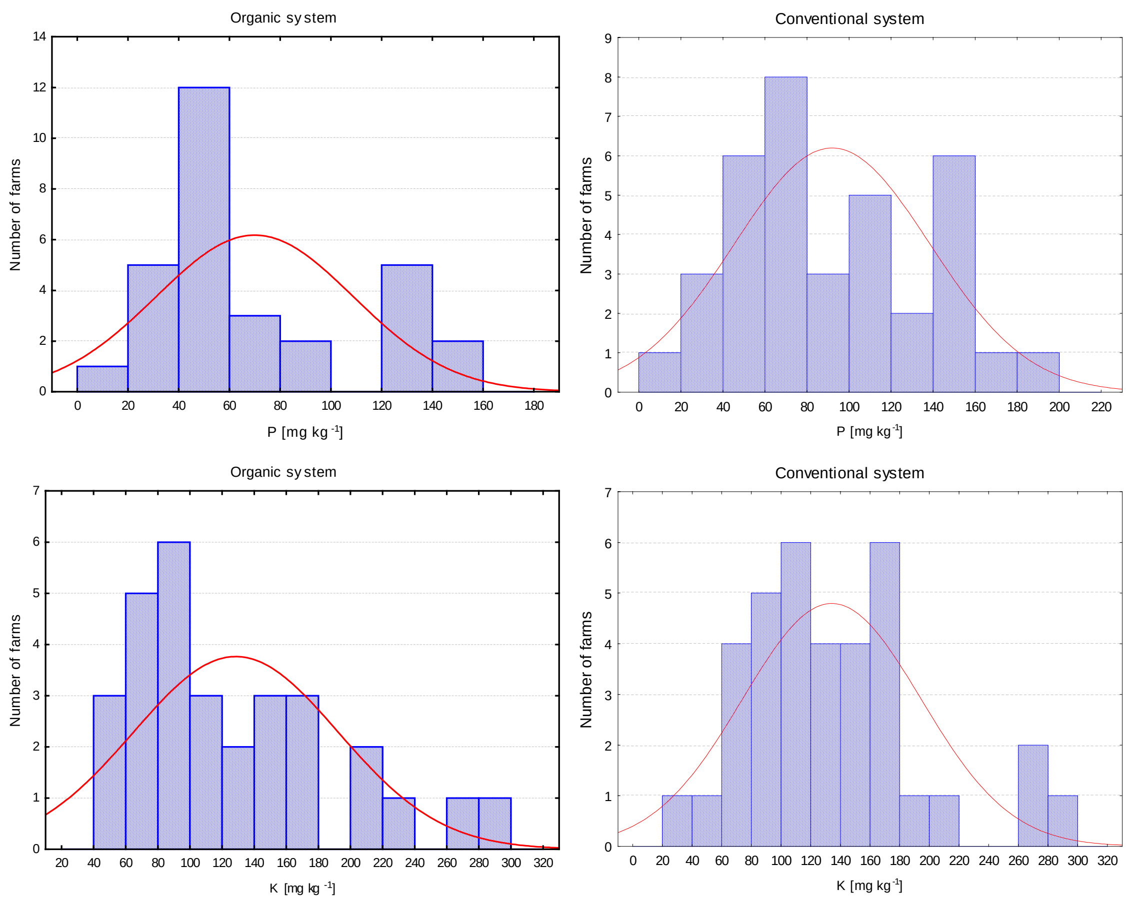
In the context of analysis of abundance in macro elements of soils cultivated ecologically, it is worth noticing that organic farmers in Poland have had an access to mineral potassium, magnesium and phosphorus fertilizers permitted in this system only for a few last years.

Table 1

Chemical properties of heavier (> 20% of content of particles Ø ≤ 0.02 mm particles) and light (< 20% content of particles Ø ≤ 0.02 mm) soils depending on a farming system

Soil's feature	The lowest value	The highest value	Mean value	Standard deviation	Standard error
Heavy soil (> 20% content of particles Ø ≤ 0.02 mm) – organic system					
P ($mg \cdot kg^{-1}$)	19,64	153,64	77,01	40,70	8,88
K ($mg \cdot kg^{-1}$)	49,83	290,70	140,01	70,39	15,36
Mg ($mg \cdot kg^{-1}$)	30,00	112,00	72,67	21,13	4,61
pH (1 mol $KCl \cdot dm^{-3}$)	5,04	7,24	6,41	0,61	0,13
$C_{org.}$ ($mg \cdot kg^{-1}$)	7,95	32,31	12,04	6,19	1,35
$N_{tot.}$ ($mg \cdot kg^{-1}$)	0,90	2,80	1,24	0,49	0,11
Heavy soil (> 20% content of particles Ø ≤ 0.02 mm) – conventional system					
P ($mg \cdot kg^{-1}$)	28,37	190,31	96,85	46,62	8,97
K ($mg \cdot kg^{-1}$)	66,45	282,39	148,27	58,89	11,33
Mg ($mg \cdot kg^{-1}$)	30,00	97,00	58,78	17,89	3,44
pH (1 mol $KCl \cdot dm^{-3}$)	4,55	7,15	6,23	0,75	0,14
$C_{org.}$ ($mg \cdot kg^{-1}$)	7,25	18,79	10,61	2,96	0,57
$N_{tot.}$ ($mg \cdot kg^{-1}$)	0,70	1,60	1,03	0,21	0,04

Light soil (< 20% content of particles Ø ≤ 0.02 mm) – organic system					
P (mg·kg^{-1})	25,32	123,09	52,18	28,53	9,51
K (mg·kg^{-1})	53,99	149,50	99,94	31,67	10,56
Mg (mg·kg^{-1})	21,00	63,00	45,11	16,86	5,62
pH (1 mol KCl·dm^{-3})	5,00	7,15	5,69	0,61	0,20
$C_{org.}$ (mg·kg^{-1})	6,79	13,51	9,56	2,30	0,77
$N_{tot.}$ (mg·kg^{-1})	0,80	1,30	1,04	0,17	0,06
Light soil(< 20% content of particles Ø ≤ 0.02 mm) – conventional system					
P (mg·kg^{-1})	33,17	151,90	82,17	41,42	14,64
K (mg·kg^{-1})	37,38	153,65	94,06	37,95	13,42
Mg (mg·kg^{-1})	25,00	72,00	35,63	15,31	5,41
pH (1 mol KCl·dm^{-3})	4,03	6,85	5,59	0,90	0,32
$C_{org.}$ (mg·kg^{-1})	5,92	11,25	8,85	1,90	0,67
$N_{tot.}$ (mg·kg^{-1})	0,70	1,30	0,91	0,21	0,07



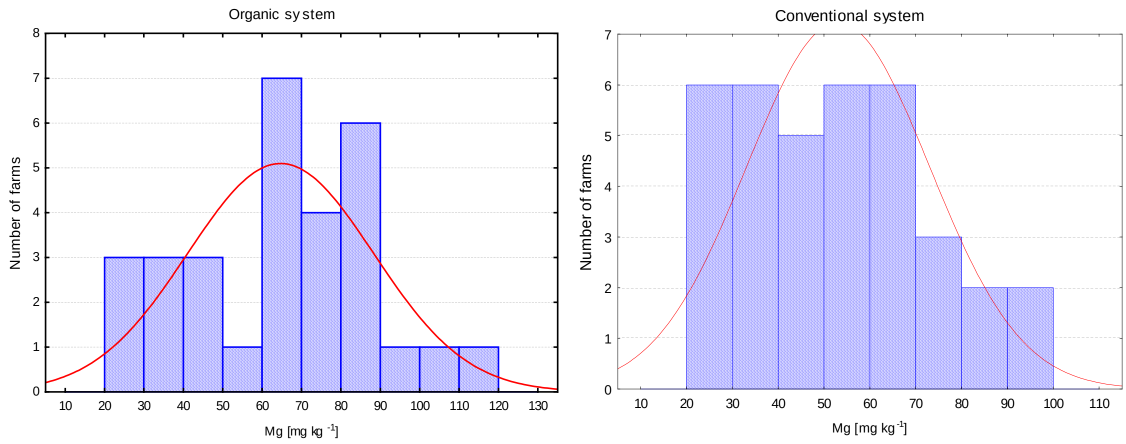
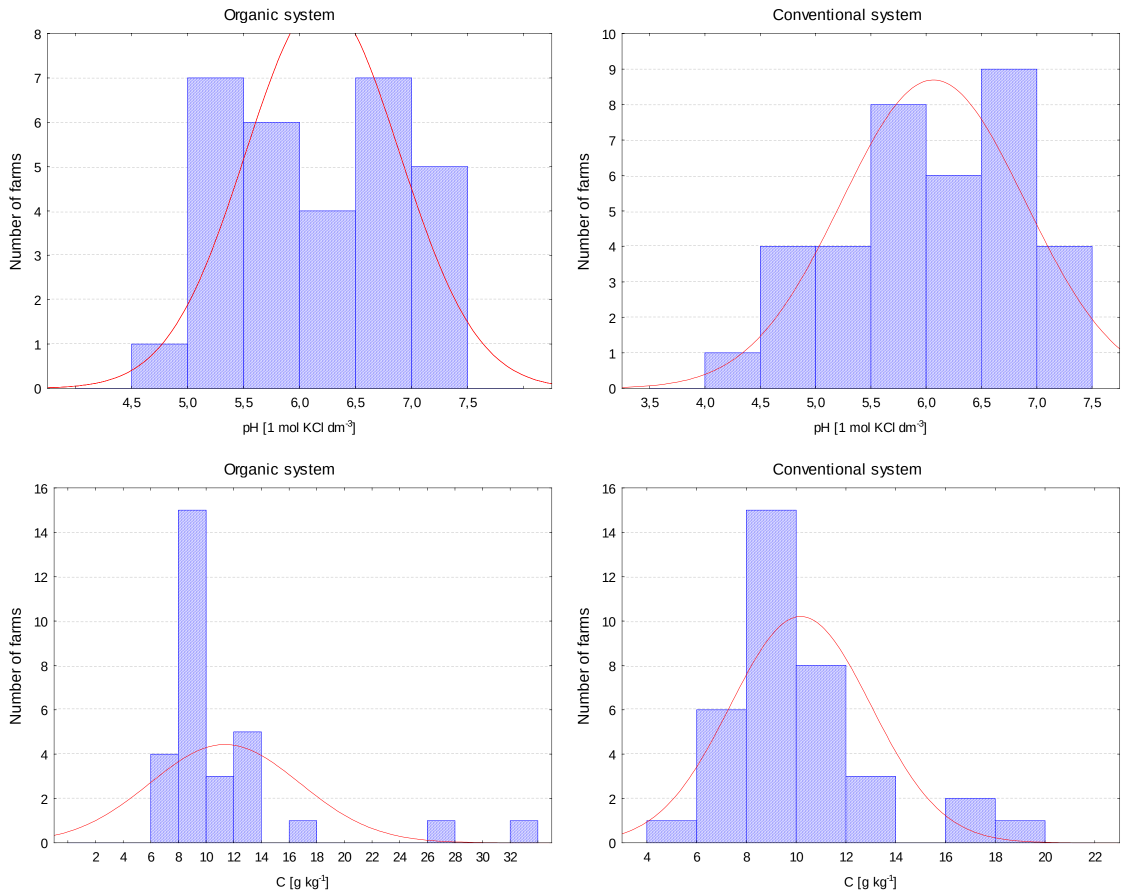


Fig. 1. Histogram of the content of exchangeable form of P, K and Mg in soil depending on the farming system (organic and conventional)



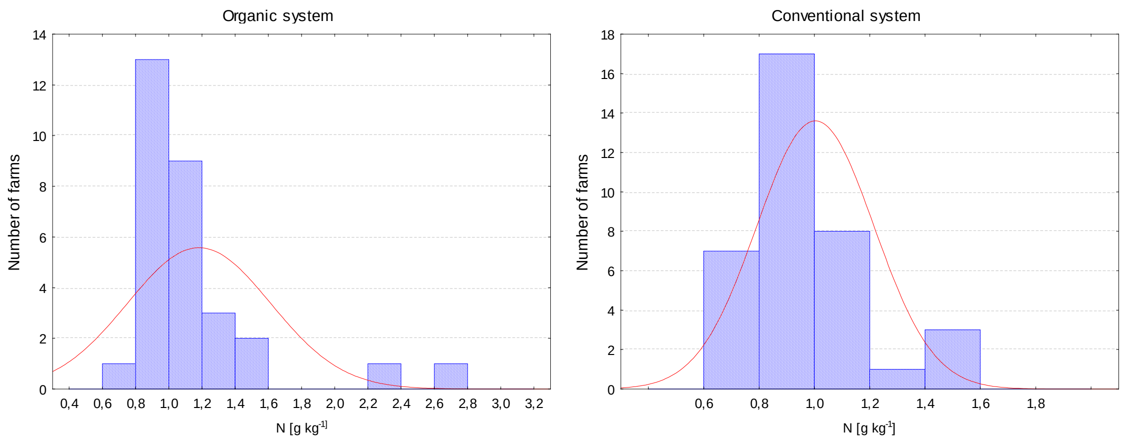


Fig. 2. Histogram of pH of soils and the content of organic carbon and nitrogen depending on the farming system (organic and conventional)

Conclusion

On the grounds of the conducted analyses of soil samples from 65 farms in Poland there was stated that the farming system influences greatly soil chemical properties.

1. Organic farming, as compared to conventional, favors stronger accumulation of organic matter in soil.
2. Organically fertilized soils are less prone to acidity.
3. On organic farms a higher content of exchangeable Mg was recorded.
4. Conventionally fertilized soils are characterized by higher abundance in exchangeable phosphorus and potassium in comparison to ecologically fertilized soils.

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THE YIELD OF COMMON PEA UNDER DIFFERENT PRIMARY SOIL CULTIVATION

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Abstract
The field poly-factor experiment was established with common pea in very warm region in 2004 - 2006. The soil type was brown-soil with a moderately acid soil reaction. The variety of Pea was Dunaj. Three variants of soil cultivation were searched: A. tillage to the depth 0.25 m, B. tillage to the depth 0.15 m, C. cultivation with disk tools to the depth 0.10 m. The variants of fertilization: 1.control variant (without fertilization), 2.fertilization with the industrial fertilizers, 3.fertilization with industrial fertilizers and remains of the preceding crop, which was winter wheat. Sowing rate was 1.0 mil. germinative seeds. ha^{-1}. The highest statistically significant, economic yield was in 2006 (4.51 t ha^{-1}). Soil cultivation and fertilization did not influence significantly yield. The highest yield was achieved at tillage to the depth 0.25 m (4.46 t ha^{-1}) and at variant with the use of industrial fertilizers (4.44 t ha^{-1}) in average of three years.
Key words: common pea, soil tillage, fertilization, yield

Introduction

Common pea (*Pisum sativum* L) is crop used especially for feeding. Considering that volume of animal husbandry is reducing in Slovakia, the demand for feeding mixtures is also decreasing. Despite this fact, common pea still remains dominant legume crop. In 2007, common pea was harvested from area 9245 hectares and it reached yield 2,40 $t.ha^{-1}$ (Tibenská, 2007). Soil cultivation is the most important and energetically the most demanding agro-technical measure at crop production. Soil cultivation creates conditions for development of plant root system and activity of micro-organisms. The aim is improvement of soil structure, disintegration of compressed layers, to plough down harvest remains and organic fertilizers, control of weeds, and preparation of quality bed for seeds. The fulfilment of the aim is possible via various ways of soil cultivation which have to be adjusted to specific conditions. In connection with cost reduction, minimal and reduced ways of soil cultivation are more and more utilized. The important motivation is effectiveness of crop production (Pospíšil, Pačuta, 2000).

In comparison with classical technologies, economical technologies significantly reduce consumption of propellants (Horák, Šařec, Šařec, 2005).

Material and methods

Field poly-factor experiment with common pea was carried out in 2004 - 2006 at Experimental base of Slovak University of Agriculture in Nitra. The territory belongs to very warm area with sum of average daily air temperatures (TS ≥ 10 °C) during main growing season 3 000 °C and more. Locality has flat character with altitude 175 metres above sea level. Agro-climatic sub-area is very dry, climatic indicator of irrigation in months June - August is 150 mm and more. Territory belongs to agro-climatic district of moderate winter with average value of absolute minimal temperatures (T_{min} ≥ 18 °C) (Špánik, Repa, Šiška, 2002). The soil type is Haplic Luvisol (HMa) with soil volume weight 1470 - 1530 $kg.m^{-3}$. Soil reaction is from 5,03 to 5,69.

Experiment was established by method of long strips with upright split blocks. The area of variant was 30 m^2 (10 x 3 m) in four repetitions.
Variants of soil cultivation investigated in experiment:

A 1 - tillage to depth 0,25 m,
A 2 - tillage to depth 0,15 m,
A 3 - disk tools to the depth 0.10 m.

Variants of fertilization:

B 1 - control variant (without fertilization),
B 2 - N = 20 $kg.ha^{-1}$(LAV), P = 30 $kg.ha^{-1}$ (superphosphate with content of 18 % phosphorus)
B 3 - N = 20 $kg.ha^{-1}$(LAV), P = 30 $kg.ha^{-1}$ (superphosphate with content of 18 % phosphorus) plus ploughing down of harvest remains.

LAV – ammonium nitrate with limestone. Nutrients were applied based on balance method according to their content in soil. Fertilization with potassium was not necessary. Fertilization was calculated on level of 3 tons of dry seeds per hectare, according to norm for nutrient consumption for 1 ton of yield: N 63 kg, P 7,4 kg, K 37,4 kg (Fecenko, Ložek, 2000). Soil cultivation before sowing was done with combination tool. Variety Dunaj was sown after preceding crop winter wheat. Sowing rate was 1,0 mil. germinative seeds per hectare, the depth of sowing was 40 mm and inter-row distance 125 mm.
Terms of sowing: 1. 4. 2004, 6. 4. 2005, 6. 4. 2006
Terms of harvest: 19.7. 2004,15. 7. 2005, 18. 7. 2006.

Results and discussion

The importance of legumes arises not only from their direct production but also from their favourable effects on soil and its fertility. Positive effect of legumes on soil and following crop is the most distinctly demonstrated by higher accumulation of organic matter in soil, fixation of atmospheric nitrogen, lower occurrence of deceases, higher productivity of soil environment (Škrobáková, 1995). Apart from growing point of view, there are also energetic, economic aspects and also demand for rationalization of this crop (Slinkard, 1999). With interest of cost saving, growers effort to utilize various ways of primary and pre-sowing soil cultivation. Applied tools significantly influence overall energetic balance of given working process (Nozdrovický, 1994). Conventional process markedly increases costs of energetic inputs and there is high demand for working time (Stehlo, 1994).
The results, achieved in growing seasons 2004 – 2006, have shown noticeable influence of soil cultivation on common pea yield of seeds and its straw. The lowest yields of seed and straw of common pea were achieved at variant with minimal soil cultivation in all three years. Marko (1993) states, that conventional technology significantly worsens physical properties of soil. Reduced soil cultivation improves porosity and higher values of soil volume weight. The highest yield was reached at variant with conventional soil cultivation. Similar results were obtained also by Šariková, Hnát (2005) and Žák, Kováč, Lehocká (2002) when higher yield of pea was found out after conventional soil cultivation than after sowing without preceding soil cultivation. Kováč et al. (2005) found out higher soil moisture after conventional soil cultivation in comparison with soil-protective technologies which could have positive influence on higher yield of seeds at conventional variant of soil cultivation. However, Kováč et al (2003) hold opinion that reduced way of soil cultivation can be under favourable conditions utilized for growing of most agricultural crops.

Table 1: The influence of soil cultivation and fertilization on yield of seeds and straw of common pea

Soil cultivation	Variant of fertilization	Seed yields ($t.ha^{-1}$)				Straw yields ($t.ha^{-1}$)			
		2004	2005	2006	Average	2004	2005	2006	Average
	B 1	4,22	3,08	4,34	3,88	3,34	3,22	5,32	3,96
	B 2	5,98	3,74	4,45	4,72	3,94	4,09	7,02	4,02
	B 3	4,94	4,90	4,51	4,78	4,05	5,09	7,17	5,44
A 1	Average	5,05	3,91	4,43	4,46	3,78	4,13	6,50	4,80
	B 1	4,18	3,44	4,37	4,00	2,82	3,87	5,81	4,17
	B 2	4,29	3,55	4,54	4,13	3,36	4,09	9,05	5,50
	B 3	4,30	4,01	4,40	4,24	2,91	5,01	6,04	4,65
A 2	Average	4,26	3,67	4,44	4,12	3,03	4,32	6,97	4,77
	B 1	3,33	3,18	4,39	3,63	3,09	3,29	4,94	3,77
	B 2	4,05	3,86	4,76	4,22	3,52	3,90	6,27	4,56
	B 3	4,38	3,82	4,74	4,31	3,51	4,07	5,99	4,52
A 3	Average	3,92	3,62	4,63	4,06	3,37	3,75	5,73	4,29

Hernanz, Girón, Cerilosa (1995) evaluated three technologies of soil cultivation – conventional, reduced and without tillage from point of view of costs and reached profit. The best indicators were on reduced variant, the worst variant was conventional technology in all indicators. We did not perform economic evaluation.

The yield of seeds depends on overall amount of produced phytomass. Ratio seeds and straw is expressed by harvest index (Table 2). The highest ratio of seeds to phytomass was in 2004 and the lowest in 2006. Due to sufficiency of moisture during first growing phases in 2006, there was distinct accumulation of organic matter but proportion of seeds was not markedly increased. The differences among ways of soil cultivation were statistically non significant.

Table 2: Harvest index of common pea in years 2004 – 2006

Soil cultivation	Variant of fertilization	2004	2005	2006	Average
		0,56	0,49	0,45	0,50
	B 2	0,60	0,48	0,39	0,49
	B 3	0,55	0,49	0,39	0,48
	Average	0,58	0,49	0,41	0,49
	B 1	0,60	0,47	0,43	0,50
	B 2	0,56	0,46	0,33	0,45
	B 3	0,60	0,44	0,42	0,49
A 2	Average	0,58	0,46	0,39	0,48
	B 1	0,52	0,49	0,47	0,49
	B 2	0,54	0,50	0,43	0,49
	B 3	0,56	0,48	0,44	0,49
A 3	Average	0,54	0,49	0,45	0,49

Yield production of field crops is complex process which is influenced by many objective and subjective factors. Legume crops are particularly sensitive to weather conditions of year. The average values of experimental years are given in table 3.

Table 3: Temperatures and precipitation in examined years

Year	Temperature (°C)	Diversion of normal	Precipitation (mm)	% of normal
Normal (1951 – 1980)	9,7	0	561	100
2004	9,9	+0,2	514,5	91,7
2005	9,6	-0,1	638,3	113,8
2006	10,1	0,4	507,1	90,39

Yields were relatively steady in 2004 and 2006. Despite sufficiency of moisture, the lowest yield of seeds was achieved in 2005. The reason was uneven distribution of precipitation within vegetation season. The course of temperatures and precipitation in vegetation season distinctly impacts the intake and consumption of nitrogen. Higher sum of precipitation causes lower nitrogen intake and positively influences intake of phosphorus. Nitrogen fertilization, without consideration of year, increases intake of nitrogen (Bízik, 1989). Utilization of nutrients from fertilizers was related to conditions of year and ways of soil cultivation. At conventional soil cultivation variant as well as at variant with disk tools, the highest yield was achieved at variant where industrial fertilizers were used together with harvest remains of preceding crop.

Fertilization positively influenced also yield of straw. Javor, Surovčík (2001) recommend fertilization with phosphorus and potassium in autumn and nitrogen application in nitrate form before sowing. Authors advice maximum rate 40 $kg.ha^{-1}$, which corresponds also with our results.

Yield depends on yield elements. The basic yield element is number of plants per unit area which was relatively even. Other important yield elements are number of pods, number of seeds per pod and thousand seeds weight. Number of pods and seeds per pod varies under the influence of growing conditions. In 2004 and 2005 the highest number of pods per plant was found out at conventional variant of soil cultivation. In 2006, better results were achieved after tillage to depth 0,15 m. With higher number of pods, number of seeds per pod was reduced. The highest number of seeds per pod was reached in 2006. Fertilization affected number of seeds positively. Legumes are typical by low auto-regulative potential. They are very sensitive to environmental conditions particularly during period of generative organs differentiation, which results into variability of yield elements and lower yield stability (Kostrej, 1998). It was proved by number of seeds per pod, where lower number of pods was not compensated by radical increase of seeds number in pod (table 4).

Table 4: Number of pods and seeds per pod in 2004 – 2006

Soil cultivation	Variant of fertilization	Number of pods per plant,				Number of seeds per pod			
		2004	2005	2006	Average	2004	2005	2006	Average
	B 1	7,90	4,92	6,33	6,38	2,60	3,18	3,69	3,16
	B 2	8,70	6,46	5,25	6,80	3,00	2,92	3,86	3,26
	B 3	8,30	7,80	6,13	7,41	2,60	3,19	3,87	3,22
A 1	Average	8,30	6,39	5,90	6,87	2,73	3,10	3,81	3,21
	B 1	7,50	6,50	6,27	6,76	2,90	2,68	3,55	3,04
	B 2	7,10	6,28	7,23	6,87	3,20	3,09	3,35	3,21
	B 3	7,30	6,24	9,20	7,58	3,20	2,95	3,66	3,27
A 2	Average	7,30	6,34	7,57	7,07	3,10	2,91	3,52	3,18
	B 1	6,60	5,03	6,15	5,93	2,50	2,83	3,78	3,04
	B 2	7,00	6,40	7,00	6,80	3,10	2,72	3,86	3,23
	B 3	6,90	7,06	6,68	6,88	3,00	3,06	3,86	3,31
A 3	Average	6,83	6,16	6,61	6,54	2,87	2,87	3,83	3,19

Experimental results were statistically evaluated by analysis of variance in software Statgrafics. In the scope of tested factors, yield was significantly influenced only by year (P 0,05 = 0,455). Interactions of year with soil cultivation and fertilization were also significant. The same tendency was found out also at yield of straw, which was high significantly influenced only by year (P 0,05 = 0,516).

Conclusions

Common pea is legume crop which should have stable position in crop rotations within sustainable husbandry. It positively influences soil structure and improves its fertility. Present opportunities of big choice among machinery and tools for soil cultivation enable utilization of modern technologies. These options offer apart from classical soil cultivation also reduced ways of soil cultivation. Since every agricultural enterprise farms in different conditions, there is necessary to try out these innovations on specific sites. Our results have shown that conventional soil cultivation to depth 0,25 m was more suitable for production of common pea yield in comparison with shallower tillage to depth 0,15 m or the use of disk tools to depth 0,10 m. But the differences among yields were not statistically significant. The course of weather had a high share on reached yields because year significantly affected yield of seeds and also straw. Plant nutrition of common pea is important as well. Even though common pea is able to provide nitrogen through nodule bacteria, the sufficiency of all nutrients in balanced ratio is necessary. Investigated variants of fertilization positively influenced the formation of yield elements and overall phytomass amount but statistically this effect was not significant.

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IMPACT OF DIFFERENT SOIL TILLAGE SYSTEMS ON EARTHWORM'S POPULATION AND RESIDUE COVER

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Abstracts

To determine soil surface coverage by harvest residues and number of earthworm's as an excellent indicator of soil productivity two soil properties, the research of different soil tillage systems for the winter wheat – soybean crop rotation had been conducted at the north-eastern Croatian chernozem soil type, during the seasons 2002/03-2004/05. The harvest soybean residues measurements showed the least covered soil at CT treatment (7%), followed by more coverage at DH (16%), CH (21%) and the most covered soil at NT treatment (86%). Regarding earthworm population, during three year average, their number was higher with the smaller soil disturbance by more and more reduced soil tillage systems, and it showed CT<CH<DH<NT order. Longer period than three years is needed to reflect positive effects of reduced soil tillage systems on build-up of crop residues and earthworms population.

Keywords: Soil tillage, residue covers, earthworms.

Introduction

The conservation soil tillage is defined as any soil tillage system where the soil surface is covered by 30% of harvest residues at the time when subsequent crop is sown (*Eck and Brown, 2004.*), or any soil tillage system which is reducing loss of water and soil if compared with conventional soil tillage (*Butorac, 1999.*). In conservation soil tillage systems, harvest residues are presented as very important factor, which has positive, but also negative, implications at crop production. The most frequent cited negative impacts are stronger disease and pest infestation, harder soil tillage and sowing, nitrogen depression, together with higher knowledge and specialized agricultural tool. The most important advantages of conservation soil tillage are in domain of physical, chemical and biological complex of the soil, with the emphasis of reduced impact of direct sunlight at soil surface, decreased evaporation, snow capture and better water infiltration (*Barnes and Bohmount, 1958.*), avoidance of soil crusting, wind and water erosion prevention, and higher biogenity of the soil (*Moldenhauer, 1983.*).

Many authors presented strong correlation of earthworms and amount of harvest residues at the soil surface. Earthworms play a major role in overall soil fertility and productivity (*Jordan et al. 1997*), and may alter the physical, chemical, and biological properties of a crop production soil ecosystem. Agricultural management practices affect earthworm populations (*Hubbard et al. 1999*). Any physical manipulation (e.g. soil tillage) of the soil ecosystem may, in turn, affect the activities and ecology of earthworms (*Jordan et al. 2000*). As the number and intensity of tillage operations increase, so does the physical destruction of burrows, and the earthworm themselves. Less intensive tillage systems that leave residues on the surface throughout the year improve the environment for earthworms.

The residues provide food, insulate earthworms from weather conditions, provide cover to protect them from surface predators, and protect their burrows. Earthworms do some main soil function: Shred residues, stimulating microbial decomposition and nutrient release; improve soil stability, air porosity and moisture holding capacity; reduce disease by bringing deeper soil to the surface; improve water infiltration; improve root growth by creating channels lined with nutrients for plant roots to follow.
The objective of this research was to establish differences in soil surface coverage by soybean harvest residues among soil tillage systems, together with its influence at earthworm population beneath different soil tillage systems.

Materials and methods

The field experiment

Field experiment was conducted in Baranya County, at the north-eastern Croatia, at experimental field near Knezevo (N: 45°82′, E: 18°64′) for winter wheat (*Triticum aestivum* L.), cultivar Demetra, in crop rotation with soybean (*Glycine max* L.), cultivar Tisa, during three years (2002/2003, 2003/2004, 2004/2005).
The experimental site soil is classified as a calcareous chernozem on loess substrate. The soil analyses presented very favorable chemical properties (pH in H_2O = 8.1, pH in 1M KCl = 7.5; humus = 2.6%, $CaCO_3$ = 2.1%; AL-soluble P_2O_5 and K_2O = 18.7 and 28.4 mg $100g^{-1}$, respectively).
The main experimental set-up was a complete randomized block design in four repetitions, with four continuing soil tillage systems. Area of experimental field was divided into basic experimental plots of 900 m^2 for each tillage treatment (*Jug, 2006.*)
The used soybean cultivar was Tisa, with the sowing amount of 120 kg ha^{-1}. The fertilization was uniform for all soil tillage treatments and investigation years, as follows: $N:P_2O_5:K_2O$ = 40:130:130 kg ha^{-1}. The sowing was performed at all soil tillage treatments with No-till drill JD 750A. The crop protection was uniform fro all treatments. Collected data were statistically processed by ANOVA, according to the experimental design, and means were compared by the protected least significant differences for $P<0.05$ significance level of performed F-tests.

Soil tillage treatments

Soil tillage treatments were as follow: CT) Conventional tillage includes mouldboard ploughing up to 30 cm depth, followed by diskharrowing, sowing preparation and sowing with no-till driller John Deere 750A; CH) includes chiseling on up to 30 cm depth, followed by diskharrowing and sowing as for CT; DH) includes diskharrowing and sowing as for CT; and NT) No-tillage sowing without any primary tillage operation.

Weather characteristics

Weather characteristics were mainly specific in comparison with long-term means. For example, precipitation in the period April-July were lower for 116%, and mean air temperatures were higher for 2.5°C in 2003 (*Table 1*).

Residue cover

The soil surface cover by residues from the preceding harvest were made by simple "Line-transect method" (*Shelton et al., 1998*), adopted and changed for SI system of measuring units. Measurements included measure tape of 15 m with labels at each 15 cm length, set up at the angle of 45° at the planted crop rows. Only residues thicker than 2.5 mm found directly under the 15 cm label were taken into consideration. After 100 readings with this method, the recorded number presented also exact percentage of soil surface coverage. For better accuracy, the sampling has been repeated four times at each plot. Since harvest residue is in correlation with the yield, the previous soybean crop yield was also statistically processed.

Table 1.: Precipitation and mean air-temperatures (the data of Knezevo - Brestovac Weather Bureau) 2002-2005 and long-term means (LTM: 1965-2005)

Year	2002	2003	2004	2005	LTM	2002	2003	2004	2005	LTM
Period	Precipitation (mm)					Mean air temperatures (^oC)				
Humid period	182	222	332	384	266	4.8	3.5	4.3	3.8	4.5
April	64	9	119	54	49	11.4	11.2	12.0	11.5	11.1
May	86	33	77	55	58	18.8	20.0	14.9	17.0	16.5
June	49	19	114	88	88	21.7	24.5	19.5	20.4	19.7
July	61	61	41	168	68	23.8	22.8	21.9	21.4	21.2
August	111	23	52	155	54	21.5	24.7	21.6	19.7	20.9
September	63	34	43	82	55	15.9	16.4	15.9	17.5	16.4
Dry period	434	179	447	602	372	18.9	19.9	17.6	17.9	17.6

<u>*Earthworm populations*</u>

Earthworms (*Lumbricus terrestris L.*) were hand-sorted from each 10 cm layer up to 50 cm depth. They were collected each spring in 3 years (02. May 2003; 21. May 2004; 11. May 2005), after sowing soybean. Densities were determined on a per square meter basis.

Results and discussion

As it is visible from the results in *Table 2.*, the coverage of the soil surface by harvest residues strongly differed among treatments. By analyzing three-year averages at investigated treatments, it can be noted that the smallest weight was found at CT (7%), which was significantly lower than other soil tillage treatments.

Table 2: Influence of soil tillage treatments on residue covers (%) in period 2002/2003-2004/2005. year.

Soil tillage (T)		Year (Y) 2002/2003	2003/2004	2004/2005	Average (T)
CT		7a	6a	7a	7a
CH		16 b	23 c	25 c	21 c
DH		15 b	18 b	15 b	16 b
NT		75 c	89 d	95 d	86 d
Average (Y)		28 A	34 B	36 C	33
LSD (T)	0.05	2.49	3.40	4.74	1.92
	0.01	3.57	4.88	6.81	2.59
F-test		1646.45**	1234.26**	752.37**	3047.24**
LSD (Y)	0.05	1.04			
	0.01	1.57			
F-test		156.39**			

Means with the same lowercase letter(s) are not significantly different at P<0.01 level (T)
Means with the same uppercase letter(s) are not significantly different at P<0.01 level (Y)

Soil surface cover at DH was more than double higher (16%), and at CH three times higher (21%) than at the CT. As it was expected, the highest amount of harvest residues was recorded at NT (86%).

Table 3: Earthworm populations (*Lumbricus terrestris*) on four different tillage treatments in period 2003-2005.

Tillage (T)	Soil depth, cm (D)	Year (Y) 2003	2004	2005	Average (D)
CT	00 - 10	0	12	16	9
	10 - 20	4	16	20	13
	20 - 30	8	8	8	8
	30 - 40	8	8	4	7
	40 - 50	0	0	0	0
Sum (C)	Earthworms/m^2	20	44	48	37 A
Average (T)					7
CH	00 - 10	4	16	16	12
	10 - 20	8	24	24	19
	20 - 30	4	8	16	9
	30 - 40	8	8	8	8
	40 - 50	8	4	4	5
Sum (C)	Earthworms/m^2	32	60	68	53 B
Average (T)					11
DH	00 - 10	8	32	24	21
	10 - 20	8	24	28	20
	20 - 30	12	16	24	17
	30 - 40	12	8	12	11
	40 - 50	4	0	8	4
Sum (C)	Earthworms/m^2	44	80	96	73 C
Average (T)					15
NT	00 - 10	12	28	32	24
	10 - 20	20	48	48	39
	20 - 30	20	28	28	25
	30 - 40	8	8	16	11
	40 - 50	4	0	8	4
Sum (C)	Earthworms/m^2	64	112	132	103 D
Average (T)					21
Average Across Soil Tillage	00 - 10	6	22	22	17 b
	10 - 20	10	28	30	23 c
	20 - 30	11	15	19	15 b
	30 - 40	9	8	10	9 ab
	40 - 50	4	1	5	3 a
LSD (T)					
0.05					4
0.01					5
LSD (D)					
0.05					5
0.01					6

Means with the same lowercase letter(s) are not significantly different at P<0.01 level (D)
Means with the same uppercase letter(s) are not significantly different at P<0.01 level (T)

In analysis of the average values of all soil tillage treatments by year, it is very important to point out that the amount of harvest residues at CT and DH during a whole period of the experiment stayed approximately equal, whereas at CH treatment the tendency of accumulation of residues can be observed. This accumulation is even more expressed at NT, which is understandable, since the direct sowing was applied continuously during all years of the research. It can be noted that the amount of the residues, or their percentage of the soil surface cover, is proportional with the soil tillage reduction.
According to criteria of *Eck and Brown (2004.)*, where 30% of the harvest residues is the lower limit for the soil tillage system to be proclaimed conservational, only treatment NT fulfilled this requirement, with the three-year average of 86% of soil surface coverage.
Regarding the effect of soil tillage system treatments at earthworm (*Lumbricus terrestris*) population (*Table 3*), highly significant differences were recorded for all three levels of the influence, grouped in effects of Year, Tillage and Soil Depth. The lowest number of earthworms was found beneath CT (37 m^{-2}). The number of earthworms beneath CH was bigger for 16 individuals (46%) than CT, followed by DH (36 individuals more than CT, or 97%) and NT, where 66 more individuals were found (or 178% if compared with CT). This is showing clearly that the reduction of the soil tillage is contributing toward growth of earthworm population, according the sequence: CT<CH<DH<NT. Similar findings were found by other authors, such as *Parmelee et al. (1990), Kladivko (1993), Birkás et al. (2004)* and *Cathcart and Dunn (2006)*. *Hubbard et al. (1999*) stated that, in order to increase earthworm population and biomass, soil tillage should be reduced or completely omitted.
In analysis of the soil depths, it is important to emphasize that the highest number of earthworms was found at the 10 – 20 cm, regardless of soil tillage system. Lower count was established for 00 – 10 cm depth. Furthermore, earthworm count decreased in deeper soil layers, which is understandable since there have been less residues on which earthworms have been feed upon. It is important to point out that the earthworm count was higher at deeper soil depths during the drought in 2003 at all soil tillage systems but NT, with the highest soil surface cover. This is confirming better soil properties protection by harvest residues in extreme situation, presumably due to better soil moisture conservation.

Table 4: Influence of soil tillage treatments on soybean yields (t ha^{-1}) in period 2002-2004. year.

Soil tillage (T)		Year (Y) 2002	2003	2004	Average (T)
CT		3.46a	2.54b	3.13b	3.04b
CH		3.47a	2.31b	3.02b	2.93b
DH		3.43a	2.15b	3.07b	2.88b
NT		3.07a	1.32a	2.30a	2.23a
Average (Y)		3.36 C	2.08 A	2.88 B	2.77
LSD (T)	0.05	0.46	0.28	0.19	0.17
	0.01	0.66	0.40	0.27	0.23
F-test		$1.85^{n.s.}$	36.17**	45.01**	38.75**
LSD (Y)	0.05	0.21			
	0.01	0.32			
F-test		109.35**			

Means with the same lowercase letter(s) are not significantly different at P<0.01 level (T)
Means with the same uppercase letter(s) are not significantly different at P<0.01 level (Y)
n.s. – non-significant

During the three-year period, the count of earthworm grew at all reduced soil tillage systems, whereas at CT the number of earthworms stagnated after drought year 2003.
The soybean yield analysis showed that in the first year of the research there were no differences among soil tillage treatments. For second and third year, the highest yield was achieved at CT treatment. The lowest at the P<0.01 significance level was the yield of NT treatment (*Table 4*).
The average three-year yields of soybean also pointed out NT as the worst treatments, also at the highly significant level.
Although the yield at CT treatment was the highest for all three years of the research, the amount of the soil surface coverage was regularly the lowest one, due to its regular incorporation into the soil.

Conclusions

Based on this research of the coverage of soil surface by harvest residues and the earthworm population under different soil tillage systems, following conclusions can be presented:

- Line-transect method used in this research can present very simply the state of soil surface coverage for given soil tillage systems.
- The highest influence at the soil surface coverage had applied soil tillage system, where the soil coverage was proportional with the degree of reduction of intensity of soil tillage.
- At the treatments of conventional soil tillage (CT) and continuous diskharrowing (DH), the amount of harvest residues was constant in years, whereas at treatments with chiseling and diskharrowing (RH), and especially at direct drilling treatment (NT), the amount of soil surface coverage had tendency of the constant growth.
- The soil tillage system statistically influenced earthworm population.
- In three-year period average, higher count of earthworm was recorded for treatments with higher reduction of soil tillage intensity, with following CT<CH<DH<NT order.
- In comparison with conventional soil tillage system (CT), at the chiseling and diskharrowing treatment (CH) it was recorded 43% more earthworms, at the diskharrowing (DH) 97% more, and at the No-tillage (NT) even 178% more earthworms.
- The observed changes during the observed time are suggesting that longer period than three years is needed to reflect positive effects of reduced soil tillage systems on build-up of soil surface coverage by crop residues and growth of earthworms population.

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A COMPARISON OF CONVENTIONAL AND DIRECT DRILLING SYSTEMS FOR SECOND CROP CORN PRODUCTION IN EASTERN MEDITERRANEAN TURKEY: 1ST YEAR RESULTS

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Abstract
The purpose of this study was to compare a modified direct planter (DP_2) to conventional tillage (CT) and a commercial direct planter (DP_1) in second crop corn production on a medium textured soil. The comparisons were made in terms of weed population, seed distribution, plant emergence, residue cover and yield. Weed densities were lower in CT and DP_2 whereas CT resulted in much lower wet and dry based weed weights compared to both direct planting methods. Tillage method had a significant effect on emergence rate ($P<0.01$). Tillage method affected seeding depth and seed spacing at 1% level. Residue cover was less than threshold residue cover of 30% in CT while both direct planters resulted in residue coverages of about 90%. Tillage method had an effect on yield at 5% probability level whereas the highest yield was found in method DP_1.

Keywords: Conservation tillage, direct planting, seed distribution, residue cover, emergence rate, corn yield.

Introduction

Tillage has been an important aspect of technological development in the evolution of agriculture (Opara-Nadi, 2008). The tillage embraces the concepts and features of both conventional and conservation tillage systems. The use of conventional tillage, lack of crop rotation, or burning the residue results in soil erosion and the loss of organic matter (Reeves, 2004). Farmers therefore need to manage their resources and adopt appropriate tillage practices without removing residues in order to effectively store and use the limited amount of precipitation for crop production and to control soil erosion (Jin et al., 2007). The term conservation tillage generally refers to a variety of crop production systems that deliberately attempt to minimize tillage operations such as plowing, disking, ripping, and chiseling. As a result, crop residues tend to accumulate at the soil surface (Klonsky and Mitchell, 2004). Conservation tillage was defined as tillage and planting system that retains at least 30% of cover crop residues on the soil surface after planting operation is completed. The stubble or plant residues are not completely incorporated, and most or all remain on top of the soil rather than being plowed or disked into the soil (Peet, 2008).

There are many potential advantages for reducing the number of tillage operations in crop production. Erosion is reduced by at least 50% in these soils compared to bare soils (McCarthy et al., 1993; Fallahi and Raoufat, 2008). Reduced tillage reduces the number of farming operations, which ensures a reduction in tillage costs (Klonsky and Mitchell, 2004), and reducing the amount of tillage equipment needed, which results in lower machinery

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investment. Crop residue especially is effective in reducing evaporation rate of water from soil (Cassel and Wagger, 1996), provides a source of plant nutrients, improves organic matter level in the soil, and increases soil water content by reducing evaporation and increasing infiltration rate and enhances crop growth (Chastin et al., 1995; Fallahi and Raoufat, 2008), includes trapping snow, minimizes water and wind erosion, and returns valuable nutrients to the soil. Soil erosion is a leading cause of soil degradation due to the loss of organic matter (Al-Kaisi, 2001). Organic matter from straw, stubble and chaff binds soil particles, improving soil structure. Well-structured soils drain faster and make better seedbeds. Most importantly, good soil structure improves the ability of the soil to deliver water and nutrients to crops (Anonymous, 2007).

In spite of advantages of the conservation tillage, it increases the risk of poor stand establishment and therefore limits its adoption by farmers (Wells et al., 1983; Allmaras et al., 1991). In addition, weed infestations and difficulties in seeding due to residues are the problem for the adoption of direct seeding (Yalçın and Çakır, 2006). Swan et al. (1994) observed that surface residues decrease planting depth and uniformity and increases the number of seeds placed closer to the surface. In order to overcome the seed placement problems in conservation tillage systems, Erbach (1981) suggested equipping row-crop planters with rolling coulters. According to Raoufat and Mahmoodieh (2005), planters equipped with rolling coulter attachment improves seeding indices in conservation tillage systems.

In Turkey, conventional tillage methods are predominantly practiced, in which all crop residues are removed from the fields whereas conservation tillage has not become a practice for Turkish farmers, yet. Very few farmers have started applying reduced tillage and direct planting lately. Thus, extension aspect of these practices and hence the adoption of conservation tillage lags scientific research that has been conducted in the last two decades in Turkey. The desire of farmers to conserve the soil and water resources seems to have secondary importance as most decisions to change cultural practices are frequently influenced by economic factors. The risks associated with conservation farming, however, can be minimized through planning and progressive management (Bucher at al., 1983). Considering the disadvantages of intensive farming and the related costs, direct seeding becomes more vital for farmers with less plant production problems for Turkish farmers (Yalçın and Çakır, 2006).

The lack of appropriate and affordable planting equipment has limited conservation tillage practices in crop production in Turkey. Therefore, a precision planter was modified and equipped with a coulter and pressing wheels to construct an affordable direct planter for small farmers and was tested in previous research (Korucu, 2002). A three year study has been initiated to test this modified direct planter and develop the planter further as a direct planter which could be preferred more by small farmers who might be willing to adopt conservation tillage methods. The objective of the study was to determine the effect of conventional tillage (CT), conservation tillage with direct planting with a commercial direct planter (DP_1), and conservation tillage with a modified direct planter (DP_2) on residue cover, emergence rate, weed population, seeding depth, seed spacing, and yield.

Materials and Methods

Materials

The experiments were conducted in 2007 in Kahramanmaraş Province on sandy clay loam soil in the Eastern Mediterranean region of Turkey at an altitude of 640 m. Organic matter determination was done to determine the initial conditions at the first year of experiments and were 2.21% and 1.99% respectively at 0-10 cm and 10-20 cm.

A direct planter (DP_1) and a modified direct planter (DP_2) were used for conservation tillage, and were compared to conventional tillage (CT). DP_2 was equipped with double disc furrow opener and 8 wave coulter with a diameter of 0.42 m (Figure 1). The coulter cuts the residue and penetrates before furrow opener engages the soil. The coulter assembly was fixed so that the coulters could work at the same depth as furrow opener discs. DP_1 had row cleaners of a diameter of 0.33 m in front of the 13 wave coulters (diameter of 0.4 m) which clean residue thereby decreasing coulter resistance and help achieve better seedbed preparation. Row cleaner and coulter attachments are assembled on the row crop planter ahead of the furrow opener discs.

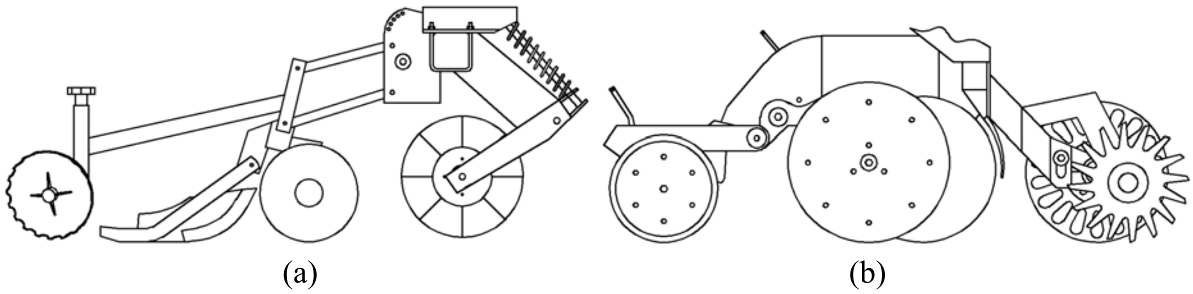

Figure 1. The schematics of the coulters of the modified planter (a) and the direct planter (b)

The PTO was used to provide with vacuum needed for disc seeders for DP_2 while DP_1 employs a hydraulic motor to drive the fan of the planters. DP_2 is a common four-row corn planter with 8 waved coulters. Extra weights were not needed on the planter for a better penetration of coulter into the soil. Another difference between the two planters is that DP_1 is equipped with a liquid fertilizer whereas DP_2 has granular fertilizer tanks. Finally, the number of rows was four on DP_2 and six on DP_1. Row spacing, seed spacing, and seeding depth were adjusted to be 70 cm, 18 cm, and 6 cm respectively on the three planters.

Methods

2.2.1 Experimental design and applications

Complete randomized design was used with three replicates in sandy clay loam soil. The size of plot was 3.4 da (66.8 x 50 m) (Figure 2). Plots were 8.4x50 m in DP_1 and 5.6x50 m in CT and DP_1 applications. The tillage equipment used in each tillage method is as follows:

1) Conventional tillage (CT) : chisel + disc harrow + planter (Sönmezler) + fertilizer spreader + disc harrow + float + planting machine
2) Direct planting 1 (DP_1) : Direct planter (JD 1700)
3) Direct planting 2 (DP_2) : Modified direct planter (Sönmezler)

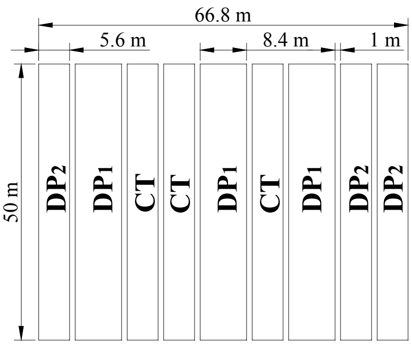

Figure 2. Experimental design. CT: Conventional tillage, DP_1: Direct planting with JD 1700, DP_2: Direct planting with a modified planter (Sönmezler)

2.2.2 Data collection and analysis

The measured parameters for comparing the three methods include weed population, residue cover, emergence rate, seeding depth, seed spacing, and yield. Moisture content, bulk density, and penetration resistance were also measured at three layers, that is 0-10 cm, 10-20 cm, and 20-30 cm.

The weed species were identified in each block and the number of weeds was counted with three replicates. Dry and wet based weights of weeds were determined. The first crop, wheat, was combine harvested, and the field was covered with residue of previous crop. Three replications of image processing measurements were done to estimate residue cover after planting has been completed. The number of plants that have emerged was counted until emergence has been completed at about 10 days from planting. The ratio of theoretical number of seeds that were planted over the number of emerged plants was calculated to be the percent emergence rate (Bilbro and Wanjura, 1982).

The seeding depths and plant spacings were measured over 10 m distances with three replicates in the middle three rows of each block. Plant spacings were measured after the emergence has been completed. Corn yield was determined by hand harvesting over 5 m lengths with five replicates in each block and then weighing corn kernels. The average yield for each block and each method was expressed in kg ha^{-1}.

Moisture content, bulk density, and penetration resistance were measured at the beginning of the experiments to determine the initial conditions of the blocks. Two more measurements were done during the rapid development stage of the plant roots to evaluate the soil moisture availability based on the method used and penetration resistance of soils during the rapid growth stage of the plants.

The effect of tillage method or the planter type on emergence rate, residue cover, yield, and soil properties was determined through multiple mean comparison tests. Emergence rate and residue cover data were transformed before the data were analyzed using the mean comparison tests.

Results and Discussion

Weed density

Ten different weed species were found in the experimental blocks (Table 1). Weed density was similar in CT and DP_2, and was higher in DP_1. Annual weeds such as *Amaranthus retroflexus* and *Solanum nigrum* emerge earlier than other weeds, whose density increases when soil is tilled since tillage create an environment conducive to faster emergence for annual weeds. *Amaranthus retroflexus* was denser in DP_1 application probably because the machine had row cleaners which helped coulters penetrate and disturb soil easily compared to DP_2. The vegetative growth of *Sorghum halepense* was higher compared to other weeds during measurements, which were denser in DP_2 application. As a result of different vegetative growth of weeds, the wet based and dry based weights of weeds in each application differed significantly even though the weed densities were similar in CT and DP_2. Wet and dry based weights of weeds were 9.7, 274.1, and 195.8 g/m^2 and 6.2, 64.5, and 58.9 g/m^2, respectively for CT, DP_1, and DP_2. The experimental blocks were not treated differently for weed control. Chemical was sprayed in all blocks once and in-row cultivator was also used once for plant protection.

Table 1. Effect of tillage on weed densities in second crop corn production

Weeds	Weed density (adet/m^2)		
	CT	DP_1	DP_2
Amaranthus retroflexus	4	5,2	1
Avena spp.	1,5	3,5	0,2
Convolvulus arvensis	-	0,4	-
Cynodon dactylon	-	-	0,25
Cyperus rotundus	-	1,95	-
Portulaca oleracea	0,25	1,7	0,1
Solanum nigrum	6	10,8	2,65
Sorghum halepense	0,25	0,4	5,5
Tribulus terrestris	0,75	0,25	0,1
Xanthium strumarium	0,25	0,6	1,5

Residue cover

Residue cover was less than the threshold residue cover of 30% in conventionally tilled blocks while direct planters resulted in much higher residue coverage rates (Table 2). As a result, sufficient residue coverage was not accomplished in conventional method to conserve the soil. Low level of variation was observed in direct planting methods while conventional method caused medium level variations in measured quantities.

Table 2. Tillage effect on crop residue (%) on soil surface after planting of second crop corn

Applications	Mean	Std. deviation	CV (%)	Skewness	N
CT	21.73 ^{b}	4.82	22.1	-1.72	3
DP_1	93.40 ^{a}	6.36	6.8	0.12	3
DP_2	90.73 ^{a}	5.50	6.1	1.73	3

CT: conventional tillage, DP_1: direct planter; DP_2: modified direct planter

The analysis of variance showed that tillage method had a significant effect on residue coverage ($P<0.01$). First crop (wheat) residue coverage was about 93% in direct planting while it was about 22% in conventional tillage. The residue cover was much higher in direct planting methods due to the fact that the wheat straw had been spread across the field by the combine and no stubble or straw had been removed from the field before corn planting. This could also partly explain the difficulty of penetration of coulters into the soil, resulting in misplaced seeds in terms of vertical seed distribution.

Emergence rate

The emergence rate was the lowest in DP_2 application with 68.1% whereas the highest emergence rate was obtained in CT with 85.1% (Table 3). Tillage method had a significant effect on emergence rate ($P<0.01$). According to analysis of variance, CT and DP_1 applications resulted in the same emergence rate. Emergence rates had small level of variations in these applications. Although the emergence rate was significantly low in DP_2 application, the average yield was not the lowest. The disagreement between the amount of yield and emergence rate could have resulted from natural variability since the sampling locations were chosen arbitrarily in the blocks both for emergence rate and yield.

Table 3. Tillage effect on emergence rates (%) of second crop corn

Applications	Mean	Std. Dev.	CV (%)	Skewness	N
CT	85.10 [a]	6.61	8	1.19	9
DP_1	80.71 [a]	13.49	17	0.08	9
DP_2	68.12 [b]	8.63	13	1.78	9

CT: conventional tillage, DP_1: direct planter; DP_2: modified direct planter

Seeding depth and seed spacings

Applications had significant effect on average seeding depth (P<0.01). The seeding depth also varied considerably within each application as suggested by coefficient of variations larger than 15% in all cases (Table 4). Skewness was slightly higher or less than 0.5 implying normality in the data set.

The planters were adjusted to place seeds at 6 cm depth, which could not be achieved on average in any of the applications except for conventional tillage with 5.27 cm. It appears that the down pressure for the seeding units on planters was not properly adjusted for coulters to penetrate to desired level thereby creating inaccurate placement of the seeds.

Table 4. Tillage effect on seeding depth (cm) and seed spacing (cm) of second crop corn

Measurements	Applications	Mean	Std. Dev.	CV (%)	Skewness	Kurtosis	N
Seeding depth (cm)	*CT*	5.27 [a]	1.62	31	0.55	0.74	63
	DP_1	4.39 [b]	1.26	29	0.21	0.37	63
	DP_2	4.63 [b]	1.21	26	-0.26	-0.44	63
Seeding spacing (cm)	*CT*	19.23 [b]	3.85	20	1.52	3.48	63
	DP_1	22.22 [a]	5.13	23	0.40	-0.04	63
	DP_2	18.43 [b]	3.86	21	0.56	0.45	63

CT: conventional tillage, DP_1: direct planter; DP_2: modified direct planter

Measured plant spacings showed that the averages were close to the adjusted spacing of 18 cm. Tillage method had significant effect on seed spacing (P<0.01), placing mean plant spacing for DP_1 application in a different group (Table 4). Coefficient of variations ascertains that plant spacing had medium level of variations. All methods could be deemed successful in terms of horizontal seed distribution considering soil roughness. Tillage effect may be explained by the well known differences in seedbed conditions due to loosening of soil in conventional tillage as compared to undisturbed topsoil in direct planting. Based on visual observations, it may be concluded that unevenness in soil surface might have contributed to the effect of application on seed spacing.

Yield

The moisture content of hand harvested crop was determined measured using a grain moisture tester and then the yield was converted at yield values at 15% moisture content (Table 5). Tillage method had an effect on yield at 5% probability level (P<0.05). The highest yield was found in method DP_1 while the remaining cases had statistically the same yield.

Table 5. Tillage effect on second crop corn yield (kg/ha)

Applications	Mean	Std. Dev.	CV (%)	Skewness	Kurtosis	N
CT	9391.26 [b]	1725.07	18	-1.30	2.37	9
DP_1	11482.90 [a]	1044.53	9	0.11	-1.05	9
DP_2	9311.38 [b]	2492.01	27	-0.15	-0.51	9

CT: conservation tillage , DP_1: direct planter: DP_2-A: modified direct planter

It can be concluded that the results in terms of achieved yield is in favor of direct planting methods since the same yield as conventional tillage was obtained with less number of operations that caused improved timelines and reduced labor, which can be related to cost of overall operations for crop production.

Moisture content, bulk density and penetration resistance

Soil moisture content during planting at the first layer (0-10 cm) was about 8-10% across the plot. Conventionally tilled blocks had slightly greater moisture content at the first layer as a result of using disk harrow and bringing moist soil up during seedbed preparation. Second and third layers had about 13-15% moisture content. During rapid root growth period, soil moisture contents were usually found to be 10-18% at the first layer and 13-19% at other two layers before the subsequent irrigations were applied.

The bulk densities did not differ significantly during plant growth either in terms of application or measurement depth except for the initial measurements suggesting lower bulk density at the top layer. Although bulk density did not vary significantly with varying depth, the average bulk density was usually the highest at 10-20 cm. The bulk density either slightly increased or decreased from the second layer to the third layer, implying soil compaction at 10-20 cm.

No significant effect was found as a result of different applications on penetration resistance. But the depth had an effect on penetration resistance at 5% level during initial conditions and 1% level during subsequent measurements. Mean penetration resistance at the top layer was lower than the other layers while the means were statistically the same in the second and third layers.

PR above 2.0 MPa can restrict root growth of many crops and further rise in PR can reduce plant growth (Junior et al., 2006). PR exceeded the threshold limit in all applications during planting. Irrigation helped PR decrease to the range where plant roots could develop free from excessive resistance in the soil. The PR, however, approached the threshold in about three weeks from the irrigation at about 10 to 20 cm depths, but not exceeded 2 MPa significantly.

Conclusions

Multiple irrigations are required in the Mediterranean region due to water deficit during vegetation period of the second crops. Annual average precipitation varies from 400 to 700 mm in the province. Sprinkler irrigation is widely practiced but is not usually applied in corn production since rapidly increasing plant height restricts the applicability of this method. One of the major drawbacks in adopting direct planting can be related to the irrigation method rather than utilization of direct planters. Crop residue severely affected water flow during irrigation in this study, requiring more labor for proper irrigation. The reduction in surface flow is in essence desired as a measure to control erosion. The farmer who is cooperating in this project, however, was interested in efficient irrigation rather than appreciating the potential benefits of erosion control. Based on first year experiences, it seems that the adoption of conservation tillage will heavily depend upon the capability to maintain crop residue while completing irrigation without loss of time. Reducing crop residue coverage may be of help but at the cost of increased erosion in inclined terrains.

Soil penetration resistance was highest at 10-20 cm in all applications. The tendency to increased soil compaction compared to 0-10 cm and 20-30 cm might have resulted from field traffic. Seed depth distribution was statistically different CT and DP applications. The best seed depth distribution was obtained in CT application. Average plant spacings were close to the theoretical spacing of 18 cm for the three methods used in the study with best spacing using DP_2. Direct planter 2, however, had the lowest mean emergence rate. Residue cover was less than the limit residue cover of 30% in the case of conventional tillage while both direct planters provided with much higher residue coverage rates compared to the threshold crop residue cover. Although the modified direct planter achieved the same yield as conventional tillage method, the yield was less than that of the direct planter. Direct planting method (DP_2) was more favorable since the same yield as conventional method or more (DP_1) was accomplished with reduced equipment and labor requirement compared to conventional tillage application. The use of an ordinary precision planter as a direct planter with some modifications was therefore encouraging. The timeliness and energy savings shall be determined next to more thoroughly compare these methods.

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EFFECTS OF DIFFERENT SOIL TILLAGE SYSTEMS ON SUGAR BEET YIELDS AND DYNAMICS OF HUMUS CONTENT IN SOIL

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Abstract
Different soil tillage practices in preparation for sugar beet cultivation and their effects on development and growth of this crop were studied in the years 2005 - 2007 in field conditions in three localities in a sugar beet growing region with different soil and climatic characteristics. Higher humus content on Chernozem soil was evident predominantly after shallow cultivation. On brown soil, humus content was increased in the treatment with depth loosening. In all localities similar yields were obtained within the treatments. However, it is impossible to conclude that reduced tillage promotes sugar beet yields. These may be influenced by other factors such as the variety or the weather pattern in the year of cultivation. Reduced yields were obtained after ploughing in all the localities under study.
Key words: soil tillage, humus content, sugar beet, yield, sugar content

Introduction
In an effort to save labour and energy in sugar beet cultivation no-till systems are used even more often. It is possible to use machinery for shallow soil cultivation which levels the soil surface and allows incorporation of commercial fertilizers in autumn. These technologies, however, increase the risk of extensive root branching in sugar beet. An important prerequisite for sugar beet production with reduced tillage is maintaining or possibly improving soil fertility and reducing energy inputs. According to Muchová *et al*. (1998) different soil tillage systems have effects on changes in the parameters of the technological quality of sugar beet. Prochot (1996) and Fecenko, Šoltysová (2000) pointed out positive effects of some growth stimulators on revitalization of soil environment, which promotes the activation of the rhizosphere. Only then shallow tillage may become very beneficial.
The conventional soil tillage practice in sugar beet production is ploughing in autumn and seedbed preparation in spring. Reduced tillage and crop planting systems are carried out mostly to save money and time. Reduced tillage can be used as no-till practice, shallow cultivation, sowing to frost-killed catch crops and as wind and water erosion control. This practice can be recommended for sugar beet cultivation on steep lands because sugar beet is a broad-row crop and there is a risk of water erosion especially in spring. Skalický (1995) and Hůla (1995) evaluated ecological technologies, e.g. sowing to frost-killed catch crops, and compared them with conventional technologies. They claim that it cannot be presumed that these technologies will mean significant cost savings or higher yields but they are effective in protection of soil surfaces from water erosion. Good results are produced after shallow tillage to a depth of 0.18 m and application of a multiple tiller in autumn and seedbed preparation by a compactor in spring and subsequent seeding.

Materials and methods
To compare different soil tillage systems for sugar beet and their effects on crop growth and development, field trials were established in the year 2004 in three localities in a sugar beet growing region differing in soil and climatic characteristics. In all localities and in all treatments the sugar beet variety Polaris was grown.

At the beginning of the study a soil survey of localities was carried out to get information about the soil conditions of the locality and about the agricultural farms involved. In all three localities, soil samples were taken to determine the content of humus and its qualitative components, to determine soil reaction and the initial nutrient status of the soil. Soil samples were collected at the start of sugar beet growing after the harvest of a previous crop (spring barley) at four depths: 0-0.10; 0.10-0.20; 0.20-0.30; 0.30-0.40 m. The total humus content (or oxidometric determination of soil organic matter) was determined by the Walkley-Black method, Novák-Pelíšek modification. The results of humus dynamics in different treatments of sugar beet growing were assessed in the years 2005 - 2007. In the localities a check on the biological yield following the methodology of Minx (1986) was performed. In each treatment a 10-m^2 plot was harvested in five replications. The roots were knocked together to remove dirt, weighed and a representative sample was chosen for laboratory determination of digestion. In the Bohuňovice locality AI (deep loosening) treatment was not assessed in the year 2005 because of technical problems. The same applies to AII treatment (shallow loosening) in the year 2007.

In all three localities three tillage treatments for sugar beet were examined:

<u>Soil tillage practices</u>
AI - depth loosening to a depth of 0.35 m
AII - shallow loosening to a depth of 0.18 m
B - ploughing to a depth of 0.25 m

<u>Basic soil and climatic conditions of the localities:</u>
Velešovice
The soil is characterized as Chernozem, modal on loess, variety carbonate, granular structure, loamy soil, topsoil thickness less than 30 cm. The soil reaction is neutral to alkaline, available P content is medium, K content is high and Mg content is high and total N content is medium. A long-term mean annual rainfall is 490 mm and a long-term annual temperature is 8.7 ^{0}C.
Morkovice
The soils are characterized as Chernozem modal on loess, loamy, granular structure, without skeleton, topsoil thickness is less than 28 cm. The soil reaction is neutral, available P content is medium, K content is good, Mg content is high and total N content is medium. A long-term mean annual rainfall is 615 mm, a long-term mean annual temperature is 8.5 ^{0}C.
Bohuňovice
The soil is characterized as brown soil, luvic on loess loam, crumb structure turning into lamellate, loamy to clay loam, topsoil thickness less than 31 cm. The soil reaction is slightly acid, available P content is medium, K content is medium, Mg content is good and total N content is medium. A long-term mean annual rainfall is 570 mm, a long-term mean annual temperature is 8.7 ^{0}C.

Results and discussion

<u>Humus content</u>
A number of authors have studied the effects of soil tillage on the distribution and degradation of soil organic matter. For example, by ploughing post-harvest crop residues are incorporated to a larger depth which accelerates the decomposition of soil organic matter - mineralization. This is due to a higher content of air in the loosened topsoil. The result is a momentarily larger amount of the nutrients available (released) for the subsequent crop. At the same time the degradation of soil organic matter increases and a large amount of released nutrients are washed away or removed by erosion. With minimum soil tillage practices there was a 100% increase in soil organic matter in the uppermost soil layer compared with ploughing which

generally results in an increased supply of humus in the top layer of the soil. A long-term input of organic matter into the soil has a favourable effect on its moisture and structure-forming process in favour of agronomically valuable structure elements.
The values of humus content in the localities over the years under study are given in Table 1.

Velešovice locality
In the year 2005 the highest humus content in AI treatment averaged 4.31%. In the horizontal distribution the highest content was in the layer from 0.10 to 0.30 m. In AII treatment humus content was the lowest (3.23%) and in B treatment the average content was 4.16%. The highest content was always in the surface layers. In the year 2006 the average humus content was the highest in treatment AII and the lowest in treatment AI. In all soil tillage systems the highest humus content was in the top layer of the soil. In the year 2007 the highest average humus content was with treatment AI (3.35 %). With shallow loosening humus content was the lowest (2.67 %). In the first two treatments humus content was always the highest in the top soil layers whereas in treatment B (ploughing) humus content was higher in the lower layers of the soil.
Graph 1 shows the equations of the trend of humus content in all the treatments of soil tillage during the three years. It was found that the highest increase in humus content was in the treatment with shallow loosening (AII), followed by the treatment with deep loosening (AI) and the slowest increase was in the treatment with ploughing (B).
Morkovice locality
In the year 2005 the highest humus content was in AII treatment and the lowest in AI. The top layers of the soil had a higher supply of humus after all soil tillage treatments. In the year 2006 humus values were consistent in all treatments. The highest average content was in AI (2.84%) and the lowest in B (2.36%). The highest values were recorded in the top layer of the soil (less than 0.10 m). In the year 2007 there was a decrease in humus content in all soil tillage treatments. The highest average value of humus content was recorded in AII and the lowest in AI.
The equations in graph 2 show the trend in this locality. The highest increase in humus content was in the treatment with shallow loosening (AII), followed by the treatment with deep loosening (AI) and the smallest increase was recorded in the treatment with ploughing (B). The trend was the same as that in the Velešovice locality.
Bohuňovice locality
In this locality there was the lowest humus content of all localities. The soils in this locality are, however, different from those of the other two localities. In the year 2005 only two treatments were compared. For technical reasons AI (deep loosening) was not involved. In AII the average humus content was 1.76% and in B it was 2.78%. As for humus distribution in individual horizons, in treatment B it was higher in the lower soil layers (0.20 – 0.40 m). In the year 2006 the highest average humus content was found in AI (2.05%) and the lowest in AII (1.54%). Humus distribution in individual horizons varied with soil tillage treatment. In AI treatment the highest humus content was in the top soil layer (less than 0.10 m), in AII in the layer from 0.20 to 0.30 m and in B in the layer from 0.10 to 0.20 m. In the year 2007 AII (shallow loosening) was not assessed for technical reasons. Higher humus content was recorded in the treatment with ploughing, especially in the lower soil layers.
The equations of the trend in this locality were not graphically shown because not all tillage treatments were assessed in the years 2005 and 2007.
From the results it is evident that humus content was most influenced by shallow loosening (Badalíková, Červinka, 2007). A significant effect on humus content in the soil and its quality is also exerted by soil compaction, as reported by Badalíková, Pokorný (2007). The results of penetration resistance showed a narrow correlation with humus content.

Sugar beet yields

All crops on small experimental plots were manually harvested, cleaned (without washing) and direct in field conditions the weight of beet roots in the treatments was determined. From each treatment and each locality a representative sample was taken in which digestion was determined. The yields from the treatments are given in Tables 2, 3 and 4.

As for the yields in the year 2005 (Table 2) in the Velešovice locality, sugar beet showed a high compensation ability – the smaller number of plants was compensated for by the higher root weights. In the Morkovice locality very consistent yields were found in all soil tillage treatments. In the Bohuňovice locality there were only slight differences in yields between treatments with and without ploughing. Černý *et al.* (2001), however, found in his study that the highest yield of sugar beet roots was in the treatment with green manure and deep ploughing.

In the year 2006 (Table 3) sugar content in beet roots was higher in Bohuňovice and Morkovice than in Velešovice. To compare the yields from individual treatments and localities a qualitative parameter (digestion) was used and a quantitative parameter (yield) was used as a converted yield at 16 % digestion. Tables 2 and 3 showing a comparison of sugar content of sugar beets did not reveal any significant differences between soil tillage treatments.

In the year 2006 in Bohuňovice the highest converted yield of 85 $t.ha^{-1}$ was found in treatment AI (deep subsoiling), and the lowest yield was in the treatment with ploughing (Červinka *et al.,* 2006). In the Morkovice locality, the highest converted yield was in the treatment with ploughing (92.5 $t.ha^{-1}$). The yield in treatment AI was 91.5 $t.ha^{-1}$. The highest differences in yields were recorded in the locality Velešovice where the highest converted yield was in AII (shallow loosening). Despite different yields in the localities treatments A (growing sugar beet without ploughing) gave results comparable to those with conventional tillage (ploughing).

In the year 2007 sugar content in all localities and in all tillage treatments was higher than in the year 2006. In Table 4 the highest sugar content was in the Bohuňovice locality where in treatment AI (deep loosening) the converted yield was 106 $t.ha^{-1}$. In the Morkovice locality, the highest converted yield and the highest sugar content in this year were in treatment B (ploughing) and the smallest with treatment AII (shallow loosening). In Velešovice the highest converted yield was in treatment AI due to the highest root yield but sugar content was the highest in treatment B.

Studies of humus content in the soil with different treatments led us to the conclusion that this is the quantity which changes in the course of the growing season, not only with climatic and soil conditions but also with soil tillage treatments. A three-year period is quite short for connected conclusions; nevertheless, the trend of dependence on the anthropogenic action on the soil showed that soil tillage with minimum impact on the soil or direct drilling promoted increased humus production. Humus content in the soil was not statistically significantly affected by different soil tillage systems.

Conclusion

On the basis of the results obtained we can state that on Chernozem soils in Velešovice and Morkovice humus content in all the years of the study was in favour of shallow loosening. On brown soil in Bohuňovice humus content was higher only in the treatment with deep loosening. In the treatments with loosening humus content was higher in the top layers of the soils (less than 0.20 m), whereas in the treatment with ploughing higher humus content was in most cases in the lower soil layers. This three-year study does not show a clear effect of soil tillage for sugar beet on humus content and distribution in different types of soil. In all localities the same treatments produced similar yields. In Velešovice and Morkovice the

lowest yield was produced in the treatment with ploughing. In the year 2005 the best yield results were obtained in the treatment with reduced soil tillage. This was confirmed in the year 2006 only in the Velešovice locality. In all localities the same treatments gave similar yields of beet roots. Also after conversion to the yield of polarised sugar the same treatments gave similar results. The results show that sugar content was the highest in the treatments with ploughing. An exception was the Velešovice locality where in the year 2005 sugar content in the treatment with deep loosening was the highest of all treatments.
It cannot be concluded that reduced tillage systems contribute to higher sugar beet yields. The yield may also be influenced by other factors such as the variety or the weather pattern in the year of growing. These factors will be subjected to further studies.

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Tab. 1: Humus content (%) by different soil tillage to sugar beet (2005-2007)

tillage treatment	depths (m)	Velešovice			Morkovice			Bohuňovice		
		2005	2006	2007	2005	2006	2007	2005	2006	2007
AI	0-0.10	4.16	4.35	3.56	1.75	3.13	1.70	0.00	2.59	1.90
	0.10-0.20	4.63	4.29	3.99	2.07	2.89	1.77	0.00	2.22	1.90
	0.20-0.30	4.46	3.92	3.11	1.52	2.86	1.70	0.00	2.12	1.66
	0.30-0.40	4.00	2.97	2.73	0.82	2.47	1.50	0.00	1.29	1.49
	average	4.31	3.88	3.35	1.54	2.84	1.67	0.00	2.05	1.74
AII	0-0.10	3.61	4.33	3.09	2.98	2.99	2.12	1.65	1.69	0.00
	0.10-0.20	3.08	4.54	3.08	2.22	2.84	2.10	1.67	1.34	0.00
	0.20-0.30	2.73	4.17	2.68	2.82	2.58	1.66	2.59	1.71	0.00
	0.30-0.40	3.51	4.06	1.86	2.09	2.56	1.48	1.15	1.41	0.00
	average	3.23	4.27	2.67	2.53	2.74	1.84	1.76	1.54	0.00
B	0-0.10	4.43	4.22	2.58	2.41	3.04	1.63	2.25	1.91	1.63
	0.10-0.20	4.40	4.61	3.17	1.98	2.36	1.89	2.48	2.05	2.05
	0.20-0.30	3.99	4.02	3.00	1.68	1.99	2.01	3.40	1.48	2.09
	0.30-0.40	3.84	3.64	2.81	1.46	2.07	1.51	3.02	1.47	2.17
	average	4.16	4.12	2.89	1.88	2.36	1.76	2.78	1.73	1.98

Tab. 2 Sugar beet yields and its sugar content by different soil tillage (2005)

lokality	variant	yield (t/ha)	sugar content (%)	re-counted yield (16% dig.)
Bohunovice	AII	70.28	18.9	83.0
	B	69.95	19.4	84.8
Morkovice	AI	91.7	18.8	107.8
	AII	91.4	18.5	105.7
	B	88.9	19.0	105.6
Velesovice	AI	84.33	19.3	101.7
	AII	86.6	18.9	102.3
	B	75.57	18.3	86.43

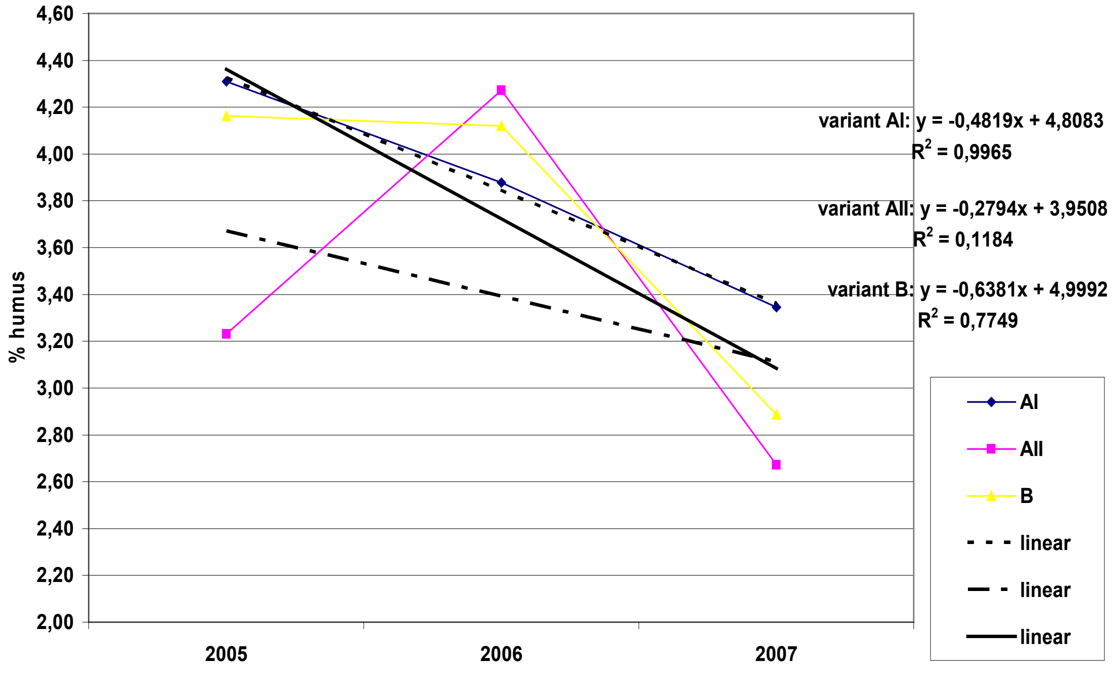
Tab. 3: Sugar beet yields and its sugar content by different soil tillage (2006)

lokality	variant	yield (t/ha)	sugar content (%)	re-counted yield (16% dig.)
Bohunovice	AI	83.53	17.5	85.05
	AII	78.13	18.9	80.92
	B	74.66	18.8	77.23
Morkovice	AI	88.53	18.4	91.14
	AII	75.8	17.5	77.18
	B	89.2	19.0	92.5
Velesovice	AI	77.26	17.2	78.38
	AII	89.86	17.8	91.83
	B	74.86	17.8	76.5

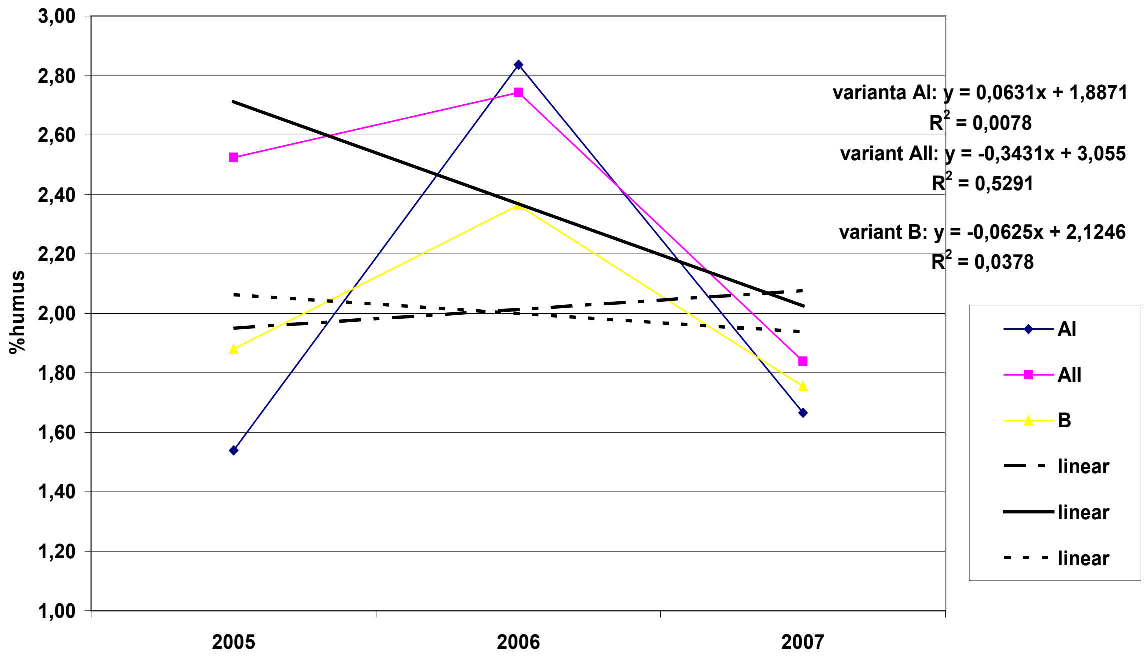
Tab. 4: Sugar beet yields and its sugar content by different soil tillage (2007)

lokality	variant	yield (t/ha)	sugar content (%)	re-counted yield (16% dig.)
Bohunovice	AI	87.9	19.3	106.0
	B	105.9	18.8	124.4
Morkovice	AI	102.6	17.7	113.5
	AII	98.7	17.1	105.5
	B	108.8	17.9	121.7
Velesovice	AI	105.3	18.9	124.4
	AII	83.1	19.2	99.6
	B	87.9	19.3	106.1

Graph 1: Trand equation of humus content
Velešovice 2005 -2007



Graph 2: Trand equation of humus content
Morkovice 2005 - 2007



IMPORTANCE OF SOIL CONDITION IN SUGAR BEET PRODUCTION

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Abstract

Numerous experiments have been carried out in order to review the soil condition needs and the right timing of tillage operations of sugar beet at the Department of Soil Management of Szent István University, Gödöllő.
Throughout the period of the three-year-long experiment series starting out in 2005, there were difficult years concerning both the weather and cultivation. In the course of the experiments we measured penetrometric resistance, moisture content, as well as mulch cover, and evaluated agronomic structure and plant phenology. As we have concluded, soil condition damages caused by cultivation, increase the climate sensitivity of soil. Climate dangers are enhanced mostly by the structure destruction, dustiness, settlement, crusting and soil compaction. We find the evaluation of sugar beet's conventional soil cultivation system important.

Keywords: looseness, compaction, climate-stress, mitigation, conservation tillage.

Introduction

The changes of the sugar market in the past years – the restricted quota system, closed up factories, a decreasing export of white sugar- and also the climatic extremes, which hinder the production more often, both lead up to difficulties for sugar beet producers and for the processing industry as well. Producers have only one chance to stay economic in a difficult situation that sugar industry must face. They must produce a quantity of raw material that is equivalent to their predetermined quota, and which also has an outstanding quality, on the lowest cost level that is possible. Exceeding or underachieving the permitted volume is not allowed. This way within the decaying market situation the improvement of cropping technologies is a possibility to stay economic (Bottlik, 2006, 2007).
The variety, the homogeneity of stand, the plant protection, the nutrient and water supply, the pre-crops and the soil conditions may be considered as the main risk factors of sugar beet production (Csorba, Birkás, 2001). The condition of soil has an effect on all factors mentioned above. Furthermore, soil is the only factor that may reduce and also intensify the weather extremes (without water supply) throughout its condition. The only economically relevant solution to avoid the climate extremes is the development and maintenance of favourable soil conditions and the adaptation of loss preventive cultivation (Birkás, Bottlik, 2006, 2007). In contempt of the climatic difficulties (drought), many farmers were able to produce on an appropriate level of quality and quantity. Examining the applied technology, it reveals that a great emphasis has been put on soil tillage.
This way it is no exaggeration to consider a reasonable, adaptive soil tillage as a defining factor to assure a safe crop production.
According to experimental results, the soil condition, that provides a secure beet production and this way a suitably good sugar yield under extreme weather conditions, is appropriate to lower damages caused by the climate (Birkás, Bottlik, 2005, 2006, 2007).

The usage of tillage tools used in soil cultivation is to be reconsidered. The development of soil condition that is appropriate to satisfy the needs of beet and also to reduce climate difficulties is not always possible with the typical machineries of conventional soil tillage systems. The necessity of conservation tillage emphasizes the usage of tillage cultivators, rippers, compact discs, flexible smoother-roller combinations, compactors. The adaptation of these tools, the right timing of operations, the influential effect of the region-soil type, a possible need for special additional processes raise many questions of details which are, in many cases, answered within our experimental series.

Material and methods

In the past years we have carried out field experiments at many sites in Hungary in order to point out the risks and errors of recently used sugar beet soil tillage systems and also to answer the questions posed by the utilization of new tillage tools and technologies.
Locations of experiments: Bácsbokod, Cegléd, Jászboldogháza, Hajdúböszörmény, Hajdúnánás-Tedej, Kiskunlacháza, Megyaszó, Szentes, Szerencs, Tímár, Tiszavasvári, Poroszló. The soil of the plots examined had predominantly loam, or clay-loam soil texture and chernozem and meadow-chernozem genetic soil type.

Applied investigations:

- Spade probe: a classic soil testing method to analyse looseness and soil structure to a depth of 30 cm, and also to reveal the tillage pan compaction and crop residues. (Figure 2)
- Penetrometer tests for soil resistance: down to 50 cm depth, measured by penetrometer (with 5 cm calibration, expressed in Mpa).
- Agronomic structure measurement: the analysis of clod fraction composition by special bolting work of soil samples taken from the 10 cm top layer. The percentage of certain aggregates (clod>10 mm; aggregate 2.5-10 mm; small aggregate 0.25-2.5 mm; dust<0.25 mm) can be expressed according to the weight of the sample. (Figure 1)
- Soil moisture test: measured by TDR 300 soil moisture sensor, expressed in weight percent.
- Measurement of mulch cover: visual comparison of a 0.25 m^2 sample field and a standard photo series.

Figure 1.: Agronomical structure analysis.

Figure 2.: Spade probe.

Applied beet tillage systems:

a) Conventional tillage:

At some parts of the locations mentioned above the so-called traditional soil cultivation system was used on the sugar beet fields (e.g. Poroszló). It is usual to base the soil cultivation on light and heavy disks, conventional or reversible ploughs without packer, harrows, combinators, clod crusher rollers.

b) Conservation tillage:

The tools of cultivation appropriate for reducing damages are: heavy duty (multi) cultivator, ripper, compact disk, compactor, flexible smoother-roller combinations. These machineries were used also at the examined fields.

In most cases these two types cannot be separated completely. Since the switchover to modern, adaptive soil cultivation needs significant investments, the development is continuous and this way the older machineries will stay in use. Therefore, choosing the right cultivation tool and the right timing of the operation requires great proficiency and discipline.

Results and discussions

The main results of the soil tests that have been carried out are to be presented below depending on the cultivation system used.

1. Investigation of soil looseness

It is proven that sugar beet doesn't require deep tillage but has a need for the looseness of soil extending to a 35-40 cm depth (Birkás, Máté, 2005, 2006). The loosening with depths differing from these data (35-40 cm) is also sufficient, if the soil gets regularly soaked with water down to this level. The presence of the compacted layer, that blocks the water infiltration, or the loose shallower layers become risk factors in extreme seasons, which revealed in the breeding seasons of 2006 and 2007 that both had an extreme distribution of precipitation. Assuming favourable precipitation conditions, (as in 2005 for e. g.), a plough pan deep down in 30 cm, unless it is too wide, did not cause any problems in the development of sugar beet tuber (Bottlik, 2005).

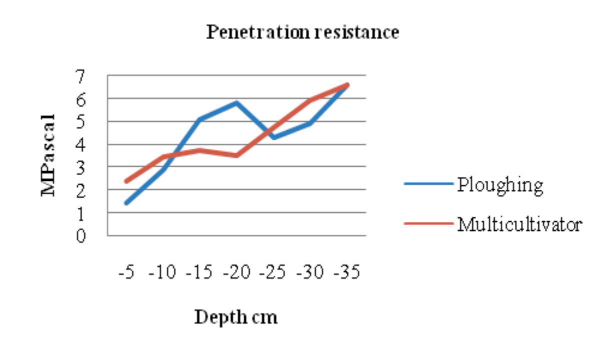

Figure 3.: Penetration resistance under different tillage in Jászboldogháza, 2007

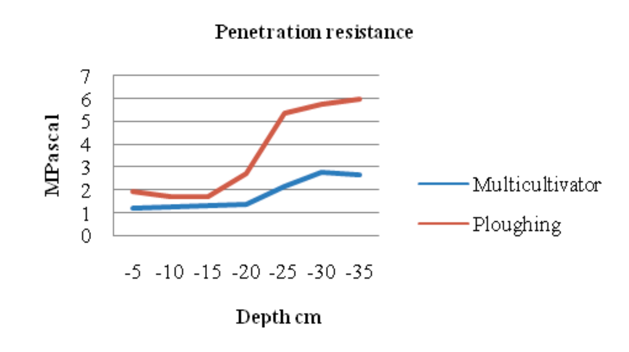

Figure 4.: Penetration resistance under different tillage in Hajdúböszörmény, 2007

As it is shown in Figure 1 and 2, in case of a ploughing primary tillage, a significant plough pan compaction occurs. Furthermore, it is a common problem that the actual tillage depth lags behind the previously planned one, which can also be seen in the diagram. According to the measurements, the pan layer can be found at 20-25 cm depth, which also means the actual depth of ploughing. In this case the depth needs of sugar beet were not fulfilled. The reason for this is the inappropriate primary tillage tool and the disregarded moisture. As for the primary tillage done by heavy cultivator, there is no pan layer. The figure shows that soil

resistance rises at the 30 cm tillage depth, though not significantly. Taking the typical soil moisture of tillaging time into account, it can be stated that primary tillage done by cultivator created a more favourable looseness than inverting tillage during the growing season.
Figure 5 demonstrates the significant difference in soil looseness at one of the habitats in two different experimental years using the same ploughing primary tillage in the growing seasons. The problem comes from the fact that the soil moisture was not taken into consideration at the time of ploughing. At the time of the tillage in 2005 the moisture was favourable at the tillage depth and this way no compaction occurred. On the contrary, at the time of tillage in 2007 on the planned level of tillage depth the moisture content was higher than the optimum moisture level.
As a result, a significant compaction had evolved that blocked the development of beet tuber and enhanced drought sensibility as well.
Many examples occurred during the experimental series showing that poor looseness is not caused by the maleficent primary tillage but by further operations. The medium-deep ripping primary tillage was followed by an additional tillage of cultivator and plough, as Figure 6 shows. The soil re-compacted significantly in a 20-30 cm depth in both cases and the measured resistance exceeded the critical 3.5 MPa rate. Thus, further operations had an unfavourable impact on looseness.

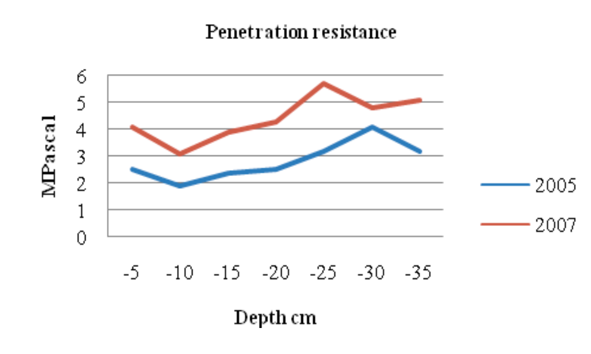

Figure 5.: Different looseness on summer of 2005 and 2007. The tillage system based on conventional ploughing in Poroszló.

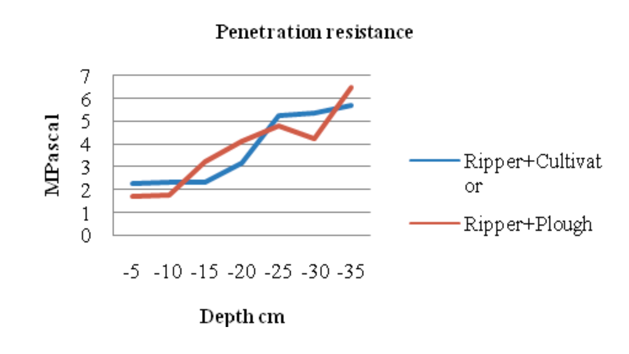

Figure 6.: The unfavourable effects of surface preparations in Jászboldogháza and Kiskunlacháza, 2007.

2. Agronomical structure analysis

The agronomical structure is the proportion of clod (>10 mm), aggregate (2.5-10 mm), small aggregate (0.25-2.5 mm) and the fraction of dust (<0.25 mm) in the given sample, which is typical for the type of soil in one hand (e.g. silt soils of better quality contain 65-70% of aggregate) and also reflects the cumulative effects of tillages on the other. The agronomic structure is in a tight connection with bearing capacity and also with workability (Kennedy 1973; Bottlik, Birkás, 2005, 2006). A proportion of aggregates around 80% suggests that the soil is saved. A decrease of the aggregate section, the greater proportion of small aggregates and the growth of the dust fraction means the crescendo of the degradation process.

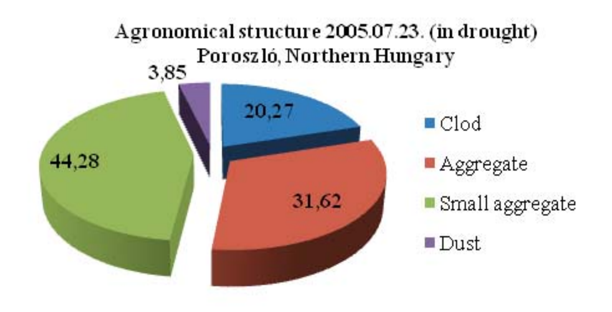

Figure 7.: Agronomical structure under conventional ploughing tillage in the summer of 2005, Poroszló.

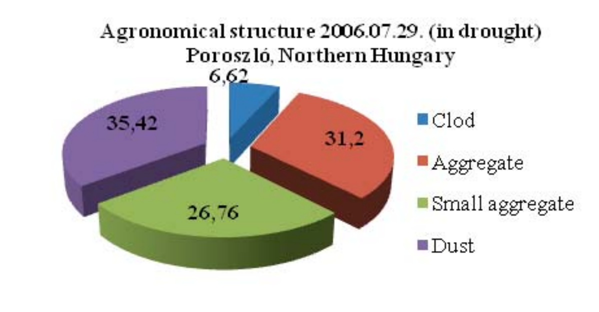

Figure 8.: Agronomical structure under conventional ploughing tillage in the summer of 2006, Poroszló.

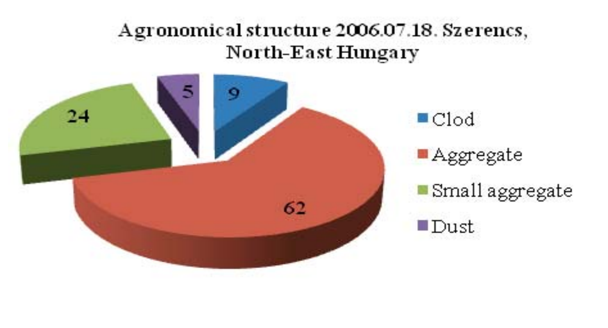

Figure 9.: Agronomical structure under conservation tillage, based on heavy duty cultivator,2006, Szerencs.

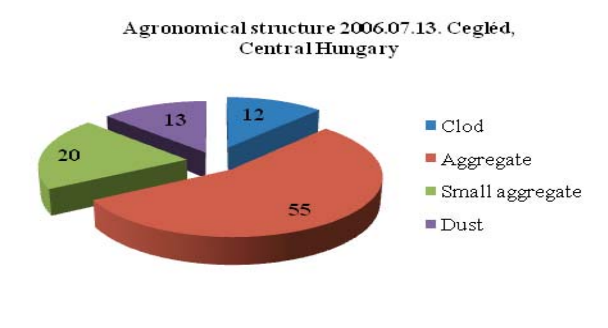

Figure 10.: Agronomical structure under conservation tillage, based on heavy duty cultivator, 2006, Cegléd.

Figure 7 and 8 shows the agronomic structure typical for the site of Poroszló (North-East Hungary) in the summer of 2005 and 2006. A conventional ploughing primary tillage was carried out in the area combined with a multitraffic seedbed preparation. In 2005 the proportion of total aggregates reached the appropriate rate (75%) but within this the proportion of small aggregates was significant (44%). A too high proportion of small aggregate fraction manifests a tendency for dustiness, crusting and settling. Besides, the proportion of clod fraction (20%) also exceeds the desired level. According to the data of the summer of 2006 it can be claimed that the created soil structure is worse than as it was in 2005. The total proportion of clod fraction is only 57%, while the proportion of dust is too high with 35%. This unfavourable structure enhanced the extreme weather conditions, which is a clean evidence for the usage of mechanical soil tillage. Figure 9 and 10 displays the data of agronomic structure measured in Szerencs and Cegléd in the summer of 2006. A heavy duty cultivator primary tillage was done in both sites combined with a one-pass springtime seedbed preparation. The structure of upper soil layer was favourable with a proportion of total aggregate between 86% and 75%. The dust and clod fraction did not exceed the crucial level. These figures suggest good structure stability and a favourable microbiological value.

Based on the agronomic structure experiments it can be stated that the heavy duty cultivator primary tillage, that leaves mulch behind, has a favourable protective effect on the top layer of soil as opposed to inverting tillage.

3. Moisture content of soil

Table 1.: Moisture content of soil under different tillage systems, 2007

Location	Method of primary tillage			Surface preparation on other operations		Moisture content	
	Plough-ing	*Ripping*	*Multi-cultivato r*	*Conser-vation*	*Conven-tional*	*0-20 cm*	*20-40 cm*
Cegléd	X				X	D	D
		X			X	D	D
Hajdúböszörmé ny	X				X	D	M
			X	X		M	M
Jászboldogháza	X			X		M	M
		X		X		M	M
			X	X		M	M
Szerencs	X				X	D	D
			X	X		D	M
Poroszló	X				X	D	D

D: dry, M: moist.

Table 1 contains the moisture conditions experienced in the summer of 2007 of each site. For simplification, we used dry and wet categories besides numerical data. It can be claimed that soil moisture can be preserved in case of ploughing primary tillage, if the operations of secondary tillage and seedbed preparations are carried out on an indulgent, moisture economic level. The sample area of Jászboldogháza is an example for this fact. On the contrary, if the tilled surface- according to the conventional practice- stays open for a longer period of time, the significant moisture loss cannot be prevented (e.g. Poroszló, Cegléd).
A surface preparation process can also be needed in case of an inverting primary tillage. It is particularly true for medium-deep loosening in which the entire positive effect of the process can be lost as a result of a bad secondary tillage (Cegléd). This was the case in the Cegléd area where a conventional disk was used for this process that resulted in a compacted, dusty soil. The multicultivator tillage and mulch leaving tillage resulted in the lowest moisture loss (Hajdúböszörmény, Jászboldogháza). These tools have sealing-compacting parts by which the re-closing happens at the same time. Furthermore, the mulch left behind by the tools holds back a significant amount of moisture during the growing season.

4. Evaluation of mulch-covering

Crop residues should be estimated by their value (not as tillage blocking factors). According to our experimental observations, the optimum level of surface's mulch cover is between 45-60% in case of stubble tillage, 25-35% after non-inverting primary tillage, and at least 15-20% after sowing (Birkás, 2007).
Such tools or processes are considered more favourable that leaves a better cover behind and this cover is even. From a technological point of view, the perfect chopping and even distribution of stalk traces is proved to be a decisive factor. Our standpoint is to create the smallest chaffs possible and to do the chopping and harvesting at the same time by a forage crimper attached to a harvester combine.
In the experimental fields the best mulch cover was observed in 2005 (10-15%) – in the middle of the summer- and in 2006 (4-10%) and it was lower in 2007 (5-8%) (Table 2).

Table 2.: Mulch-cover between 2005 and 2007.								
Location	**Ploughing**	**Cultivator**			**Ripper**	**Disc tiller**	**Ripper +Disc tiller.**	**Ripper +Culti-vator**
	2005-2007	2005	2006	2007	2006	2006	2007	2007
Cegléd	0%	10-15%	9-12%				2-4%	
Hajdúböszörmény	0%			1-4%		5-8%		
Jászboldogháza	0%	10-18%	9-14%	7-11%	6-13%			6-9%
Szerencs	0%		4%	1-6%				
Poroszló	0%							

Nowadays the number of those, who appreciate the positive effects that apply to the mulch tillage technology concerning organic material and soil structure preservation. In our experimental series we established the following statements concerning the significance of mulch leaving.

The effect of mulch-leaving on soil (previous to primary tillage):

- Protection from silting (in a rainy and extreme season)
- Protection from dry and crusty soil surface (in a dry season)
- Saving beneficial organisms
- The promotion of mellowing and edaphic life, an improvement of workability

The effects of mulch after sowing (till the bowing of leaves)

- Structure protection
- Mitigation of wind erosion and drifting of particles (versus water and wind damage)

5. Recommendation for an environmental-capable, climate-harms mitigation soil tillage system

5.1. As for stubble tillage, the usage of soil structure-protecting machineries is suggested that is appropriate for creating favourable structure, leaving mulch cover and leave no plough pan compaction behind. In this sense we emphasize the usage of compact disks and cultivators.

5.2. It is beneficial to use primary tillage tools after which there is no need for secondary tillage in the fall, which often causes damages. The primary tillage needs to be tilled in the fall to such an extent that allows a one-pass seedbed preparation. This can be carried out with modern heavy duty (multi) cultivator, ripper and reversible plough with packer. The protection of soil structure during primary tillage (in the end of summer or in the autumn) makes it possible to make less damage in springtime during the process of seedbed preparation.

5.3. Only those tools can be used securely for springtime seedbed preparation that prevent soil pugging, crusting and also reduce dusting. One preparation working processes need to be emphasized. According to my experiences, the negative effects of every additional passes are much higher than the positive effects of clod breaking.

5.4. The sowing and the fertilization should be linked with the usage of the so-called combo-tank equipped precision seed drill. It is useful to do the sowing of turning lanes on the field sides last, after an additional seedbed preparation.

Conclusions

Relying on our experiments concerning crop security, we find the following factors desirable. A soil looseness of a depth expanding from 30 to 35 (40) cm that is to remain throughout the entire growing season is indispensable. A strong tillage pan is allowed neither in the cultivated layer, nor underneath it, which blocks moisture circulation. An active edaphic life and microbiological activities are needed for an optimal excavation of nutriments. Such an upper soil layer is needed to be created by tillage that can resist water and wind erosion during the entire growing season and may also be able to reduce moisture loss.
The results of our experiments reflect well the typical failures and risks of conventional soil tillage systems and also the loss reducing capability of non-inverting, mulch leaving methods.

Acknowledgement

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CHANGES OF THE ACIDITY AND SALINITY OF THE ARABLE SOILS DEPENDING ON THE CROP ROTATION

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Abstract
The changes in pH and salinity in topsoil and subsoil caused by the crop rotations was evaluated in 1993-1999 at the Agricultural Research Institute Kroměříž, Ltd. The following crop rotations (variants) were used: A-winter wheat after spring barley, B-winter wheat after alfalfa, C-spring barley after winter wheat and D-spring barley after sugar beet. The samples for the analyses were taken pointwise from the depth of 0-30 cm for topsoil and 30-60 cm for subsoil every two weeks from the third April decade to the third July decade.
Keywords: pH, salinity, crop rotations, Luvic Chernozem

Introduction

Based on Ulrich´s theory (1991), the system of specific neutralisation reactions in the soil depends on the proportion of ions in the soil solution. The reaction rate of humus-rich horizons is high (Kaniská, 2000). However, as Susser and Schwetman (1991) found in experiments, their capacity to neutralise acids is low and on the contrary, the reaction rate of mineral horizons is lower and the capacity to neutralise acids is higher.
Saline soils often occur in arid and semiarid regions (Derici, 2002). In the former Czechoslovakia, this problem was solved in the territory of the Žitný isle (Červenka, 1958). At present, the soil salinisation under our conditions can be induced by irrigation or mineral fertilisation. Wood (2000) indicates that as much as 20 % of irrigated soils are damaged by salinity. The soil salinity increases a pH level of the soil solution, but it negatively influences the entire soil environment, physico-chemical and biological properties of such soils (Šimek, 2004). According to Brady and Weil (1999), in Europe there are 20.7 mil. ha of soil degraded by salinity. The present paper tries to answer the question how the exchange soil reaction in well-puffed chernozem is influenced by the crop rotation and what is the effect of the crop rotation on soil salinity.

Materials and Methods

pH and salinity changes in topsoil and subsoil were observed in 1993-1999 in multifactor experiments at the Agricultural Research Institute Kroměříž, Ltd. During the examined periods of the growing season in 1993-1997, the average temperature was 15.78 °C and average precipitation sum 246 mm. The soil is Luvic Chernozem (Němeček, 2001) with deep, structural, clay loam topsoil (content of particles < 0.01 mm is 42 %). Sorption complex (V = 75 %) is saturated and reserves of available phosphorus, potassium and magnesium are high.
In a 9-course crop rotation with 62.5% concentration of cereal crops (variants A-winter wheat after spring barley, B-winter wheat after alfalfa, C-spring barley after winter wheat, D-spring barley after sugar beet), soil samples from the depth of 0-30 cm for topsoil and 30-60 cm for subsoil were collected at 14-day intervals from the third April decade to the third July decade (7 samplings each year) and pH and electric conductivity (EC), characterising a level of salt soil salt load – salinity, were assessed (Pokorný, Denešová, 2005; Sbíral, 1995). Individual variants were fertilised on average with the following rates of N, P2O5, K2O (in kg/ha/year): A – 61, 67, 101; B – 46, 67, 105; C – 9, 58, 95; D – 0, 55, 111, respectively. Over the whole

period under study, average grain yields were 6.54 t/ha in variant A, 7.47 t/ha in variant B, 6.52 t/ha in variant C and 7.20 t/ha in variant D.

The results were evaluated by analysis of variance (LSD test, P>0.05) and temporal changes by regression analysis (tested by correlation index) using software Excel (Orvis 1996) and Statgraphics (Koschin et al., 1992).

Results and Discussion

Over the whole period of observations, the mean pH level in topsoil ranged from 6.13 in variant D to 6.3 in variant C and that in subsoil from 6.42 in variant D to 6.64 in variant A. The difference in pH among variants in topsoil and subsoil was insignificant (Tables 1 and 2, Graph 1).

Table 1: *pH in topsoil – analysis of variance*

Source of variation	*SS*	*Differ.*	*MS*	*F*	*P value*	*F crit*
Between sampling	0.735791837	3	0.245263946	0.5552112	**0.645245322**	2.651638908
All sampling	84.81579184	192	0.441748916			
Total	85.55158367	195				

Graph 1: *Mean values of pH in topsoil and subsoil*

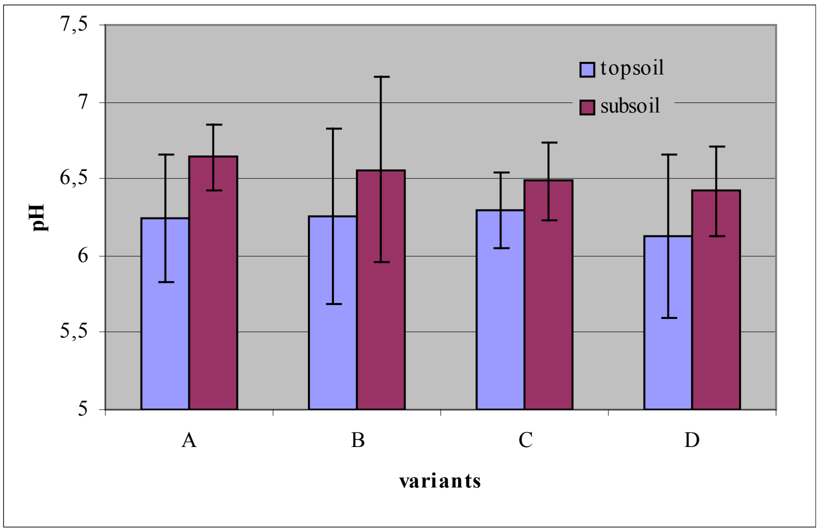


Table 2: *pH in subsoil – analysis of variance*

Source of variation	*SS*	*Differ.*	*MS*	*F*	*P value*	*F crit*
Between sampling	1.304385204	3	0.434795068	1.280691513	**0.282261069**	2.651638908
All sampling	65.1840449	192	0.339500234			
Total	66.4884301	195				

Mean values of EC in topsoil ranged from 51.41 µS/cm in variant B to 63.45 µS/cm in variant D and in subsoil from 55.65 µS/cm in variant C to 69.80 µS/cm again in variant D for the whole examined period. The difference in salinity values among variants in topsoil and subsoil was statistically significant (Tables 3 and 4, Graph 2).

Table 3: *EC in topsoil – analysis of variance*

Source of variation	*SS*	*Differ.*	*MS*	*F*	*P value*	*F crit*
Between sampling	4734.178571	3	1578.059524	3.068516299	**0.029092784**	2.651640342
All sampling	98740.69388	192	514.2744473			
Total	103474,8724	195				

Graph 2: Mean values of EC in topsoil and subsoil

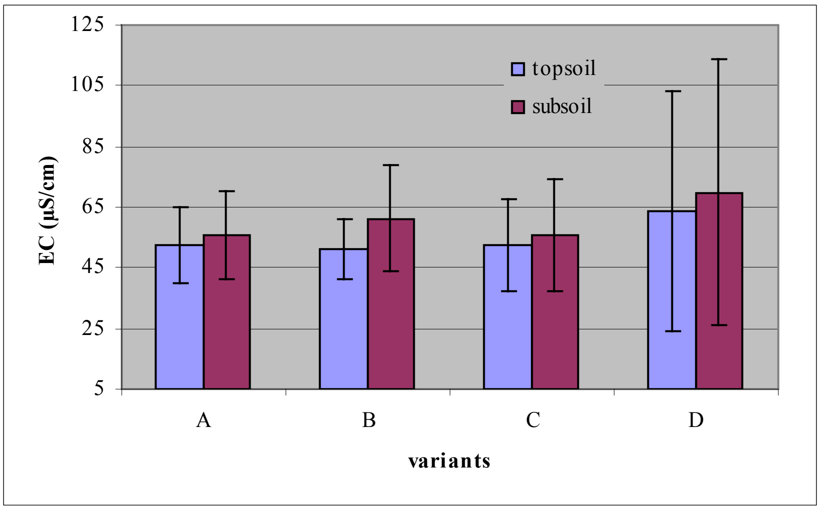


Table 4: *EC in subsoil – analysis of variance*

Source of variation	*SS*	*Differ.*	*MS*	*F*	*P value*	*F crit*
Between sampling	6520.056122	3	2173.352041	3.151326394	**0.02611574**	2.651640342
All sampling	132415.2245	192	689.6626276			
Total	138935.2806	195				

Table 5: *Limit values of EC for arable soils (Javorský, 1987)*

EC (µS/cm)	Characterisation
< 30	most arable soils, normal fertilisation intensity, minimum salt load
30-60	mineral-rich soils, medium high fertilisation intensity, no negative fertilisation effects
60-120	soils with high fertilisation on mineral-rich substrates, increased salt content
> 120	high salt load with potential negative effects on plant growth

If our data were compared with the values in Table 5 and the crop rotation was disregarded, variants A, B and C in topsoil were included in the second group (30-60 µS/cm) and variant D in the third group (60-120 µS/cm). In subsoil, variants A and C were included in the second group and variants B and D in the third group.

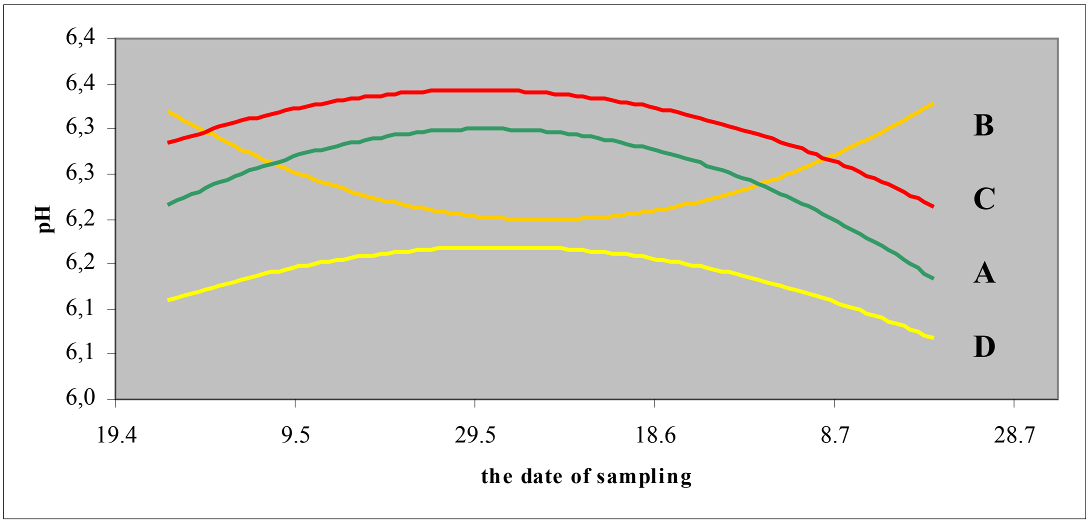
According to Brtnický (2005), mean values of EC in all variants in both topsoil and subsoil could be included in category L (low).

The differences among individual variants were more apparent in yearly dynamics of pH and EC in topsoil (Tables 5 and 6, Graphs 3 and 4).

Table 6: *Regression equation of the changes in pH values in topsoil*

Variant	Equation	R	R^2
A	y = -7E-05x2 + 0.0203x + 4.7667	**0.085**	**0.0072**
B	y = 7E-05x2 – 0.0218x + 7.9198	**0.064**	**0.0041**
C	y = -5E-05x2 + 0.015x + 5.213	**0.085**	**0.0072**
D	y = -4E-05x2 + 0.0134x + 5.1447	**0.047**	**0.0022**

Graph 3: *Dynamics of the changes in pH values in individual variants in topsoil (0-30 cm)*



The lowest values of pH in topsoil in variants A, C and D were found always at the end of the vegetative period. The highest values were found around the end of May. In variant B, the minimum begin around the middle and the highest values at the beginning and at the end of the vegetative period.

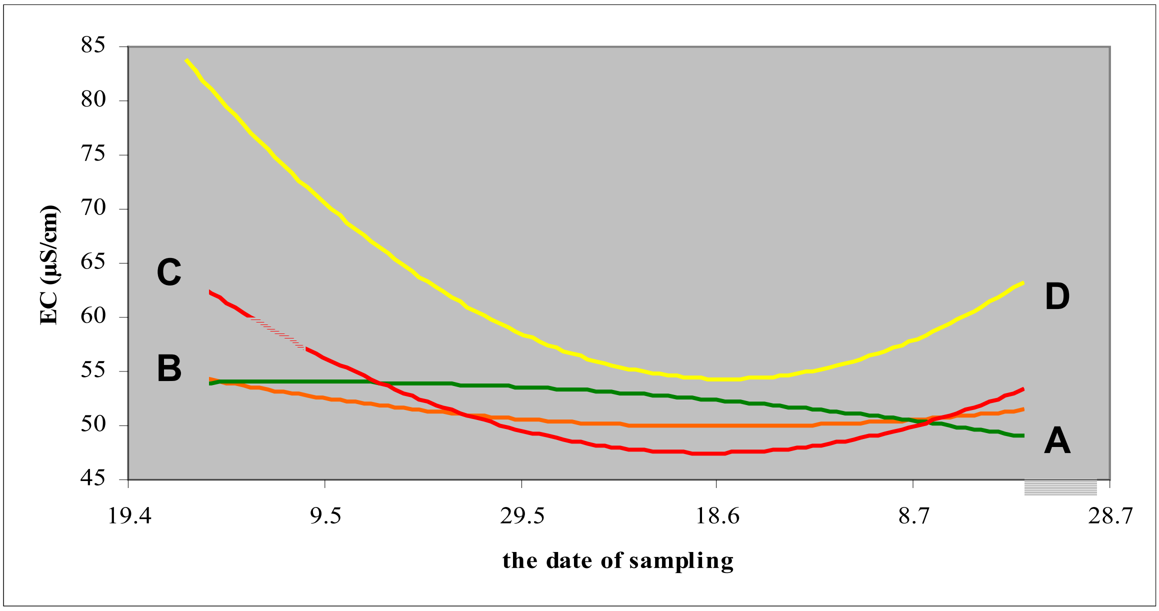
Table 7: *Regression equation of the changes in EC values in topsoil*

Variant	Equation	R	R^2
A	y = -0.0009x2 + 0.2343x + 39.129	**0.1393**	**0.0194**
B	y = 0.0016x2 – 0.5366x + 95.731	**0.1546**	**0.0239**
C	y = 0.0058x2 – 1.9501x + 212.41	**0.3487**	**0.1216**
D	y = 0.0098x2 – 3.3397x + 339.51	**0.2421**	**0.0586**

The most apparent changes in EC values were found in variants C and D, and a considerable spring decline was apparent in the latter. Variants A and B varied very little throughout the year (in units only). Minimum values in variants B, C and D occurred in mid-June and in variant A in late July.

CONTENT

Graph 4: *Dynamics of the changes in EC values in individual variants in topsoil (0-30 cm)*



Statistical assessment revealed the effect of variant D on the increase in EC values. The difference was significant in comparison with the other variants (Table 8, in red).

Table 8: *EC in topsoil*

	A	B	C	D
A	X	0.98	0.26	11.1
B	X	X	1.24	12.08
C	X	X	X	10.84
D	X	X	X	X

In topsoil (Table 7, Graph 5), minimum values of pH in variant D became to occur at the beginning and in the other variants at the end of the vegetative period. A main change throughout the year was recorded again in variant B. A considerable decline of pH during the vegetative period was apparent.

Table 9: *Regression equation of pH values in subsoil*

Variant	Equation	R	R^2
A	y = -3E-05x2 + 0.0103x + 5.8598	**0.051**	**0.0026**
B	y = -5E-05x2 + 0.014x + 5.7413	**0.127**	**0.0162**
C	y = -4E-05x2 + 0.0118x + 5.5882	**0.053**	**0.0028**
D	y = -2E-05x2 + 0.0072x + 5.8251	**0.037**	**0.0014**

Graph 5: *Dynamics of the changes in pH values in individual variants in subsoil (30-60 cm)*

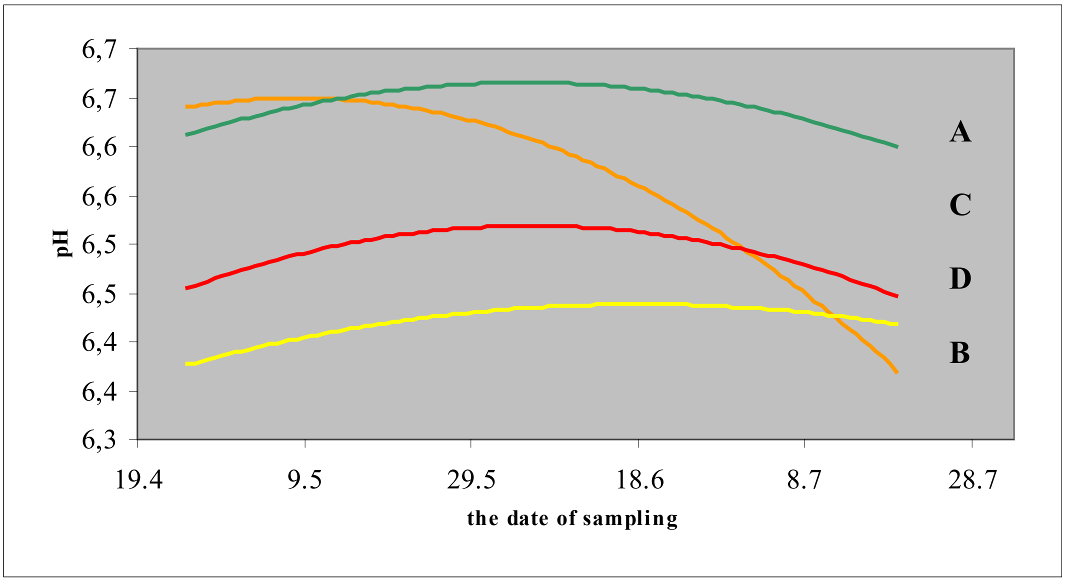
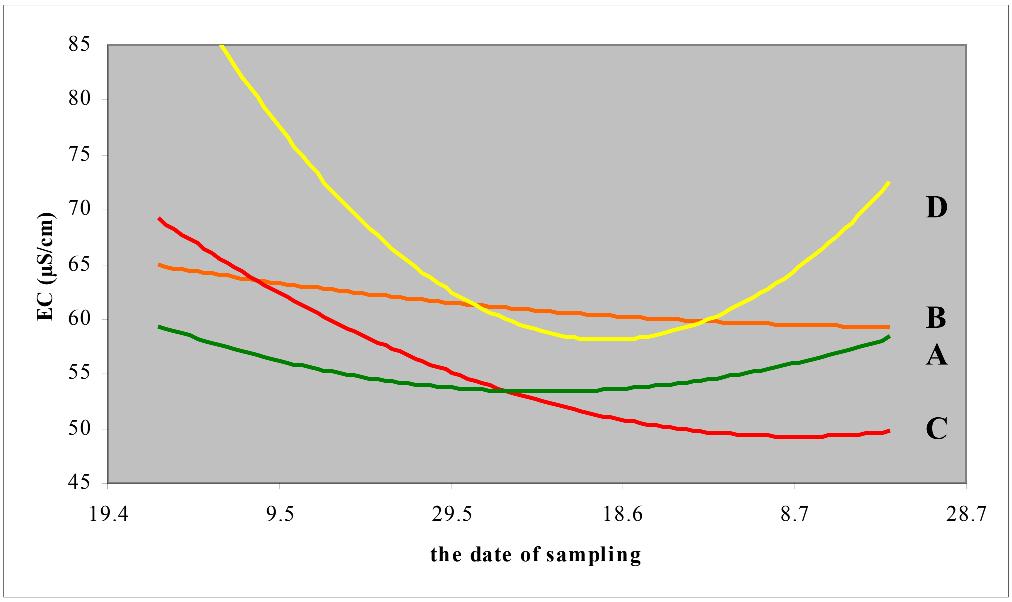


Table 10: *Regression equation of EC values in subsoil*

Variant	Equation	R	R^2
A	y = 0,003x2 – 0.9628x + 130.68	**0.1442**	**0.0208**
B	y = 0,0007x2 – 0.2737x + 87.73	**0.1109**	**0.0123**
C	y = 0,0036x2 – 1.3644x + 179.16	**0.3762**	**0.1415**
D	y = 0,0133x2 – 4.4642x + 433.53	**0.2681**	**0.0719**

The biggest changes in salinity values in subsoil were observed again in variants D and B. The highest values were obtained in all variants at the beginning of samplings. The lowest values were assessed in variants A and D in late May – early June and in variants B and C at the end of the vegetative period.

Graph 6: *Dynamics of the changes in EC values in individual variants in subsoil (30-60 cm)*



In subsoil, the significant difference in comparison with variants A and C is in red (Table 11).

Table 11: *EC in subsoil*

	A	B	C	D
A	X	5.59	0.11	14.04
B	X	X	5,7	8.45
C	X	X	X	14.15
D	X	X	X	X

Conclusion

The 7-year (1993-1999) observations of exchange soil reaction and salinity values in topsoil and subsoil of Luvic Chernozem (variants: A-winter wheat after spring barley, B-winter wheat after alfalfa, C-spring barley after winter wheat, D-spring barley after sugar beet) documented that during the vegetative period:

- Differences in exchange soil reaction among individual variants were insignificant in both topsoil and subsoil.
- Mean values of pH/KCl in topsoil ranged between 6.13 in variant D and 6.3 in variant C.
- Values of pH//KCl in subsoil ranged from 6.42 in variant D to 6.64 in variant A.
- Considering the dynamics, the pH values differentiated (again insignificantly) in dependence on variants. In variants A, C and D, the lowest value of pH//KCl in topsoil was always at the end of the vegetative period. The highest values were assessed around the end of May. In variant B, minimum values were measured around the middle and the highest values at the beginning and at the end of the vegetative period.
- In subsoil, the minimum value of pH//KCl in variant D was found at the beginning and in the other variants at the end of the vegetative period. A main change during the year was assessed again in variant B. A considerable decline of pH//KCl was apparent throughout the vegetative period.
- Based on the 7-year results, it was not possible to confirm the effect of crop rotations on the change in exchange reaction in topsoil and subsoil.
- Differences in the effect of salinity among individual variants were significant in both topsoil and subsoil.
- The mean value of EC in topsoil ranged between 51.41 µS/cm in variant B and 63.45 µS/cm in variant D. Values of EC in subsoil ranged from 55.65 µS/cm in variant C to 69.80 µS/cm in variant D.
- Considering the dynamics, the values of EC also differed (significantly) in dependence on variants. The biggest changes were apparent in variants C and D, in the latter the decline in spring was substantial. Variants A and B ranged very little through the year (in units only). The minimum in variants B, C and D was assessed in mid-June and in variant A in late July.
- In subsoil, minimum values of salinity in variants A and D were found in late May and early June and in variants B and C at the end of the vegetative period. The biggest changes were found in variants D and B. The highest values were reached in all variants at the beginning of samplings. The lowest values were obtained in variants A and D in late May to early June and in variants B and C at the end of the vegetative period.
- The 7-year results enabled to document the effect of crop rotations on the change in EC in both topsoil and subsoil. Statistical assessment shows the effect of preceding crop and crop in variant D on the increase in EC values. In topsoil, the difference was significant in comparison with all other variants and in subsoil it was significant in comparison with variants A and C. In our opinion, this difference could be caused by a high amount of organic residues after sugar beet and consequent increased nitrification.

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SPRING BARLEY (*Hordeum vulgare L.*) GRAIN YIELD UNDER LONG-TERM CONTINUOUS GROWING WITH DIFFERENT SOIL TILLAGE SYSTEMS AND STRAW MANAGEMENT PRACTICES

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Abstract

The objective of this study was to evaluate long-term effects of different straw management practices in combination with different methods of tillage and mineral fertilization on yields of continuous spring barley growing under dry and warm conditions and to evaluate this results with different grain yield in year 2007. Evaluated variants were: variants of straw management (straw harvested-removed, straw incorporated into soil and straw burned); variants of soil tillage (conventional plough tillage to 0.22 m and shallow tillage to 0.12-0.15m); variants of mineral fertilization - in kg of pure nutrients.ha^{-1} (1^{st} 30 N, 26 P, 66 K; 2^{nd} 60 N, 40 P, 100 K; 3^{rd} 90 N, 40 P, 100 K). The statistically significant highest grain yields were reached with conventional plough tillage to 0.22 m (5.46 t.ha^{-1}), straw burned (5.42 t.ha^{-1}) and with the highest nitrogen doses (5.49 t.ha^{-1}) compared with other equivalent factors level.

Key words: spring barley, grain yield, soil tillage, straw management

Introduction

A number of agricultural enterprises without livestock production, or with livestock production but without need of straw, have been increasing. A question arises how to use straw. Effects of various straw management practices on yields of successive crops and modifications of the soil environment have been described by a number of authors. Their studies show that straw fertilization, and particularly in combination with minimum soil tillage often results in difficult establishment of stands and straw can induce inhibitory effects on germination, emergence and initial growth of following crops. The objective of the presented results is to evaluate long-term effects of different straw management practices in combination with different soil tillage techniques and mineral fertilization on yields of continuous spring barley under dry and warm conditions of the maize-growing region.

Material and methods

Long-term field experiment with spring barley (*Hordeum vulgare* L.) was established in 1969 in the maize-growing region in Žabčice (experimental fields of Dpt. of Agrosystems and Bioclimatology of FA MUAF in Brno). The experiment was established in split-plot design in four replicates. The area of the plot was 37 m^2.

Site characteristics: the altitude is 179 m above sea level, average annual temperature 9.2°C, average annual sum of precipitation 480 mm; heavy gleic fluvisol (FMG), neutral pH, humus content in topsoil 2.5% and content of available phosphor and potassium good.

These variants were studied: variants of straw management (straw harvested-removed, straw incorporated into soil and straw burned); variants of soil tillage (conventional plough tillage to 0.22 m and shallow disc tillage to 0.12-0.15m); variants of mineral fertilization - in kg of pure nutrients.ha^{-1} (1st 30 N, 26 P, 66 K; 2nd 60 N, 40 P, 100 K; 3rd 90 N, 40 P, 100 K).

Results

Average grain yield over all experimental variants was 5.21 t.ha^{-1} in evaluated period 1975-2005. Effects of different straw management practices on yields of continuous spring barley differed in dependence on soil tillage practices and mineral fertilization (Table 1). Effects of studied years are presented in Figure 1 (with statistical assessment for P ≥ 95 %. Analysis of variance achieved significant effect of all studied factors. The statistically significant highest grain yields were reached with conventional plough tillage to 0.22 m (5.46 t.ha^{-1}), straw burned (5.42 t.ha^{-1}) and with the highest nitrogen doses (5.49 t.ha^{-1}) compared with other equivalent factors level. The obtained data from long-term experiment on heavy gleic fluvisol under dry and warm conditions demonstrate that shallow soil tillage in continuous spring barley for a long time leads to decrase of level of yields.

Table 1 Yields of continuous spring barely (t.ha^{-1}), comparison of long-term mean (1975-2005) with different year 2007.

Soil tillage variant	N doses (kg ha^{-1})	Straw management variant					
		Straw harvested		Straw incorporated		Straw burned	
		Mean	*Y. 2007*	*Mean*	*Y. 2007*	*Mean*	*Y. 2007*
Conventional plough tillage to 0.22 m	30	4,87	2,33	5,28	3,04	5,36	3,60
	60	5,22	2,34	5,66	3,26	5,71	3,60
	90	5,46	2,70	5,73	3,66	5,83	3,87
	Me an	*5,18*	*2,46*	*5,56*	*3,32*	*5,63*	*3,69*
Shallow tillage to 0.12-0.15 m)	30	4,40	2,96	4,43	2,34	4,73	2,79
	60	4,87	3,74	4,93	2,85	5,26	3,09
	90	5,13	3,86	5,21	3,28	5,60	3,28
	Mean	*4,80*	*3,52*	*4,86*	*2,82*	*5,20*	*3,05*
Mean		4,99	2,99	5,21	3,07	5,42	3,37

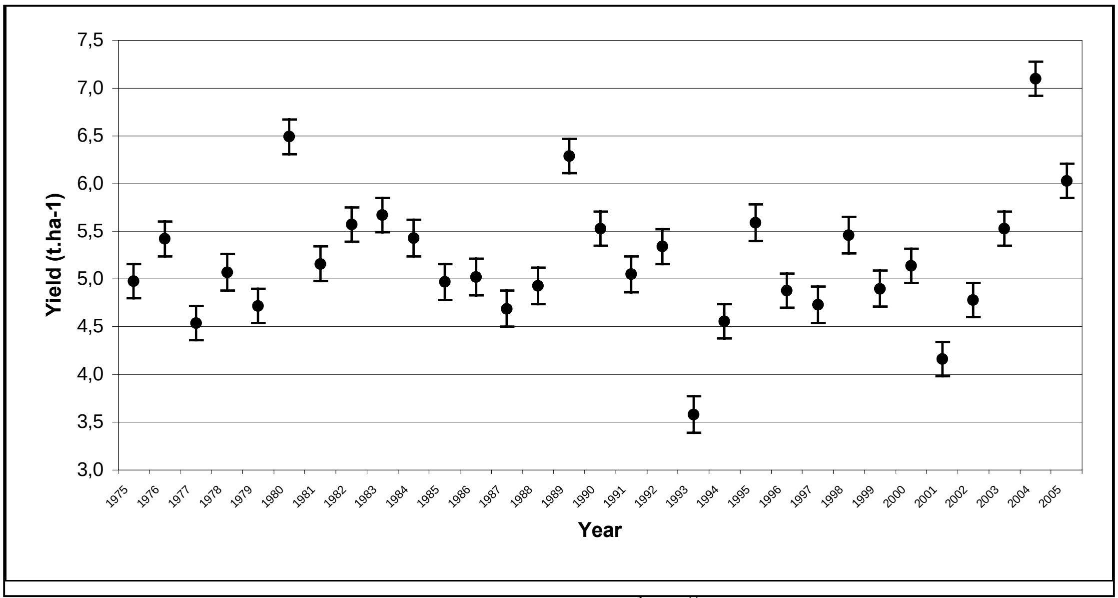

Figure 1 Average grain yields of spring barley (t.ha^{-1}) - Žabčice (1975 - 2005; P ≥ 95 %

When evaluating effects of various methods of straw management on grain yields of spring barley grown as a monoculture, the best results were always obtained in the variant with burning; the second best was the variant with straw embedding and the worst one that with conventional harvesting of straw. These results represent an average of years 1975 - 2005 and were obtained in both variants of tillage. When evaluating effects of different methods of tillage, higher yields were obtained in the variant with conventional ploughing. In this case, the highest yield was obtained in the variant with straw embedding. When evaluating effects of various levels of supply of mineral fertilisers it was found out that grain yields increased with the increasing levels of nitrogen supply not only in all variants of straw management but also in both variants of soil tillage.

Conclusions

When comparing long-term effects of straw embedding and burning on yields of spring barley with the conventional method of harvesting it was found out that in the variant with a shallow incorporating of straw there was a trend toward yield depression and that this adverse effect could be partly compensated by the application of nitrogen. In a spring barley monoculture, a shallow tillage of soil, especially in the variant with the straw embedding, resulted in a gradual decrease in grain yields.

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CHANGES OF THE BIOLOGICAL PROPERTIES OF THE ARABLE SOILS DEPENDING ON THE CROP ROTATION

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Abstract
There is evaluated the survey of the changes of biological properties. The survey took place in 1993 - 1999 at the Agricultural Research Institute in Kroměříž.. There were surveyed changes of microbiological respiration in topsoil and subsoil depending on the crop rotation concretely. There was used the interferometrical method (Novák, Apfelthaler. 1964) for this purpose. The survey alternates: A) winter wheat after spring barley, B) winter wheat after alfalfa, C) spring barley after winter wheat and D) spring barley after sugar beet. The samples for the analyses were taken pointwise from the depth 0 – 30 cm for topsoil and 30 – 60 cm for subsoil every two weeks from third April decade to third July decade.
Keywords: soil respiration, microbiological respiration, potential respiration, CO_2 production

Introduction

Soil fertility, which is the result of effects of the complex set of mutually influencing properties, is mostly defined as the potential of soil to supply requirements of plants for water, air, nutrients and biologically active substances.
In addition to physical and chemical soil properties, the fertility of soil is created by its biological properties. It means the activity of adaphon, ie soil microorganisms and animals. Microorganisms, ie bacteria, micromycetes, actinomycetes and blue-green algae predominate both numerically and by biomass. According to present knowledge microorganisms play a key role in soil metabolism.
Soil organisms show an unsubstitutable function in all processes conditioning soil fertility and further they support the decomposition of organic matter in soil, make nutrients available for plants, are able to detoxify extraneous substances. which enter the soil through anthropogenic activities (eg pesticides, heavy metals, organic pollutants).
The biological activity of soil, which is detected by the respiration activity of microorganisms was measured by an interferometric method together with basic test variants, which were described by Dr. Ing. Bohumír Novák, CSc. and Ing. Roman Apfelthaler in a journal Plant Production in 1964.

Material and methods

The study was carried out under exact field experiments of the Agricultural Research Institute Ltd. in Kroměříž in 1993 – 2000 on 4 variants of crop rotations in topsoil and subsoil. viz. (A) - winter wheat after spring barley, (B) winter wheat after alfalfa, (C) spring barley after winter wheat and (D) spring barley after sugar beet. Luvic chernozem is a soil type, which occurs in the experiment.
A respirometric test is based on the measurement of the intensity of the carbon dioxide formation in a soil sample. It is a standard gauge of the rate of decomposition of materials in soil. The amount of produced CO_2 [mg/100 g soil/h] is measured in an incubated sample of soil either without the addition of any substrate (B – basal sample) or with the addition of nutrients, which can be easily used by microorganisms (potential). Glucose (G) serves as the source of carbon, ammonium sulphate as the source of separate nitrogen (N) and the combination of glucose and ammonium sulphate (NG) serves as the source of both carbon and

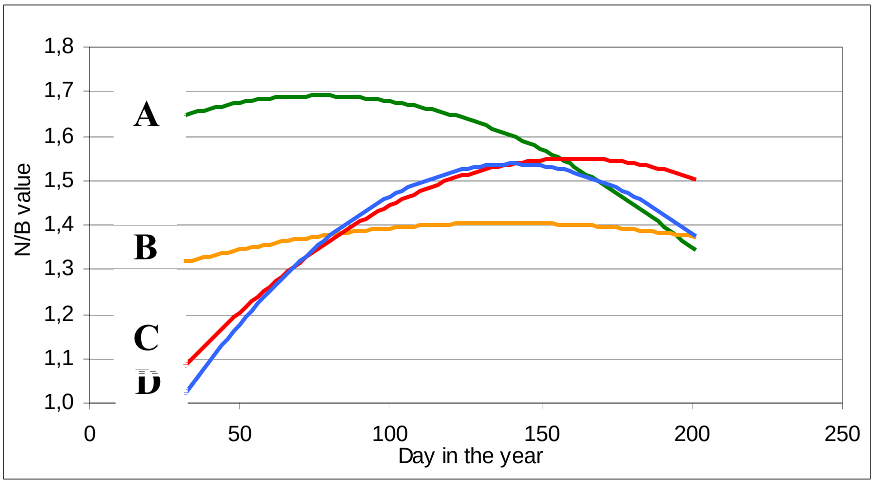
nitrogen. Thus, by means of the basic respirometric analysis four data were obtained from each of the samples and quotients calculated from them serve for the classification of soil conditions. The most important characteristics, which will be measured are as follows:

- *Physiological availability of soil nitrogen* (N/B). The higher the value the lower the physiological availability of soil nitrogen. If there is enough available nitrogen in soil then the addition of another nitrogen does not increase respiration and the N/B value approaches 1.
- *The factor of a complex effect* [(NG:G)/(N:B)] - a deviation from 1 shows to what degree other factors, particularly physical factors make possible the higher use of carbon and nitrogen in total effects than it corresponds to the product of this effect at separated application.

Results and discussion

In the variant of wheat after alfalfa (B), barley after whet (C) and barley after sugar beet (D), it is possible to see the gradual increase of N/B values in topsoil, which means the physiological availability of soil nitrogen. In these variants, the highest values were determined in the second half of May. It means that in this season, the amount of physiologically available nitrogen was smallest. In a variant wheat after barley (A), a fall is evident during the growing season. There, on the contrary, the highest value occurred about mid-March. At the end of the growing season, however, the content of physiologically available nitrogen already increased. At the sufficient amount of physiologically available nitrogen, these values approach 1 and there, at the beginning of the growing season, the best variants are C and D and variant B shows relatively uniform condition (Diagram 1, Tab. 1).

Diagram 1 Dynamics of changes in the physiological availability of soil nitrogen (N/B) of particular variants in topsoil (0 - 30 cm)

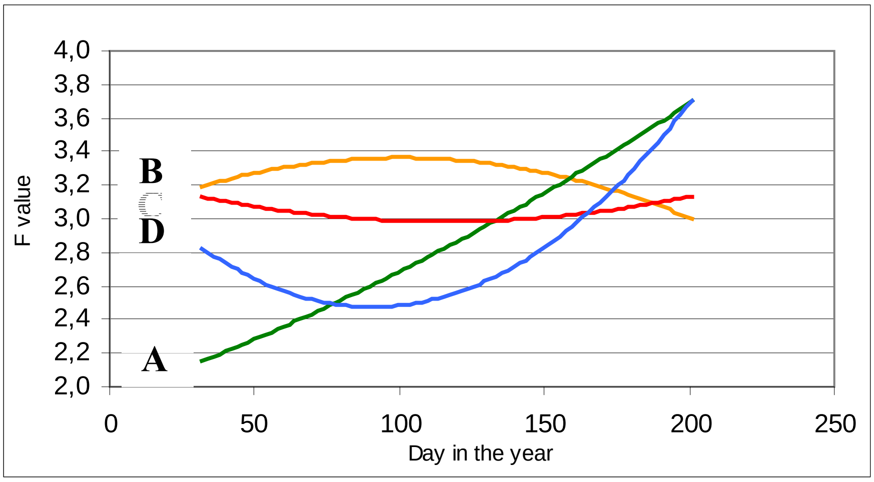


Tab. 1 *Regression equations of the physiological availability of soil nitrogen in topsoil*

Variant	Equation	R	R^2
A	$y = -2E-05\ x^2 + 0.0034\ x + 1.5606$	0.1140	0.0130
B	$y = -8E-06\ x^2 + 0.0022\ x + 1.2563$	0.0300	0.0009
C	$y = -3E-05\ x^2 + 0.009\ x + 0.8236$	0.1628	0.0265
D	$y = -4E-05\ x^2 + 0.0123\ x + 0.6714$	0.1463	0.0214

In the factor of a complex effect, the deviation 1 shows to what degree other factors, particularly physical factors, make possible higher availability of carbon and nitrogen in total effects that it would correspond to the product of this effect at a separate application. The highest values of this parameter in topsoil correspond to wheat variants after barley (A) and barley after sugar beet (D), namely at the end of the examined period (Diagram 2, Tab. 2)

Diagram 2 Dynamics of changes in values of the factor of complex effects of particular variants in topsoil (0 - 30 cm)

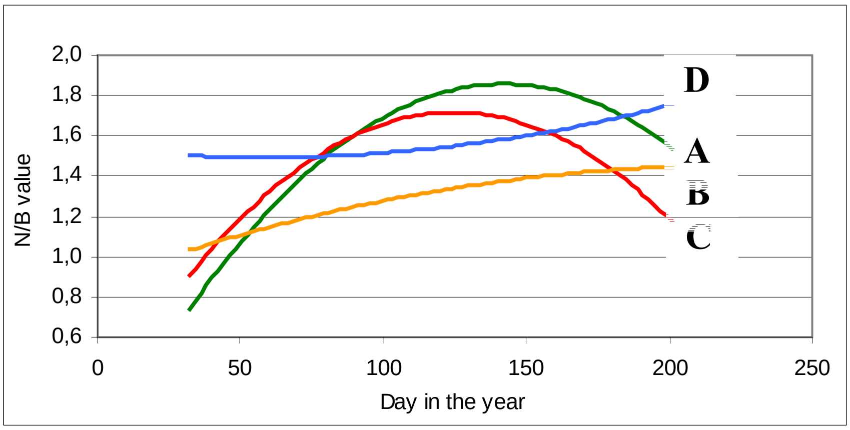


Tab. 2 Regression equations of the factor of complex effects in topsoil

Variant	Equation	R	R^2
A	$y = 1E\text{-}05\ x^2 + 0.0061\ x + 1.9432$	0.2478	0.0614
B	$y = -4E\text{-}05\ x^2 + 0.0072\ x + 3.0005$	0.0648	0.0042
C	$y = 2E\text{-}05\ x^2 - 0.0048\ x + 3.2625$	0.0316	0.0010
D	$y = 0.0001\ x^2 - 0.0184\ x + 3.3114$	0.2478	0.0614

In a variant wheat after barley (A) and barley after wheat (C), it is possible to monitor the gradual increase of N/B values in subsoil, which indicate the physiological availability of soil nitrogen. In these variants, the highest values were determined in the second half of May. Then, the values began to fall at the end of the period. It means, that in this period (the second half of May), the amount of physiologically available nitrogen was smallest. In a variant wheat after alfalfa (B), the highest value occurred at the end of the growing season and thus also the low content of physiologically available nitrogen. Variants B and C approached most a value of 1 when the amount of nitrogen was sufficient, namely at the beginning of the period under study. In a variant barley after sugar beet (D), the lowest amount of nitrogen occurs at the end of the season and relatively the highest amount occurs in the first half of the growing season (Diagram 3, Tab. 3)

Diagram 3 Dynamics of changes in values of the physiological availability of soil nitrogen of particular variants in subsoil (30 - 60 cm)

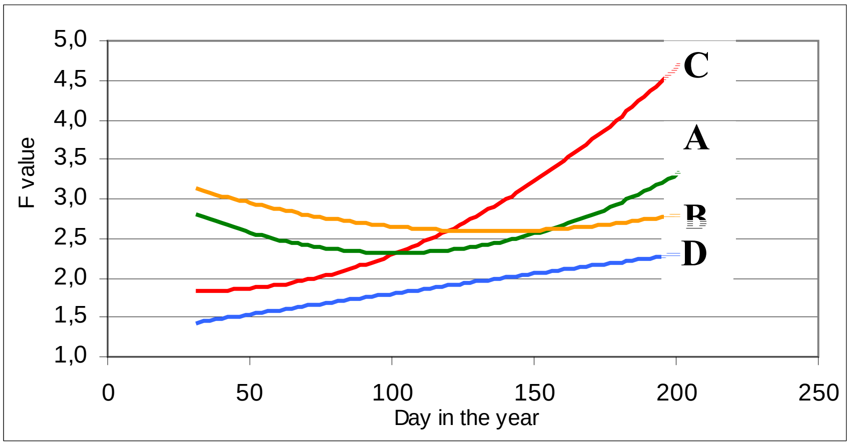


Tab. 3 *Regression equations of the physiological availability of soil nitrogen in subsoil*

Variant	Equation	R	R^2
A	$y = -9E\text{-}05\ x^2 + 0.0263x - 0.0118$	0.1487	0.0221
B	$y = -1E\text{-}05\ x^2 + 0.0051x + 0.8819$	0.2550	0.0650
C	$y = -9E\text{-}05\ x^2 + 0.0235x + 0.2469$	0.2632	0.0693
D	$y = 1E\text{-}05\ x^2 - 0.0015x + 1.5356$	0.0889	0.0079

In the factor of total/complex effects, a deviation from 1 indicates to what degree other factor, particularly physical factors, make possible the higher availability of carbon and nitrogen in complex effects than it would correspond to the product of the effect at separate application. The highest values of the parameter in subsoil correspond to variants of wheat after barley (A) and barley after wheat (C) similarly as in topsoil - at the end of the studied period (Diagram 4, Tab. 4)

Diagram 4 Dynamics of changes in values of the factor of complex effects of particular variants in subsoil (30 - 60 cm)

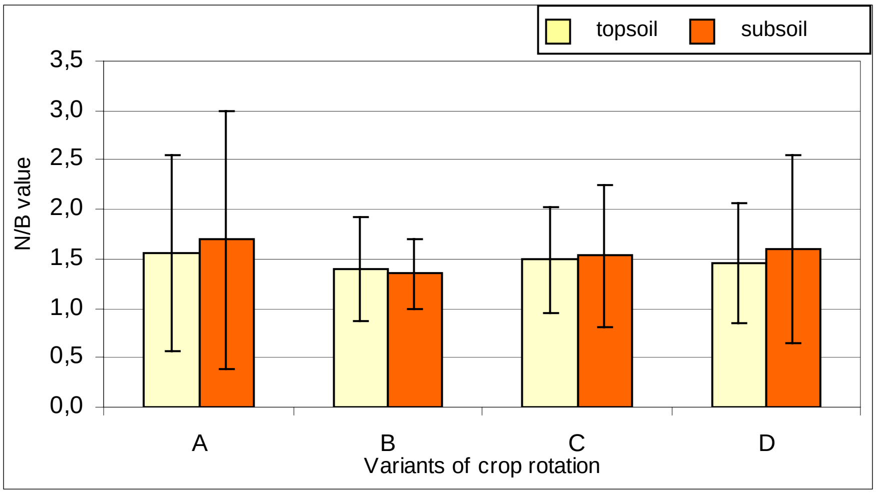


Tab. 4: *Regression equations of the factor of complex effects in subsoil*

Variant	Equation	R	R^2
A	$y = 0.0001\ x^2 - 0.0203x + 3.3417$	0.1814	0.0329
B	$y = 5E\text{-}05\ x^2 - 0.0133x + 3.4914$	0.0640	0.0041
C	$y = 0.0001\ x^2 - 0.0067x + 1.9465$	0.3370	0.1136
D	$y = -2E\text{-}06\ x^2 + 0.0055x + 1.2671$	0.2022	0.0409

Mean values of physiologically available/utilizable soil nitrogen in subsoil were relatively similar and their value ranged about 1.5. Only in variant B, higher values occurred for topsoil than for subsoil. In other variants, values of N/B were higher than for topsoil. However, a difference was not proved between particular variants of a crop rotation there (Diagram 5, Tab. 5, 6)
Novák (1969) mentions mean values for chernozem 1.02 (topsoil) and 1.25 (subsoil). These values indicate higher (or sufficient) amounts of physiologically available nitrogen in soil than it was found in our experiment. Němeček (1990) mentions for chernozem a value of 1.08. Also this value approaches 1 indicating again the sufficient amount of available nitrogen. Pokorný, Denešová (2005) mention mean values of 1.26 (topsoil) and 1.25 (subsoil) for the group of selected soil types in the area of central Moravia. For permanent grasslands, the mean interval of N/B values ranges from 1.10 to 1.20 (Pokorný, Šarapatka, Nenátková 2007).
A final report of the research plan 2005 (responsible researcher Prof. Ing. Václav Vaněk, CSc.) mentions particular data for the calculation of the given quotient and the value 1.25 or 1.89 (two variants of the experiment) shows a difference between selected experimental localities affected by the various amount of physiologically available nitrogen. In selected soil types with values of potential respiration given in the survey of biological properties (Střalková, Pokorný 2001), the ratio of N/B is 1.49. For selected localities, where chernozem is a characteristic soil type, Pokorný, Střalková and Denešová (1997) mention the following values: locality Kostelec – 1.00 and locality Zahnašovice – 0.90. There is a sufficient amount of physiologically available nitrogen in soil – a value approaching 1. Values found by our research team range about 1.50 being relatively similar to data obtained from literature sources (0.90 – 1.89).

Diagram 5 *Mean values and standard deviations of the physiological availability of soil nitrogen in topsoil and subsoil*



Tab. 5 Physiological availability of soil nitrogen in topsoil – analysis of variance

Source of variability	SS	Difference	MS	F	P value	F critical
Between sampling	0.922133	3	0.307378	0.639688	0.590137	2.641596
All sampling	117.245034	244	0.480512			
Total	118.167167	247				

Tab. 6 Physiological availability of soil nitrogen in subsoil – analysis of variance

Source of variability	SS	Difference	MS	F	P value	F crit.
Between samplings	3.851273	3	1.283758	1.570711	0.197118	2.642371
All samplings	195.337111	239	0.817310			
Total	199.188384	242				

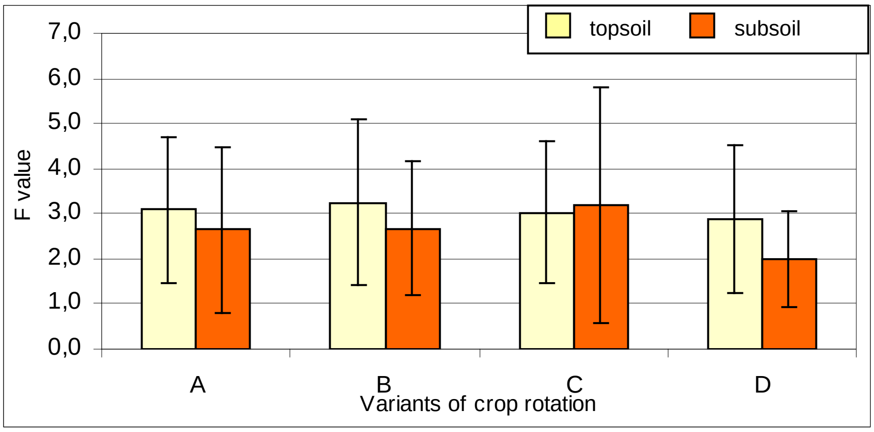
Men values of the complex effect factor for topsoil and subsoil ranged from 2.00 to 3.20. Only in subsoil, a difference was proved between particular variants (Tab. 8). The lowest values showed a variant barley after sugar beet (D). On the other hand, the highest values occurred in a variant barley after wheat (C). (Diagram 6, Tab. 7, 8).

The factor of integrated effects is an indicator of the suitability of physical conditions of the environment for soil microflora. A deviation from a value of 1 says to what degree other particularly physical factors make possible the higher utilization of carbon and nitrogen in integrated effects than it would correspond to the product of this effect at a separated application. Novák (1969) mentions these mean values in chernozems: 10.43 (topsoil) and 7.61 (subsoil). These values show very good physical conditions as compared with our results. Němeček (1990) gives a value of 2.00 in chernozems. Pokorný and Denešová (2005) mention a mean value of 1.96 for the group of selected soil types in the area of central Moravia. For permanent grasslands, the mean range of this parameter is 1.20 – 1.40 (Pokorný, Šarapatka, Nenátková 2007).

In selected soil types, whose values of potential respiration are given in the survey of biological properties (Střalková, Pokorný 2001), this quotient is 2.81. For selected chernozem localities, Pokorný Střalková and Denešová (1997) mention following values: locality Kostelec – 4.30 and locality Zahnašovice – 2.60.

Values found by our workplace (2.00 - 3.20) are relatively similar to data from literature sources. Values mentioned by Novák (1969) are an exception. Thus, it is possible to observe important changes in soil properties, which occurred within 40 years.

Diagram 6 *Mean values and the standard deviation of the factor of complex effects in topsoil and subsoil*



Tab. 7 *The factor of complex effects in topsoil – analysis of variance*

Source of variability	SS	Difference	MS	F	P value	F crit.
Between samplings	3.78944	3	1.26315	0.44985	0.71763	2.64160
All samplings	685.13855	244	2.80794			
Total	688.92799	247				

Tab.8 *The factor of complex effects in subsoil – analysis of variance*

Source of variability	SS	Difference	MS	F	P value	F crit.
Between samplings	43.43637	3	14.47879	4.31506	0.00550	2.64253
All samplings	798.58776	238	3.35541			
Total	842.02413	241				

Conclusion

The monitoring was carries out in field experiments of the Agricultural Research Institute, Ltd. in Kroměříž in 1993 – 2000 on 4 variants of crop rotations in topsoil and subsoil.
The biological activity of soil, which is represented by measuring the respiration activity of microorganisms, was measured by an interferometric method.
N/B (topsoil): at the shortage of physiologically available nitrogen the values approach one. At the beginning of the growing season, variant C keeps at its disposal the highest amount of nitrogen – spring barley after winter wheat with a value of 1.09 and D – spring barley after sugar beet with a value of 1.01.
F (topsoil): at the factor of complex effects, a deviation from one says to what degree other particularly physical factors make possible higher use of carbon and nitrogen in integrated effects than it corresponds to the product of this effect at a separate application. The highest values at this parameter in topsoil correspond to variants A (winter wheat after barley), viz. 3.7 and D – spring barley after sugar beet, namely at the end of the studied season (3.7).
N/B (subsoil): at variant A (winter wheat after barley) and C (spring barley after winter wheat) it is possible to monitor the gradual increase of values in subsoil, which shows the physiological utilization of soil nitrogen.
The highest values (A – 1.85, C – 1.70) were determined in these variants in the second half of May, then the values fall at the end of the season. It means, that in this period (the second half of May), the physiological utilization of nitrogen was least. In a variant wheat after alfalfa (B), its highest value occurred at the end of the growing season (1.42) and thus also the lowest content of physiologically available nitrogen from the whole season. Variant B – 1.02 (winter wheat after alfalfa) and variant C – 0.92 (spring barley after winter wheat) approached maximally a value of one when the amount of nitrogen is sufficient, namely at the beginning of the studied period. In variant D – spring barley after sugar beat – there is the lowest amount of available nitrogen at the end of the growing season (1.79) and relatively the highest amount of nitrogen occurs in the first half of the growing season (1.51).
F (subsoil): the highest values of parameter F in subsoil correspond to variants wheat after barley (A) – 3.4 and barley after wheat (C) – 4.6, viz. as in wheat - at the end of the studied season.
Mean values of physiologically available soil nitrogen for topsoil and subsoil were relatively similar and their values ranged about 1.5. As for variants under monitoring, there was higher value only in variant B for topsoil than for subsoil. In other variants, values of N/B were higher in topsoil. However, the difference between particular variants of a crop rotation was

not proved there. Mean values of the factor of a complex effect for topsoil and subsoil ranged between 2.00 and 3.20.
Only in subsoil, a difference was proved between particular variants of the crop rotation (Tab. 8). A variant barley after sugar beat (D) showed the lowest value – 2.00 and, on the contrary, the highest value occurred a variant barley after wheat (C) – 3.20.

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SOIL INFILTRABILITY BY DIFFERENT SOIL TILLAGE

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Abstract
Soil infiltration properties have an important role in soil protection against water erosion. One of agronomical factors influencing soil infiltration is soil tillage. On experimental site in Višňové (South Moravia, CZ) with monoculture of maize was observed an influence of different tillage technology (ploughing, shallow tillage and no tillage - direct drilling) on infiltration of rainfall water into soil and physical soil properties. Measurements of infiltration were made with double ring infiltrometers in two terms (during vegetation and after harvest) with additional measurement of soil penetration resistance. In the first term was found the highest water infiltration on ploughing variant while the lowest was on no tillage variant. Different results were obtained from the measurement after harvest - the highest infiltration was on shallow tillage variant and the lowest one on ploughing variant. The results show that soil tillage has a different effect on soil infiltrability and can help to protect soil against effects of water erosion.

Keywords: soil infiltration, tillage, soil erosion

Introduction

Soil infiltrability is one of the key factors in soil protection against water erosion. Water dropping on soil surface in form of rainfall can infiltrate to the soil or it can run off. Insufficient infiltration decreases water downward movement into soil and in combination with high rainfall intensity (or its longer persistency) can lead to water runoff and negative erosion effects.

Infiltration is influenced by number of factors which can be classified into four classes (Lal 2002) – soil properties (structure, texture, morphological, chemical and moisture parameters), soil surface properties (soil crust), crop management practices (soil tillage, vegetation cover) and nature condition (precipitation, temperature and soil moisture).

Modification of crop management practices presents the easiest way of anti-erosion proposals. Besides change of crops or way of field cultivation on slopes it is also possible to use positive effects of soil tillage. Soil tillage technologies influence differently soil physical properties, especially bulk density, porosity and structure and this is reflected in the soil infiltration. From these reasons an experiment was conducted. This experiment observed influence of different tillage systems on soil infiltration on maize field. The goal of this research is verification of different influence of tillage technologies on soil infiltration and to show the importance of tillage system for soil erosion control.

Materials and method

Observation was made in year 2007 on pilot stationary field experiment with maize on locality Višňové (South Moravia) on loamy haplic Luvisol. The experimental field with maize monoculture was conducted in 2001 in three different tillage variants:

- traditional tillage – ploughing (PL) 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

The measurement of soil infiltration was made in 2007 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 0.28m and 0.54m in soil depth of 0.1m were used for soil infiltrability measurement. In smaller ring is monitored decrease of water volume in time and larger ring eliminates horizontal water leakage from smaller ring. When water surface decreased on given level then the rings were filled again and time interval between fillings was recorded. The measurement spent 2 – 4 hours.

Fig.1 Double ring infiltrometer and Penetrologger with Theta probe

Simultaneously with infiltration capacity was measured soil compaction by soil penetration resistance. There was used Penetrologger (Eijkelkamp, Netherland) suitable for measurements up to a depth of 0.80 m and equipped with Theta probe for soil moisture estimating. On each variant there were made five penetrations within a circle of 3m diameter. Simultaneous soil samples were taken for labor analysis of soil physical properties.

Results and discussion

Figure 2 shows a curve of cumulative infiltration and cone index from spring measurement. Higher infiltration was on the variant with conventional tillage – ploughing (PL). Conversely the lowest water volume infiltrated on the no-tillage variant (NT). These results analogically reflect the soil compaction on the variants. In topsoil has PL lower cone index than on the ST and NT variant. With lower depth soil compaction on PL variant is rapidly increasing while on ST and NT variant are values of cone index equable and even in 0.2 - 0.3 m soil depth are decreasing. This is a typical example of different tillage influence on soil compaction when the use of tillage minimization technology reduces the negative subsoil compaction

CONTENT

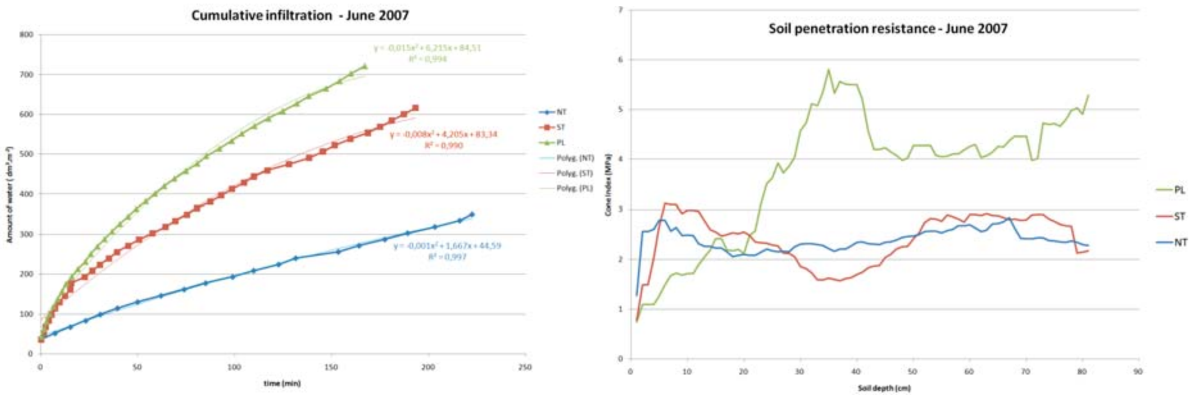

Fig. 2 Graphs of cumulative infiltration and soil penetration resistance from June 2007

Results from measurement after harvest of maize (Fig. 3) are different compared to spring term. The larger volume of water was infiltrated on ST variant, smallest on PL. Results of soil penetration resistance are different too. All three variants show very similar cone index curve which is continuously increasing according to decreasing depth. The reason of this phenomenon is probably harvesting of maize by heavy mechanization and too many crossings of this mechanization through the field, which induce negative increasing of subsoil compaction on minimization variant (ST and NT).

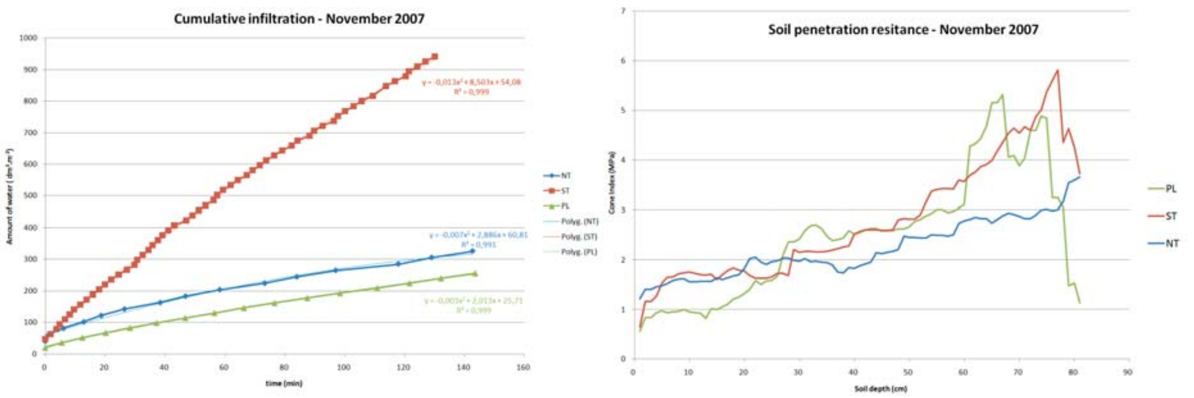

Fig. 3 Graphs of cumulative infiltration and soil penetration resistance from November 2007

Conclusion

Obtained results confirm different effect of soil tillage on infiltration capacity of soil surface. Soil tillage and seeding are another factors influencing negatively impact of water erosion in potential erosion areas. This fact can be important for anti-erosion proposals because this operation does not cause any landscapes changes. It can be easier acceptable in practice than restrictions of crop management or expensive landscapes recultivation.

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PHYSICAL SOIL PROPERTIES IN DIFFERENT SOIL TILLAGE BY MAIZE MONOCULTURE

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Abstract
The study is focused on comparison of physical soil properties changes in different soil tillage systems to corn. The experiment was established in maize growing region. Soil on the trials was brown soil with humus content 2%, with good content of phosphorus, potassium, magnesium and neutral soil acidity.
Three technologies of soil tillage was compared – 1. ploughing to 0,22 m, 2. shallow loosening 0,10 – 0,12 m, 3. direct seeding.
The modified method of Kopecký-Novák was used for analyses. The depth of soil sampling was 0-0.10, 0.10-0.20, 0.20-0.30 m with five repetitions.
The realized analyses evaluated the impact of different soil tillage on the physical soil properties. The ploughing had better values by bulk density, porosity, minimum air capacity than the technologies without ploughing - loosening or direct seeding. The results showed that the technologies without ploughing had higher amount of water in soil. Better water-supply of corn becomes more evident in dry years.

Keywords: soil tillage, soil physical properties, maize

Maize is a crop which still attracts attention of farmers. In recent years we have been witnesses of noticeable climatic changes and this crop seems to be very flexible and tolerant to the changes of weather and to potential faults in agricultural engineering. Maize becomes still more important crop mainly in areas suitable for its growing. Agriculture practice is trying to find and use new ways of soil tillage and maize stands establishing. In this article there are compared physical soil properties in different soil tillage systems and corn maize stand establishing on experimental field in maize production area.

The experimental field with corn maize was established in maize production area on clay orthic luvisol soil with humus content 2% and with proper amount of phosphorus, potassium, magnesium and neutral soil acidity.
The experiment was established in these three variants:

1. ploughing to the depth 0.22 m, spring harrowing, cultivation by tiller Horch Phantom before seeding, seeding by precise drill seeder JOHN DEER MaxEmerge (eight-row) with plant precision fertilization, rolling.
2. shallow loosening by disc equipment to the depth 0.10 – 0.12 m, cultivation by tiller Phantom before seeding, seeding by precise drill seeder JOHN DEER MaxEmerge (eight-row) with plant precision fertilization, rolling
3. direct seeding without soil tillage, sowing by drill seeder for precise sowing JOHN DEER MaxEmerge with plan precision fertilization, rolling

Variants were fertilized in the same way:

N – 155 kg.ha^{-1} before seeding – fertilizer carbamide, 20 kg.ha^{-1} – precision plant fertilization – fertilizer Amofos
P, K – reserve supply before establishment of the experiment in autumn 2001 (100 kg P_2O_5 and K_2O), 30 kg P_2O_5. ha^{-1} in fertilizator Amofos – precision plant fertilization every year during seeding.
There was used hybrid Suarta, precocity FAO 400.

Measurements of physical soil properties were made in 2005 – 2007. There was used method of taking samples into so called Kopecky physical rollers. These main physical characteristics were observed: bulk density (g.cm^{-3}), total porosity (%) and minimum air capacity (%). The depth of soil sampling was 0-0.10; 0.10-0.20; 0.20-0.30 m in five replications.

Analysis were made by method of taking undisturbed soil samples Kopecky-Novak modified by Kostelansky (Kostelansky 1980) used on the Department of Agriculture and Bioclimatology, MUFA in Brno. Statistical evaluation of detected physical soil properties was processed by computer program Unistat 5.1 for Excel.

Results

From the observed physical soil properties were chosen bulk density (OH), total porosity (P) and minimum air capacity (MVK) as representative indicators of changes in top soil layers caused by different technologies of soil tillage. These main physical soil properties reflect each mechanical intervention to the three-phase soil system (hard soil mass, water and air). Then there were founding moisture soil characteristics – volume soil moisture (%), weight soil moisture (%).

Tab. 1: Influence of different soil tillage on bulk density

Variants	**Bulk density (g.cm^{-3})**			
	0 – 0,10 m	**0,10 - 0,20 m**	**0,20 – 0,30 m**	**average 0 – 0,30 m**
1	**1,07**	**1,33**	**1,40**	**1,27^{a}**
2	**1,17**	**1,51**	**1,48**	**1,39^{b}**
3	**1,29**	**1,51**	**1,49**	**1,43^{b}**

different letters (a, b) indicate significant differences at $P \leq 0.05$

Determined values show that for minimum tillge technologies are typical higher values of soil bulk density in the top soil layer 0 – 0.10 m. In case of both minimum tillage technologies there were marked quite high values of bulk density in the depth 0.10 – 0.20 m. There probably still remain influence of former ploughing to the depth 0.22 – 0.25 m when there were created more compact soil layer or this more compact layer can be crated by repeated shallow tillage to the same depth. In this case ploughing shows more positive values of OH.

By statistical evaluation of bulk density reduced by Least Square Difference method (LSD) there was found statistically significant difference between the variant 1. (ploughing) and the variant 2. (shallow loosening) and between variant 1. (plouhging) and variant 3. (direct seeding). Between 2. (shallow loosening) and 3. variant (direct seeding) there was not found statistically significant difference.

Tab. 2: Influence of different soil tillage on total soil porosity

Variants	**Total porosity (%)**			
	0 – 0,10 m	**0,10 - 0,20 m**	**0,20 – 0,30 m**	**average 0 – 0,30 m**
1	**59,04**	**49,06**	**46,39**	**51,50^{a}**
2	**55,29**	**42,30**	**43,48**	**47,03^{b}**
3	**50,58**	**42,34**	**43,22**	**45,39^{b}**

different letters (a, b) indicate significant differences at P ≤ 0.05

Situation with total porosity is quite similar. Total porosity declines with depth. In soil profile there prevail capillary pores only in variant 1. (ploughing) there is relation of capillary and non capillary pores 1 : 1 and this hold for the whole profile.

There were made statistical evaluation of bulk density and also of total porosity by LSD method. Statistically significant difference was found between variant 1. (ploughing) and variant 2. (shallow loosening) and between variant 1. (ploughing) and variant 3. (direct seeding). Between 2. (shallow loosening) and 3. variant (direct seeding) there was not found statistically significant difference.

Tab. 3: Influence of differnet soil tillge on minimum air capacity

Variants	**Minimum air capacity (%)**			
	0 – 0,10 m	**0,10 - 0,20 m**	**0,20 – 0,30 m**	**average 0 – 0,30 m**
1	**25,28**	**11,50**	**9,20**	**15,33^{a}**
2	**19,15**	**8,26**	**10,41**	**12,^{61a,b}**
3	**14,75**	**8,52**	**10,00**	**11,10^{b}**

different letters (a, b) indicate significant differences at P ≤ 0.05

Values of minimum air capacity in minimum technologies were very low and on the level of critical state. The highest values of minimum air capacity were in ploughing variant. Statistical evaluation of results from three years detected statistically significant difference between 1. variant (ploughing) and 3. variant (direct seeding). There was not detected statistically significant difference between 1. (ploughing) and 2. variant (shallow loosening) and also between 2. (shallow loosening) and 3. variant (direct seeding).

Sample analysis shown soil moisture too. On the other hand this very important soil property was positively influenced by minimum technologies for which higher soil moisture was typical and mainly its distribution on every sample depth was better balanced. By statistical method of LSD there were found statistically significant differences between variant 1. (plouhging) and variant 2. (shallow loosening) and between variant 1. (ploughing) and variant 3. (direct seeding). Between variant 2. (shallow loosening) and 3. variant (direct seeding) there was not found statistically significant difference. Variant 3. (direct seeding) reached in each observation in each year always the highest value of volume soil moisture. We found the same conclusions in case of weight soil moisture.

Tab. 4: Influence of different soil tillage on soil moisture (by volume)

Variants	Soil moisture (by volume) (%)			
	0 – 0,10 m	0,10 - 0,20 m	0,20 – 0,30 m	average 0 – 0,30 m
1	15,50	27,25	27,53	23,43[a]
2	23,51	26,77	27,32	25,87[b]
3	27,80	25,12	28,36	27,10[b]

different letters (a, b) indicate significant differences at $P \leq 0.05$

Analysis summed up influence of different soil tillage and crop stand establishment on physical soil properties in case of corn maize monoculture growing. Ploughing shown better values of bulk density, prosity and minimum air capacity compared to non plouhging technologies (shallow loosening and direct seeding). Better supply of maize by water is more significant in dry years. During the observed period there was not noticed statistically significant difference among yields from variants. But on average plouhging technology reached higher yields.

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EFFECT OF TILLAGE DEPTH ON PHYSICAL AND CHEMICAL SOIL PROPERTIES

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Abstract
The studies on the effect of tillage depth on physical and chemical soil properties in comparison to both successive and cut fallow soils were conducted in the Experimental Station Baborówko, Poland during the years 2004-2006. Both fallowed soils (no tillage) were characterized by significantly lower mineral nitrogen content in 0-30 and 30-60 cm soil layers than soils tillaged to 30 cm (traditional system) and 8 cm (reduced system) tillage depths. Soil of cut fallow were also distinguished by the highest penetration resistance than soils of the other tillage systems in 0-10 cm soil layer and significantly higher CO_2 flux than soil of reduced tillage. The soil of traditional soil tillage system were distinguished by the lowest penetration resistance in 10-20 cm soil layer and the smallest bulk density and the highest pH in 10-15 cm soil layer. Comparing to soils of both reduced tillage system and direct sowing soil of traditional tillage system were distinguished by higher CO_2 emission and a tendency to higher content of available phosphorus and potassium.

Keywords: soil, soil tillage systems, physical properties, chemical properties

Introduction
From many papers (Blecharczyk i in. 2007, Al.-Kaisi i Yin 2005, Tarkalson 2006) it is known that the depth of soil tillage effects physical and chemical status of soil environment. Simplifications of tillage, including no tillage system, lead to increase of soil density, compaction and humidity (Pabin 2002, Tendziagolska i Parylak 2004). It reduces also the rate of soil organic matter mineralization and emission of CO_2 to atmosphere (Al.-Kaisi i Yin 2005) and protects soil against erosion (Dzienia 2006, Kraska i Pałys 2004). As a result of too low soil tillage the increased concentration of organic matter and fertilizer components in upper soil layer is possible (Dzienia i in. 2001, Rhoton 2000, Tebrügge i Düring 1999). However compensation of bigger amounts of water and organic matter in soil promotes both increase of NO_3 leaching and acidification (Bowman et. al 1995).
The literature (Diaz-Zorita 2004, Dzienia i in. 2001, Hussain i in. 1999) shows that the results of soil tillage simplifications are evident after a few years. The purpose of the study was to determine the influence of some soil tillage systems on physical and chemical soil properties in comparison to traits of both successive and cut fallow soils after four years from differentiation of tillage systems. Due to simplifications of soil tillage are related to reduction of machinery interference depth into soil, the characteristics of soil tillage results were resolved into determination of soils changes as a result of tillage measures to different soil depth. According to actual knowledge of authors the fertility indicators of treated soil wasn't compared with status of soil typical for both successive and cut fallows. Such direct comparison in the sequence: successive fallow - cut fallow –direct sowings – reduced tillage – traditional tillage wasn't done yet.

Material and methods
The studies were conducted in production fields of the specialistic Experimental Station in Baborówko, Poland in 2004-2006 on the soils with Podzoluvisols in priority.

Since 2002 the Station area was divided into three fields, where three crops (rape/lupine – winter wheat – spring barley) have been cultivated in crop rotation. Beside that two fields: successive and cut fallow were separated. On the area of each field three tillage systems differentiated by soil depth are used: traditional tillage (skimming to 8-10 cm and sowing plough to 30 cm soil depth), reduced tillage to 8-10 cm depth (cutting of stubble from previous crop and soil loosening with Ares harrow) before sowings and system of direct sowing (2-3 cm depth). In each of the three winter wheat fields and two fallow fields physical and chemical soil properties were estimated in four stable areas (100 m^2) during wheat harvest time. Directly in the field the following measurements of physical soil properties were taken:

- soil compaction (MPa) – using electronic penetrometer in 0-10, 10-20 and 20-30 cm soil layers, with 2 cm accuracy, in 10 replications.
- Soil CO_2 flux ($\mu mol \cdot m^{-2} \cdot s^{-1}$) – using LI-6400 instrument

The other physical and chemical soil properties were estimated in soil samples taken from 0-5, 10-15 and 20-25 soil profile layers:

- soil stability - on the base of readily dispersible clay RDC content ($g \cdot 100$ g of $soil^{-1}$) – turbinimetric method according to Czyż et. al (2002).
- Bulk density ($Mg \cdot m^{-3}$) and actual water content (%, v/v) –oven-dry method using 100 cm^3 Kopecky's cylinders,
- soil reaction – potentiometricallly in 1 M KCl solution
- organic carbon content (%) –Turin's method
- soil available potassium and phosphorus content ($mg \cdot 100\ g^{-1}$ of soil) – Egner-Richm's method
- magnesium content ($mg \cdot 100\ g^{-1}$ of soil) – Schachtschabela method

Mineral nitrogen (Nmin) content ($kg \cdot ha^{-1}$) was estimated in soil samples taken from three soil profile layers: 0-30, 30-60 and 60-90 cm.
Results of measurements and analyses were statistically analyzed by ANOVA. Means were compared by Tukey test and considered significant at P=0.05. Calculations were performed using statistical program Statgraphics Centurion v.15.

Results and discussion

Soil physical properties

Tillage measures into different soil depth influenced the variability of physical soil properties. Bulk density was significantly differentiated in upper soil layers (tab.1). Bulk density of both successive and cut fallow soils was usually higher than density of cultivated soils in winter wheat fields. In surface layer (0-5 cm) bulk density of successive fallow soil was significantly higher than bulk density of reduced tillage soil and in 10-15 cm layer soil density of both fallows was significantly higher than soil of traditional tillage.
The results confirm earlier studies of other researches. Blecharczyk et. al (2007) have found higher bulk density in soil surface layer of direct sowings than in soils of other tillage systems. In the layer 10-20 cm bulk density of soil in both direct sowings and surface tillage systems was higher than in traditional tillage. In studies of Tendziagolska and Parylak (2004), as a result of mechanical measures, resignation in direct sowing system soil bulk density increased by 3.7, 1.8 and 2.9 in 5-10, 15-20 and 20-25 soil layers, respectively. Hunsjak et. al (2002) showed the smallest bulk density in the soil of traditional tillage system.

Table 1. Physical soil properties. Mean of 2004-2006

Treatments	Bulk density $Mg \cdot m^{-3}$			Readily dispersible clay RDC $g \cdot 100\ g^{-1}$			Water content (%v/v)		
	Soil layer (cm)								
	0-5	10-15	20-25	0-5	10-15	20-25	0-5	10-15	20-25
Successive fallow	1,63	1,77	1,71	0,36	0,49	0,34	15,5	14,6	11,2
Cut fallow	1,59	1,72	1,73	0,25	0,36	0,34	14,5	15,5	13,4
Direct sowing	1,57	1,64	1,63	0,47	0,70	0,57	15,2	15,1	10,6
Reduced tillage	1,50	1,66	1,65	0,28	0,37	0,37	13,2	13,9	10,5
Conventional tillage	1,57	1,56	1,64	0,44	0,56	0,55	16,1	16,0	15,5
$LSD_{(0.05)}$	0,098	0,139	r.n.	r.n.	0,266	r.n.	r.n.	r.n.	r.n.

Tillage depth significantly influenced also soil stability i.e. resistance to leaching, in 10-15 soil layer (tab.1). Soils of direct sowing, traditional tillage and successive fallow systems were characterized by the highest stability. The smallest stability characterized soils of reduced tillage and cut fallow systems.
Tillage depth did not effect water content in studied soils (tab.1). However, soil of traditional tillage system was characterized by a tendency to higher humidity than soils of other systems. Relatively smaller water content was found in soil of reduced tillage system.
In Blecharczyk et. al (2007) tillage systems did not differentiate soil humidity in surface layers, either. In deeper layer (10-20 cm soil of no-plough system was characterized by smaller humidity than soil of plough system. The other authors Tendziagolska and Parylak (2004) and Blecharczyk et. al (1999) showed increase of soil humidity in direct sowings in comparison to traditional plough system.
Soil compaction was significantly differentiated between tillage systems in layers up to 20 cm depth (tab.2). The highest soil compaction in the surface layer (0-10 cm) was found in soil of cut fallow. In 10-20 cm layer the compaction of traditional system soil was significantly smaller than in other tillage systems.
The results are in agreement with studies of other authors. Tendziagolska and Parylak (2004) showed higher soil compaction in direct sowing system than in soils of traditional tillage system. In studies of Blecharczyk et. al (2007) both direct sowing and other reduced tillage systems increased soil compaction in 0-10 and 10-20 cm soil layers. No studied tillage system effected compaction of soil in 20-30 cm layer.

Table 2. Penetration resistance (MPa). Mean of 2004-2005

Treatments	Soil layer (cm)		
	0-10	10-20	20-30
Successive fallow	1,34	2,92	3,65
Cut fallow	1,84	2,94	3,57
Direct sowing	1,37	2,86	3,58
Reduced tillage	1,18	2,99	2,57
Conventional tillage	1,06	2,57	3,57
$LSD_{(0.05)}$	0,212	0,213	n.s.*

*n.s. not significant difference

Depth of soil tillage differentiated CO_2 flux between soil and ambient area (fig.1). Soil of cut fallow showed significantly higher rate of CO_2 emission in comparison to that of reduced tillage system.

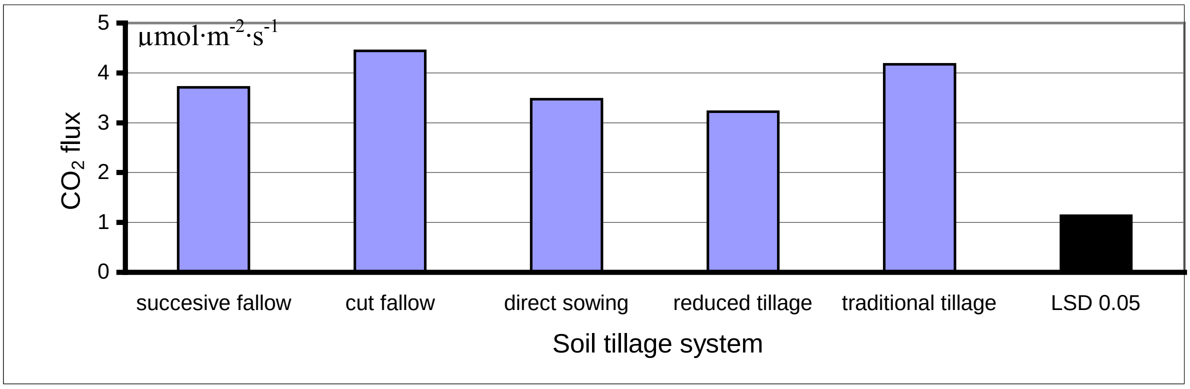

Figure 1. CO_2 flux between soil and ambient air. Mean of 2005-2006

Raich and Schlensinger (1992) said that the rate of CO_2 flux from soil to ambient air was modified by tillage measures, which increase emission by improvement of soil aeration, ameliorate contact of soil with after harvest residues and increase the nutrient availability for crop plants and organic matter for microorganisms, which is quickly oxidized. The amount of CO_2 lost from soil as a result of tillage measures is highly related to the frequency and intensity of cultivation tools interference into the soil.

Soil chemical properties

Soil tillage depth modified some chemical properties, mainly in surface layer. Soils of both successive and cut fallows showed a tendency to higher organic carbon content and significantly smaller mineral nitrogen content in comparison to both traditional and reduced tillage systems (tab.3). Among cultivated soils on winter wheat field direct sowing system showed tendency to smaller organic matter content in 0-5 and 10-15 cm layers and Nmin in the whole 0-25 cm layer. Independent of the tillage system surface soil layer (0-5 cm) showed higher organic carbon and mineral nitrogen contents than deeper soil layers.

Table 3. Organic carbon and mineral nitrogen content and soil reaction. Mean of 2004-2006

Treatments	Organic carbon (%)			Nmin ($kg·ha^{-1}$)			pH_{KCl}		
	Soil layer (cm)								
	0-5	10-15	20-25	0-30	30-60	60-90	0-5	10-15	20-25
Successive fallow	1,46	1,25	1,23	30,6	14,9	7,1	6,3	6,4	6,4
Cut fallow	1,48	1,31	1,36	25,3	8,7	5,5	6,0	6,4	6,6
Direct sowing	1,24	1,07	1,07	40,6	20,8	20,0	5,7	6,2	6,3
Reduced tillage	1,39	1,22	1,03	52,8	27,3	16,2	5,9	6,3	6,4
Conventional tillage	1,34	1,19	1,09	49,8,	29,3	13,9	6,1	6,6	6,6
$LSD_{(0.05)}$	n.s.*	n.s.	n.s.	14,28	15,06	10,24	0,45	0,27	n.s.

*n.s. not significant difference

The results are in full agreement with the previous studies of other authors, who emphasize positive effect of direct sowing system on organic matter accumulation. Dzienia et. al (2001) such effect showed in 0-10 and 10-20 soil layers in comparison to traditional plough tillage of brown soil. Pranagal (2004) stated sufficient effect of multi-years direct sowings on organic matter content in 0-10 and 10-20 cm layers of Orthic Luvisol developed

from loess**.** Both Rendzina and Eutric Cambisol showed tendency to better ability for higher organic matter accumulation in 0-10 cm layer.

Some differences in this study resulted probably from the short period (4 years) after tillage depth differentiation in the experiment.

Soil reaction was significantly differentiated in both 0-5 and 10-15 cm soil layers (tab.3). In surface layer (0-5 cm) direct sowing significantly decreased pH values in comparison to soil of successive fallow. In 10-15 soil layer of both direct sowing and reduced tillage systems significantly decreased pH in comparison to traditional tillage.

Soil reaction decrease as a result of soil tillage simplification and direct sowing was observed also by Dzienia et. al (2001) and Blecharczyk et. al (2007). The differences of soil reaction between soils of direct sowing and traditional tillage systems resulted probably from nitrogen fertilization and soil redistribution with ploughing (Tarkalson et. al 2006). Leaching of nitrates to deeper soil layers in direct sowing system was the main reason of soil acidification.

Soil tillage depth differentiated the content of macronutrients but the differences wer not significantly proved (tab.4). Tendency to increased contents of available phosphorus and potassium in surface (0-5 cm) layer showed soils of both successive and cut fallows in comparison to soil of traditional tillage system. Soils of direct sowing showed some smaller content of the nutrients than soils of other systems. Upper layers of both fallows soils contained also the highest amount of available magnesium. Soil of traditional tillage system was characterized by the smallest content of available magnesium in the whole arable 0-25 cm layer and some higher content of phosphorus and potassium in comparison to soils of both direct sowing and reduced tillage systems.

Table 4. Content of available forms of macronutrients (mg·100 g^{-1} of soil).
Mean of 2004-2006

Treatments	P			K			Mg		
	Soil layer (cm)								
	0-5	10-15	20-25	0-5	10-15	20-25	0-5	10-15	20-25
Successive fallow	62	60	65	176	119	112	82	73	79
Cut fallow	60	59	59	171	110	112	85	71	74
Direct sowing	44	59	62	151	116	100	60	70	65
Reduced tillage	46	53	50	155	99	81	65	79	73
Conventional tillage	54	61	67	163	126	106	54	47	50
$LSD_{(0.05)}$	n.s.*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

*n.s. not significant difference

The results of other studies are not explicit, although our studies confirmed some of them. Dzienia et. al (2001) have not found any significant differences between available phosphorus content in soils of different tillage systems. Blecharczyk et. al (2007) have shown significantly highest phosphorus content in surface layer (0-5 cm) of soil in traditional tillage system. Tarkalson et. al (2006) have noticed smaller potassium content in upper layer of soil in direct sowing system and as a consequence of increased crop yield and content of macronutrients in grain. Dzienia et. al (2001) and Hussain (1999) indicated an increase of available potassium accumulation in soils of both direct sowing and reduced tillage system in comparison to traditional system.

Conclusions

1. After four years since tillage depth has been differentiated no explicit changes of physical and chemical soil properties were found.
2. Soils left as both successive and cut fallows showed significantly smaller mineral nitrogen content in 0-30 and 30-60 cm layers than soils of traditional and reduced tillage systems. Soil of cut fallow was characterized also by the highest compaction in the 1-10 cm layer and significantly higher CO_2 flux between soil and ambient air than soil of reduced tillage system.
3. Traditional tillage up to 30 cm depth decreased soil compaction in 10-20 cm layer and in 10-15 cm layer it decreased bulk density and increased soil reaction ?. Soil of that system showed the tendency to higher water content and magnesium content in the whole arable layer (0-25 cm). In comparison to reduced tillage (8 cm depth) and direct sowing (2-3 cm depth) soil of traditional tillage distinguished by higher CO_2 flux and the tendency to higher available phosphorus and potassium content.

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RESPONSE OF DIFFERENT WINTER WHEAT CULTIVARS TO REDUCE TILLAGE

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Abstract

The present research covers the field experiment conducted in years 2005-2007 in Research Station Grabow, Poland. The aim of the research was to evaluate grain yield of 6 winter wheat cultivars: Finezja, Rywalka, Kobiera, Satyna, Zawisza, Bogatka, respectively, in two different soil tillage systems (conventional tillage and reduced tillage) and at two different sowing densities 3.0 and 4.5 mln grains ha $^{-1}$. The influence of the soil tillage system on grain yield depends on weather conditions during vegetation season. In 2006 the reduce tillage caused the decrease in grain yield in comparison with conventional tillage. The decrease of grain yield with use of sowing density of 4.5 mln grains ha $^{-1}$ and with use of sowing density 3.0 mln grains ha $^{-1}$ was by 43% and 51%, respectively. It was found that in reduced tillage conditions the biggest grain yield was obtained when sowing density of 4.5 mln grains ha $^{-1}$ was applied. Experiment has shown that the various cultivars reacted differently on the reduced tillage. The biggest grain yield was obtained from: Bogatka, Finezja and Kobiera cultivars whereas Satyna and Rywalka gave the lowest grain yield. The data indicate that Bogatka, Finezja and Kobiera cultivars are considered as more suitable and more useful in reduced tillage system conditions, than Satyna and Rywalka.

Key words: cultivars, grain yield, soil tillage systems weight of 1000 kernels, wheat.

Introduction

Yield formation of winter wheat is influenced by agronomical factors including soil tillage systems. Conventional tillage can be gradually replaced by various new methods which involve machines development and a decreased time-consumption in tillage operations. Tillage is an element of growing practices, showing considerable time and energy-consumption, which has become of special importance with new generations of tillage-sowing aggregates and a wide range of herbicides (Kuś 1999). That results in more frequent use of reduced tillage and direct drilling systems (Dzienia and Piskier 1999, Frant and Bujak 2005). The results obtained in different soil and climate conditions do not give the explicit answer about how the reduction of soil tillage influences the productivity of wheat plants (Hammel 1995., Malicki et al. 1997). Most of the scientific papers report the effects of the reduced soil tillage on yield, yield components and soil properties. Winter wheat cultivars have different response to agrotechnical measurements. It is likely that winter wheat cultivars may respond differently on the soil tillage system. The aim of present research was to evaluate grain yield of winter wheat cultivars in two different soil tillage systems.

Material and Methods

The research was conducted at the Grabow Experimental Station of the Institute of Soil Science and Plant Cultivation - National Research Institute of Pulawy, in 2005-2007 years. Two tillage systems (conventional tillage and reduced tillage), two sowing densities (3, 0 and

4.5 mln grains ha $^{-1}$), and 6 cultivars (Finezja, Rywalka, Kobiera, Satyna, Zawisza and Bogatka) were analyzed. Conventional tillage was a typical tillage after harvested forecrop. The grubber together with disking was applied, followed by pre-sow plugging.
In reduced tillage system after forecrop harvesting, only the disking of soil was applied. The forecrop used in this experiment was a spring burley. Experiment was carried out on pseudopodsolic soil. The soil was qualified as good rye soil complex. The phosphorus and potassium was applied in autumn in dose 50 kg P_2O_5 and 75 kg K_2O and 7,5 kg S. Nitrogen fertilization level was 83 kg ha^{-1}, applied in 3 doses (15 kg in autumn, 34 kg in early spring, 34 kg in shooting phase). The harvest was done in full vegetation phase. The grain yield and weight of 1000 kernels were investigated. The multiple range test (Tukey) was used to compare mean values.

Results and Discussion

Table 1 shows weather conditions changes occurring in different years. The most unfavourable weather condition (uncommonly hot summer together with lack of rainfall in the intensive vegetation period of winter wheat) were in 2005/2006.

Table 1
The weather conditions during vegetation season

Month	Temperature			Precipitation		
	2004/2005	2005/2006	2006/2007	2004/2005	2005/2006	2006/2007
IX	13.0	14.8	15.5	17.5	43.6	13.8
X	9.7	8.8	10.0	35.4	5.6	33.8
XI	3.3	2.8	5.4	64.2	29.0	47.1
XII	1.6	-0.4	3.1	16.6	81.6	26.0
I	0.3	-8.7	3.0	46.5	25.7	73.5
II	-4.0	-4.1	-0.9	26.9	23.9	37.4
III	-0.2	-1.5	6.3	41.9	51.8	38.0
IV	8.6	9.0	8.7	10.2	30.1	13.3
V	13.5	13.6	15.2	84.0	53.4	74.6
VI	16.1	17.4	18.7	46.3	38.3	99.9
VII	20.0	22.4	19.2	132.8	10.0	75.5
VIII	17.5	17.9	19.1	36.8	219.5	151.7

Tables 2-9 show the grain yield of winter wheat depending on the tillage system and cultivars. The grain yield is influenced by tillage soil systems, year of cultivation (weather conditions), cultivar and sowing density.
In the 2005 at sowing density of 3.0 mln grains ha $^{-1}$, the tillage system did not have any significant influence on the grain yield. On conventional tillage system, grain yield was higher by 7% in comparison to the reduced tillage however, the difference is not significant. The Finezja, Kobiera and Bogatka cultivars gave the highest grain yield (table 2). At sowing density 4.5 grains ha $^{-1}$the grain yield was comparable to the grain yield obtained while lower sowing density was applied. The Rywalka and Bogatka cultivars gave the biggest grain yield (table 3).
In 2006 the tillage system had significant influence on grain yield of winter wheat cultivars. In sowing density 3.0 mln grains ha $^{-1}$ the cultivation at the conventional tillage system conditions resulted in 50% higher grain yield than the grain yield obtained with applying the reduced tillage. Differences in grain yield between cultivars were recorded as well. In reduced

tillage conditions in comparison to the conventional tillage, Satyna, and Kobiera gave the most significant grain yield decrease of approximately 54%.

With use of sowing density of 4.5 grains ha $^{-1}$ the differences between grain yield in conventional tillage compared with reduced tillage conditions, were less significant, namely 45%. The interaction between tillage soil system and type of cultivar was found. Kobiera, Finezja Zawisza and Bogatka cultivars are the most appropriate for cultivation at reduced tillage conditions. The reduction of grain yield in reduce tillage compared with conventional tillage for Kobiera, Finezja Zawisza and Bogatka cultivars was 39%, 42%, 45% and 45%, respectively. The biggest grain yield in conventional tillage system was obtained with Bogatka, Satyna, Finezja, Zawisza cultivars (table 5)
In the 2007 there are no significant differences between conventional tillage compared with reduced soil system in grain yield. In sowing density 3.0 mln grains ha $^{-1}$ and sowing density 4.5 mln grains ha $^{-1}$, the grain yield on conventional tillage compared with reduced tillage was 4% bigger and 3% bigger, respectively. In sowing density 3.0 mln grain ha $^{-1}$ the Bogatka cultivar gave the biggest grain yield of all cultivars (table 6). In 4.5 mln grains ha $^{-1}$ the Bogatka, Finezja, Kobiera and Zawisza cultivars gave the biggest grain yield, while Satyna gave the lowest (table 7).
The data from 2005-2007 indicated that there are effectiveness differences in grain yield depending on sowing density (3.0 mln and 4.5 mln grains ha $^{-1}$), between conventional and reduced tillage systems. In lower sowing density reduction of grain yield in reduced tillage system was 18%, in bigger sowing density 15%.
Frant &Bujak (2005) investigated influence of different tillage system on grain yield of winter wheat. They compared classical plough tillage, reduced to shallow plough before sowing, and reduced plough less tillage. Authors found that the highest yield was obtained under classical tillage. The shallow ploughing slightly decreased the yield, while eliminating the ploughing caused the yield decrease substantially for about 10%. Comparative tillage methods, essentially differentiated ear density, plant length and ear length. Similar results have been obtained by (Radecki 1986, Nowicki 1988, Jabłoński i Kaus 1997, Blecharczyk 1999, Dzienia i Dojs 1999). Authors mentioned above, claim that siplyfying the pre-sowing cultivation down to shallow ploughing does not cause major decrease in winter wheat grain yield. However, significant decrease of the grain yield, with use of cultivator instead of ploughing in the soil tillage has been observed by Frant i Bujak 2005, Skrzypczak i In.1995, Bujak i Pawłowski 1997, Dabek-Gad, Bujak 2002

Figures 1 and 2 indicate influence of soil tillage on weight of 1000 grains. It is shown that tillage system dependent the weight of 1000 grains only in 2006. The reduced tillage system caused the decrease in the weight of 1000 grains.
The results obtained by other authors vary. Blecharczyk et al. (1999) observed increase of 1000 grain weight after no tillage cultivation. Results obtained by Kuś (1999) showed that replacing of ploughing by reduced soil tillage decrease grain weight. Vavera et al. (2005) and Stankowski et al. (2007) indicated that different tillage systems had no influence on physical properties of grains.

Table 2
Winter wheat grain yield depending on soil tillage system and the cultivar at sowing density 3,0 mln grains ha $^{-1}$ (2005).

Tillage system	Cultinars						Average
	Finezja	Rywalka	Kobiera	Satyna	Zawisza	Bogatka	
Reduced	8,82	8,35	8,95	8,43	8,40	9,36	8,72
Conventional	9,71	9,15	9,39	9,17	9,29	9,77	9,41
Average	9,27	8,75	9,17	8,80	8,85	9,57	
LSD for: Tillage system cultivars interaction;	 r.n. 0,349 r.n.						

Table 3
Winter wheat grain yield depending on soil tillage system and the cultivar at sowing density 4.5 mln grains ha $^{-1}$ (2005).

Tillage system	Cultinars						Average
	Finezja	Rywalka	Kobiera	Satyna	Zawisza	Bogatka	
Reduced	8,81	8,99	8,52	8,43	8,46	9,16	8,73
Conventional	9,15	9,33	9,06	9,07	9,09	10,04	9,29
Average	8,98	9,16	8,79	8,75	8,77	9,60	
LSD for: Tillage system cultivars interaction;	 r.n. 0,482 r.n.						

Table 4
Winter wheat grain yield depending on soil tillage systems and cultivars at sowing density 3,0 mln grains ha $^{-1}$ (2006).

Tillage system	Cultinars						Average
	Finezja	Rywalka	Kobiera	Satyna	Zawisza	Bogatka	
Reduced	3,09	2,57	2,69	2,64	2,97	2,88	2,81
Conventional	5,98	5,30	5,66	5,73	5,71	5,92	5,72
Average	4,54	3,94	4,18	4,18	4,34	4,40	
LSD for: Tillage system cultivars interaction;	 0,208 0,341 r.n.						

Table 5
Winter wheat grain yield depending on soil tillage systems and cultivars at sowing density 4.5 mln grains ha $^{-1}$ (2006).

Tillage system	Cultinars						Average
	Finezja	Rywalka	Kobiera	Satyna	Zawisza	Bogatka	
Reduced	3,44	2,88	3,46	2,99	3,23	3,40	3,24
Conventional	5,91	5,76	5,61	5,94	5,82	6,15	5,86
Average	4,68	4,32	4,53	4,46	4,52	4,78	
LSD for: Tillage system cultivars interaction;	 0,198 0,261 0,369						

Table 6
Winter wheat grain yield depending on soil tillage systems and cultivars at sowing density 3,0 mln grains ha $^{-1}$ (2007).

Tillage system	Cultinars						Average
	Finezja	Rywalka	Kobiera	Satyna	Zawisza	Bogatka	
Reduced	6,86	7,03	6,87	6,55	6,74	7,62	6,94
Conventional	6,94	7,08	7,29	7,07	7,02	7,88	7,21
Average	6,90	7,06	7,08	6,81	6,88	7,75	
LSD for: Tillage system cultivars interaction;	 r.n. 0,548 r.n.						

Table 7
Winter wheat grain yield depending on soil tillage systems and cultivars at sowing density 4.5 mln grains ha $^{-1}$ (2007).

Tillage system	Cultinars						Average
	Finezja	Rywalka	Kobiera	Satyna	Zawisza	Bogatka	
Reduced	7,21	7,20	6,99	6,88	7,13	7,61	7,17
Conventional	7,31	7,17	7,57	7,06	7,38	7,74	7,37
Average	7,26	7,18	7,28	6,97	7,25	7,68	
LSD for: Tillage system cultivars interaction;	 r.n. 0,528 r.n.						

Table 8
Winter wheat grain yield depending on soil tillage systems and cultivars at sowing density 3,0 mln grains ha $^{-1}$ (average from 2005-2007).

Tillage system	Cultinars						Average
	Finezja	Rywalka	Kobiera	Satyna	Zawisza	Bogatka	
Reduced	6,3 16	6,0 16	6,2 16	5,9 20	6,0 18	6,6 17	6,2 18
Conventional	7,5	7,2	7,4	7,3	7,3	7,9	7,5
Average	6,9	6,6	6,8	6,6	6,7	7,2	
LSD for: Tillage system cultivars interaction;	 0,854 0,465 r.n.						

Table 9
Winter wheat grain yield depending on soil tillage systems and cultivars at sowing density 4.5 mln grains ha $^{-1}$ (average from 2005-2007).

Tillage system	Cultinars						Average
	Finezja	Rywalka	Kobiera	Satyna	Zawisza	Bogatka	
Reduced	6,5 13	6,4 13	6,3 15	6,1 18	6,3 15	6,7 16	6,4 15
Conventional	7,5	7,4	7,4	7,4	7,4	8,0	7,5
Average	7,0	6,9	6,9	6,7	6,9	7,4	
LSD for: Tillage system cultivars interaction;	 0,658 0,395 r.n.						

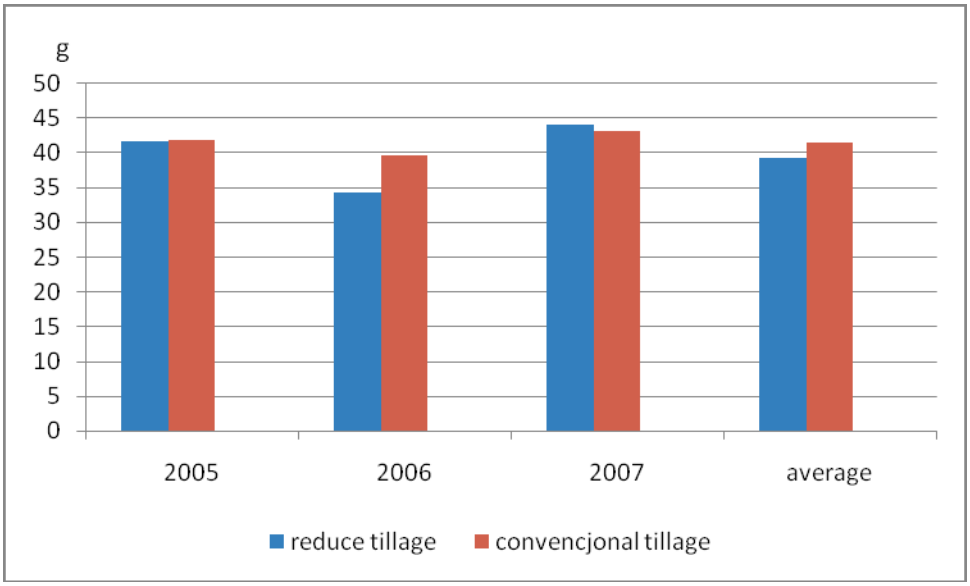

Fig. 1 Weight of 1000 kernels depending on soil tillage at sowing density 300 grains m $^{-2}$

CONTENT

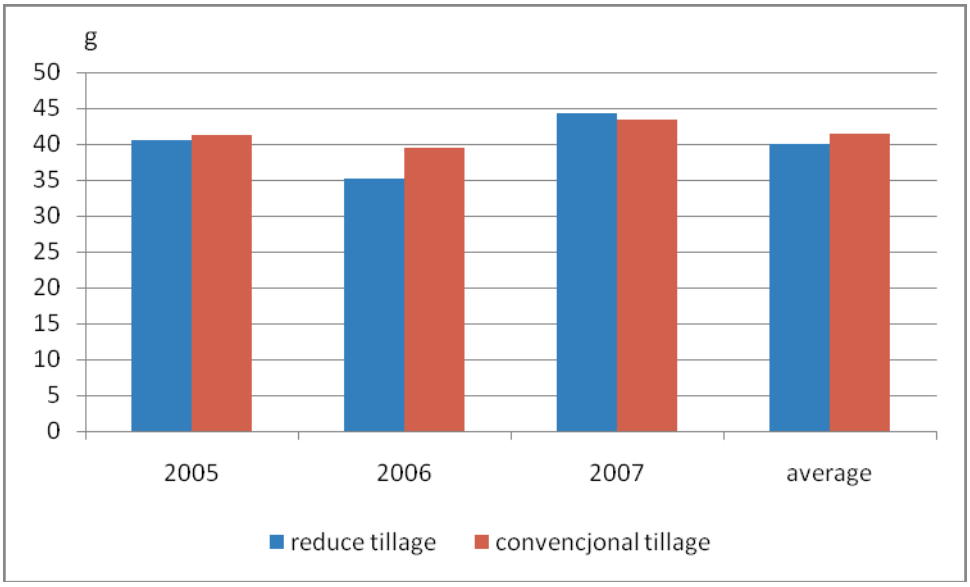

Fig. 2 Weight of 1000 kernels depending on soil tillage at sowing density 450 grains m $^{-2}$

Conclusions

The effect of soil tillage system on grain yield and weight of 1000 grains were affected by weather conditions during growing season. In 2006 unfavourable weather conditions (uncommonly hot summer together with lack of rainfall in the intensive vegetation period of winter wheat) caused significant decrease in the grain yield. Under typical weather condition, with application of reduced soil tillage, no significant change in grain yield was detected. It is likely that winter wheat cultivars may respond differently on the soil tillage system. Under drought stress conditions, with use of reduced tillage system, Finezja, Kobiera, Zawisza i Bogatka cultivars has shown the smalles reduction in grain yield, therefore those cultivars could be recomended as the cultivars siutable for reduced tillage system. It was found that in reduced tillage conditions use of sowing density of 4.5 mln grains ha $^{-1}$ in comparison to the 3.0 mln grains ha $^{-1}$ caused slight increase in grain yield. Application of reduced soil tillage system in comparison with conventional tillage had negative effect on the grain yield and weight of 1000 grains only in 2006 year.

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THE EFFECT OF REDUCED SOIL TILLAGE ON GRAIN YIELD AND YIELD QUALITY

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Abstract
The material used for investigation was the grain samples obtained from field experiment conducted in 2004/05, 2005/06 and 2006/07 years in Research station Grabow, Poland. The examined experimental factors were: soil tillage systems (conventional tillage, reduced tillage), winter wheat cultivars: Finezja, Rywalka, Kobiera, Satyna, Zawisza, Bogatka, 2 different sowing densities of 3.0 and 4, 5 mln grains ha $^{-1}$ were applied and various sowing terms, namely: early, optimal and late was used. It was found that the quality of winter wheat grain, namely: gluten content, falling number and gluten index were affected by all experimental factors.

Key words: soil tillage systems, wheat, grain quality, cultivars, sowing density, sowing term

Introduction

Most of the papers reports that yield quality of winter wheat is influenced by weather conditions, cultivars and by agronomical factors like nitrogen fertilization, crop protection and their interactions. Some of the papers report the effects of tillage system on grain quality Stankowski et al. (2007), Baenzinger et al. 1985, Cox and Shelton, 1992, Lopez-Bellido et al. (1998), but it is still not many reports were investigated about interaction between agrotechnical factors and tillage system in grain quality formation. The aim of this research was to estimate the quality of winter wheat as affected by different soil tillage systems, sowing term and sowing density.

Material and Methods

The material used for investigation was the grain samples obtained from field experiment conducted in 2004/05, 2005/06 and 2006/07 years in Research station Grabow, Poland. The experiment was conducted on pseudopodsolic soil on good rye soil complex. The fore crop used in this experiment was a burley. Nitrogen fertilization in dose 90 kg N ha $^{-1}$ was applied during winter wheat vegetations season. The phosphorus and potassium in dose 50 kg P_2O_5 ha $^{-1}$ and 75 kg K_2O ha $^{-1}$ was applied before sowing. During vegetation season the experimental crop was protected against insects, weeds and diseases. The examined factors were soil tillage systems - conventional tillage (after forecrop grubber plus pre-saw ploughing) and reduce tillage (after forecrop – disk the soil), different winter wheat cultivars: Finezja, Rywalka, Kobiera, Satyna, Zawisza, Bogatka, various sowing term and sowing density.
The following traits were estimated: falling number by Hagberg-Perten, total gluten content and gluten index (Praca zbiorowa 1983). One factor analysis of variance was used to determine the significance ($P<0.05$) of main effects and interactions. The multiple range test (Tukey) was used to compare mean values.

Results and Discussion

Figures 1-3 show the influence of tillage system on grain quality in dependence on cultivars.
Use of different tillage systems caused significant differences in the gluten content in various winter wheat cultivars (fig. 1). Lower gluten content after conventional tillage system as compared with reduced tillage systems gave Rywalka, Kobiera, Satyna, Zawisza, Bogatka cultivars. The Finezja cultivar gave the higher gluten content after conventional tillage system.
Both factors of experiment: the tillage system and cultivars had influence on falling number. The biggest decrease of falling number after conventional tillage system was observed when Bogatka and Kobiera cultivars were used. In case of application of reduced tillage system in Satyna and Finezja cv. the decrease of falling number was observed (fig. 2).
The formatting of gluten index in various soil tillage conditions (conventional tillage, reduced tillage) was different for various cultivars. Finezja, Satyna and Zawisza cultivars in case of conventional tillage application, showed decreased index gluten. In Rywalka cv. the tillage system had no effect of index gluten but in case of Kobiera and Bogatka cv. the application of reduced tillage caused decrease of gluten index (fig.3).
In early sowing term and sowing density of 3.0 mln grains ha $^{-1}$ the reduced tillage increased the gluten content in grains for approximately 1,6%. In optimal sowing term conditions, the increase of gluten content was higher, came up to 3.0%. In late sowing term however, the tillage systems have no influence on the gluten content (fig.4).
In the sowing density of 4.5 mln grains ha $^{-1}$ and early sowing term there was no effect of tillage systems on gluten content. In optimal sowing term the tillage system had influence on the gluten content. Reduced tillage caused the raise in the gluten content for app. 2.5%. However, when late sowing term was applied, increase of gluten content was observed only with application of conventional tillage system (fig.4).
Nor the tillage system under different sowing densities conditions, neither do sowing term conditions had any effect of falling number (fig.5).
In the conditions of sowing density of 3.0 mln grains ha $^{-1}$ and early and late sowing terms, the gluten index was higher on reduced tillage. In optimal sowing term the increased of gluten index was observed when conventional tillage was applied (fig.6)
In the conditions of sowing density 4.5 mln grains ha $^{-1}$ and early as well as optimal sowing term, slightly higher gluten index was found when conventional tillage was applied. However, in the conditions of sowing density 4.5 mln grains ha $^{-1}$ and late sowing term, higher gluten index was found when reduced tillage was applied (fig.6).
Results obtained by Stankowski et al. (2007) indicated that different tillage systems (conventional, reduced and direct sowing) had no influence on most of the grain quality traits. Higher values were obtained for falling number, gluten content and water absorption when direct sowing was applied, effects were not significant however. Some other studies concerning protein content, a main trait connected with grain quality, as a function of tillage systems reporting no significant differences (Baenzinger et al. 1985, Cox and Shelton, 1992). In contrast Lopez-Bellido et al. (1998) reported higher protein content and alveograph parameters for conventional tillage in comparison to the no tillage conditions. Author explained more significant results for conventional tillage due to the greater availability of soil nitrogen. In the other experiment (Lopez-Bellido et al. 2001) observed positive effect on grain protein, but there were no differences in dough quality as expressed by alveogram indices.

Conclusions

The quality of winter wheat grain, namely: gluten content, falling number and gluten index was affected by all experimental factors: tillage systems, cultivars, sowing term and sowing density.

Fig. 1 Gluten content depending on tillage systems and cultivars

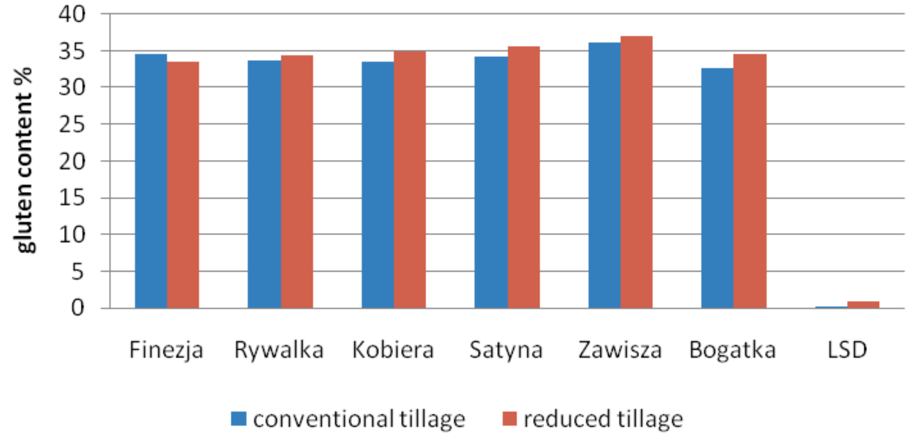
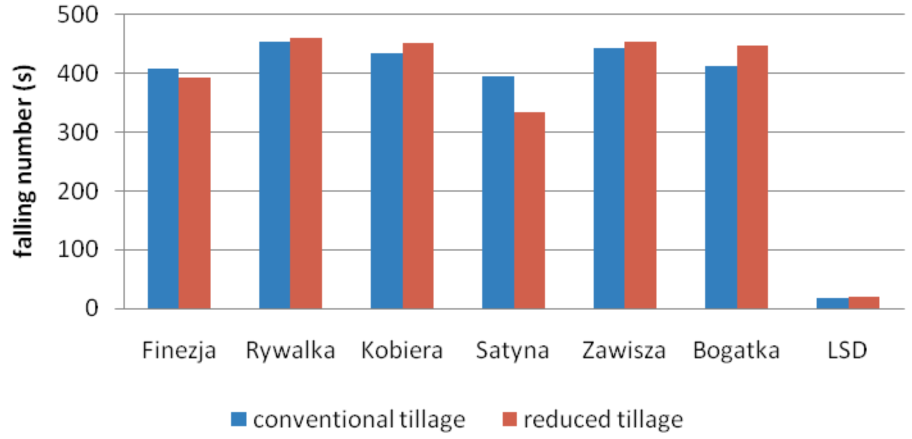


Fig. 2 Falling number of winter wheat depending on tillage systems and cultivars



CONTENT

Fig. 3 Gluten index of winter wheat depending on tillage systems and cultivars

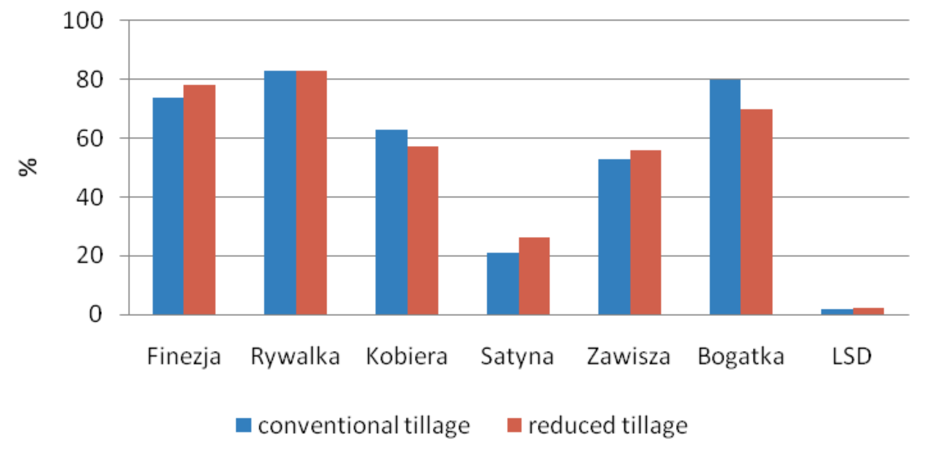
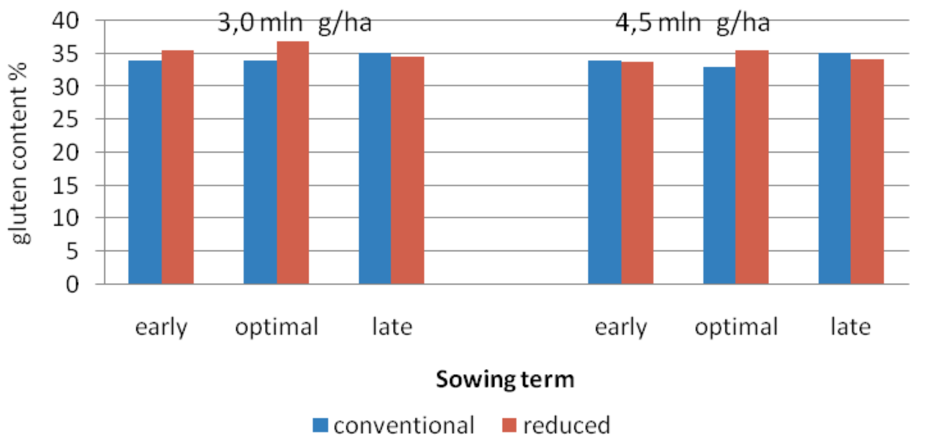
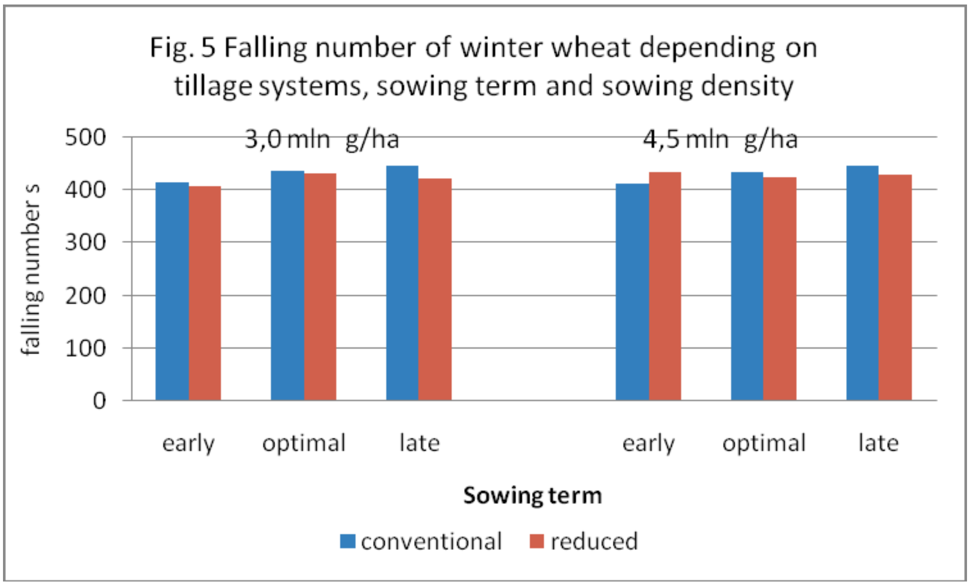
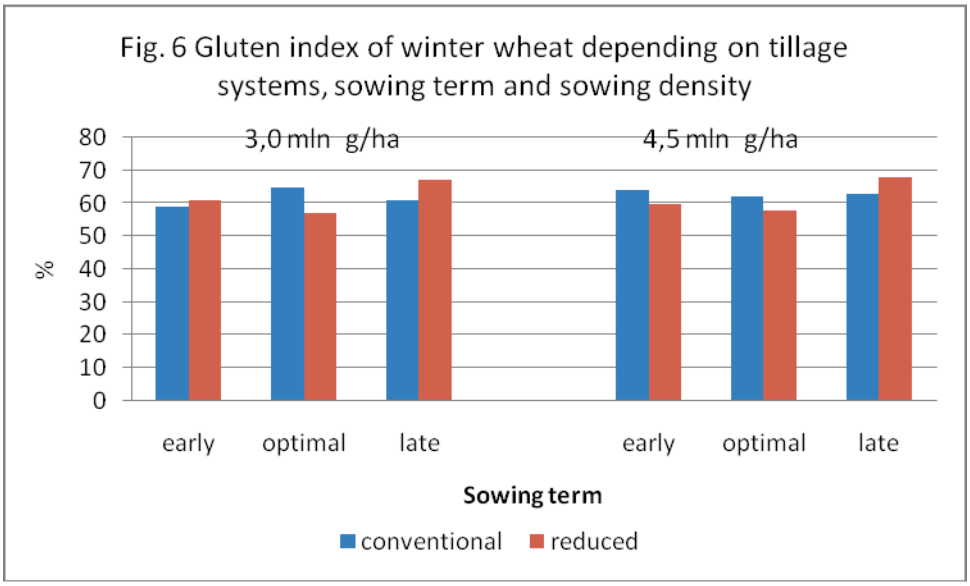


Fig. 4 Gluten content of winter wheat grains depending on tillage systems, sowing term and sowing density







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SOIL ORGANIC MATTER QUALITY AS INFLUENCED BY TEXTURE

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Abstract
Content and stability of soil organic matter is given by environmental factors, management factors and by land history. We followed humus content and quality as influenced by soil texture. Long - term field experiments started in 1999 at the Czech-Moravian Upland. Two types of cropping practices (L-legume–based crop rotation system and G-grassy soil) - were studied during 7 years. Soil was sampled in 25cm upper layer twice a year and analysed for TOC, fractional composition and texture. Multifactor analysis and ANOVA for statistical evaluation was used. Results showed that humus content and quality strongly depends on soil management practices. TOC content was mostly influenced by particles less than 0,001mm. HS sum and HA content were influenced by particles less than 0,01mm. We can conclude that humus content and quality was closely connected with soil texture and management practices.

Key words: soil texture, fractional composition of humus, total carbon content

Introduction

Soil organic mater usually measured and expressed as total organic carbon content (TOC) influences all of the basic soil properties. Their importance for agriculture is very significant.
Changes in the total carbon content (TOC) usually occur slowly over periods of years or decades whereas some fractions within the total respond more rapidly to changes in management. Management of crops and soils is an important parameter in controlling the inputs of organic matter to the soil. It is supposed that soils under constant management for a long time were able to assume steady stable-state conditions. They can secure an optimum humus status or even a balance surplus of humus, improving soil quality and fertility (Gonet et al., 1999). Quantitative and qualitative differences in crop residues are supposed to be important for the humus quality (e.g. legume-based rotations tend to conserve more of their organic matter inputs in the soil than continuous cropping systems with non-leguminous crops (Drinkwater et al., 1998). The aim of our study was to evaluate the quality of soil organic matter content and quality as influenced by different cropping systems.

Material and Methods

Disturbed soil samples were taken from the topsoil (0-20cm) at stationary long-term field experiments at the Czech-Moravian Upland (locality Vatín, 530 m above sea level, average yearly air temperature 6.9°C, average yearly precipitation 621mm). We observed texture, total carbon content and fractional composition of humus during the years 1999 - 2006. Two types of cropping practices were followed: arable soil (legume – based crop rotation system) and grassy soil. Soil type was classified according to Němeček et al. (2001) as Eutric Cambisol. Total carbon content (TOC) was estimated by titrimetric method (In: Jandák et al., 2003). Fractional composition of humus was determined according to Kononova-Beltchikova method (In: Podlešáková et al., 1992). Texture was determined by pipette method (In: Jandák et al., 2003). Multifactor analysis and ANOVA for statistical evaluation was used.

Results and discussions

Soil was light - middle heavy textured according to Němeček (2001). Results of total carbon content and fractional composition of humus during studying period is listed in Fig. 1, 2. Average carbon content was 1.98% under grassy soil and 1,51 under arable land. Statistically significant differences between variants were found (Fig. 1). Fractional composition of humus showed average values about 10 mg/kg under both variants. No statistically significant differences were found. HA content was about 5mg/kg under both variant and no statistically significant differences were found. FA content was about 7mg/kg under both variant and no statistically significant differences were found (Fig. 2, 3). HA/FA ratio was <1. The last indicated low quality of humic substances. According to multifactor analysis we came to the conclusion that texture (% of silt fraction) influenced TOC content by 11%. Texture influenced the sum of humic substances content by 17%. Texture influenced HA content by 16.6%. Texture influenced FA content by 38.2%.

Conclusions

We can conclude that lower carbon accumulation was found under arable soil to compare with grassy soil. Texture directly influenced carbon accumulation and quality of humic substances. Type of land management was an important factor that influenced TOC content in Eutric Cambisol.

Acknowledgements
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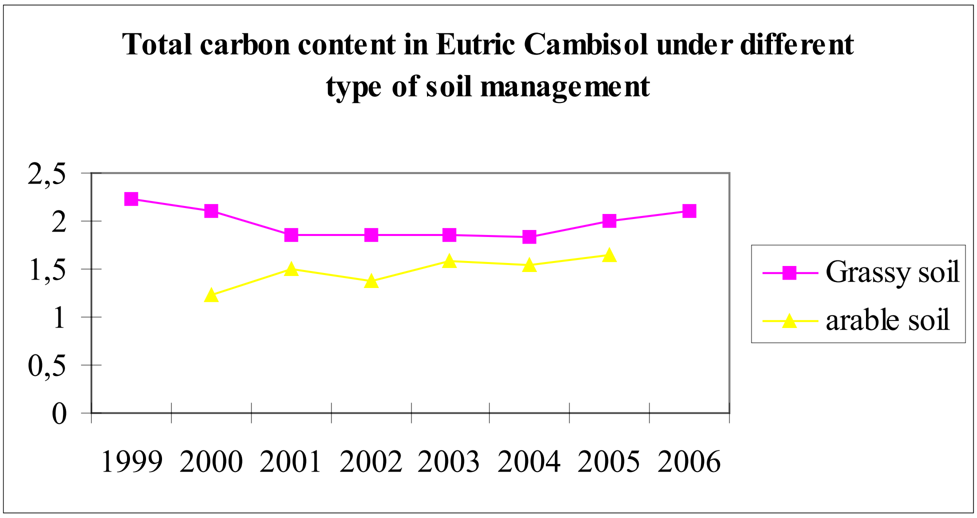

Fig.1 Total carbon content in Eutric Cambisol under different type of soil management

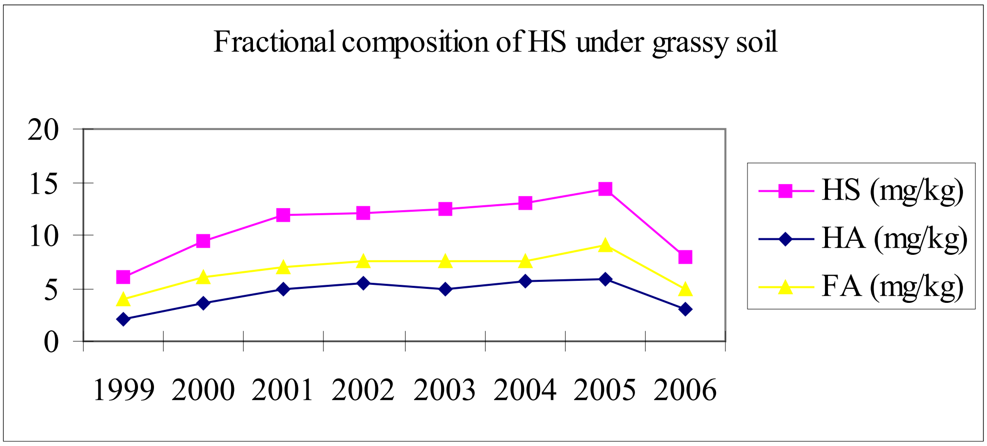

Fig. 2 Fractional composition of HS under grassy soil

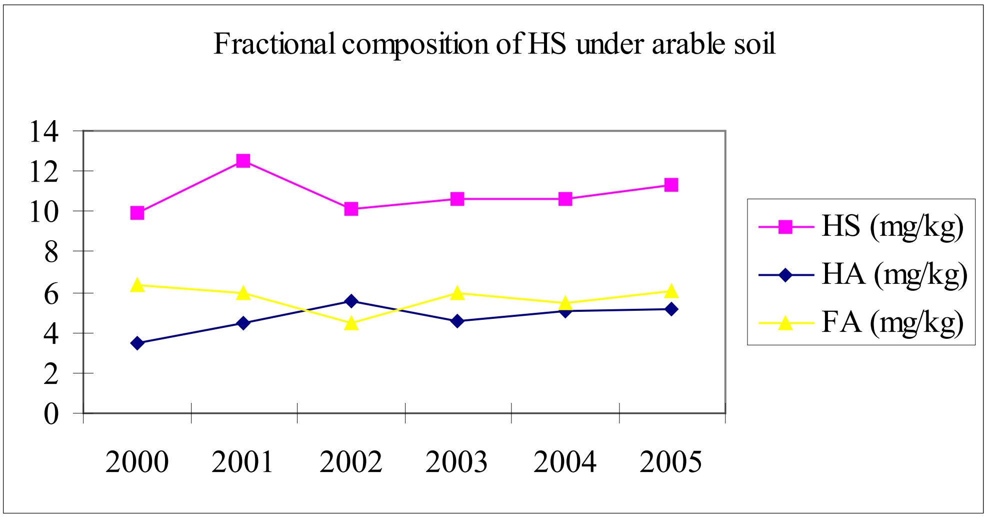

Fig. 3 Fractional composition of HS under arable soil

EFFECT OF PERENNIAL FODDER CROPS ON THE CONTENT OF MINERAL NITROGEN IN SOIL

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Abstract

Perennial leguminous plants (lucerne, clovers etc.) on the arable land are the important part of crop rotations and farming systems. High amount of plant rests has a positive effect on soil fertility and also a content of nutrients in the soil. In the years 2004 – 2007 was evaluated the content of mineral nitrogen and nitrates in the soil under the lucerne, red clover , white clover and grass mixture stands. The lowest content in the spring terms was observed under grass mixture stands.Under the leguminous plants stands was mineral nitrogen content higher, but mostly not significantly to grass mixture. The risk of nitrates leaching occurs in autumn month after dry summer period, first of all after plants, less resistant to drought.

Key words: lucerne, red clover, white clover, soil mineral nitrogen, soil nitrates

Introduction

A positive effect of the involvement of members of perennial leguminous plants into crop rotation and their value as forecrops are generally accepted and appreciated. Their high forecrop value is manifested both through sustainability of crop management systems and yield stability of subsequent crops (especially of cereals) under nearly all growing conditions (Norton et al. 1995). Only under conditions of competition for water some authors (Kismanyioki and Toth, 1997; Lehocká et al., 2004 and others recommended to replace alfalfa by other plants (e.g. clovers, legumes or cash crops). Under Mediterranean conditions, Campiglia et al. (1999) recommended including of cereals after alfalfa at least after three years; however, in their opinion members of this tribus are a backbone of crop rotation also in various systems of organic farming.

Within the last decade, substantial changes in the structure of plant production took place in the Czech Republic. A decrease in the acreage of legumes, together with a reduced production of manure due to decreasing numbers of farm animals, may influence the stability of yields not only of cereal crops but also of complex systems of plant production, above all on specialized farms without animal production.

Fodder crops represent a very large group of crops capable to affect significantly the balance of nitrogen in soil, partly as clovers that fix atmospheric nitrogen and partly as annual fodder crops and grasses that uptake great amounts of nitrogen from soil. Colebatch at al. (2002), Sanchez et al. (2001) and some other authors mentioned that production systems, which involve clovers (i.e. plant species with an extended diversity), increase the capacity of soil to supply nitrogen also to other crops; they represent a suitable both quantitative and qualitative source of organic matter and create therefore preconditions for a long-term productivity and sustainability of agricultural systems. Also Dalal et al. (1994) demonstrated that the inclusion of alfalfa into crop rotation resulted in a twofold increase in soil microbial biomass, total amount of organic matter and overall level of nitrogen in soil (even as compared with some legumes).

Recently, the problem of intensity of fertilisation, losses of mineral nitrogen (above all of nitrates due to leaching and contamination of groundwater) has been becoming more and more important. These problems were studied by many authors, especially with regard to the use of catch crops (Hansen and Djurhuus 1997, Boolting 1995, Strebel et al. 1989, Hasler 1998 and others). In the Czech Republic, however, more detailed studies are only exceptional (Málek and Procházka 2002, Procházková et al. 2001).

Material and methods

Within the period of 2004 – 2007, small plot field experiments with the following selected perennial species of fodder crops were established in Troubsko: 1. Meadow grass mixture 2. Lucerne 3. Red clover 4. White clover

The experimental site is situated in a sugar-beet growing region with the following parameters: altitude 270 m, soil type degraded chernozem, soil category clayey loam, pH 6.9, and nutrient reserves good. Long-term annual sums of precipitation and temperatures are 547 mm and 8.6 ^{o}C, respectively.

Clover stands were established in the spring without any cover crops and they were used for production of forage. In the year of sowing only one cutting was performed while in production years the stands were harvested mostly three times per year.

Soil sampling took place every year in early spring and in late autumn.

Results and discussion

In the year of sowing, the content of total soil reserves of mineral nitrogen was relatively high and depended on the pre-sowing fertilisation and/or the method of stand establishment. During the growing season its content significantly decreased. The most marked decrease was observed in the grass stand and the levels of both total mineral and nitrate N were nearly negligible in the autumn. As compared with grass mixtures, the content of soil nitrogen after clover stands was in average two times higher but the differences were statistically insignificant due to a considerable yearly variability. However, basing on the calculation of losses in kg per 1 ha it can be said that the risk of nitrogen leaching into groundwater was relatively low.

Table 1: Average contents of mineral nitrogen in soil in the autumn of the year of sowing

Variant	$N0_3$		N_{min}	
	$mg.kg^{-1}$	%	$mg.kg^{-1}$	%
Grass mixture	2.8	100.0	3.0	100.0
Lucerne	5.0	178.6	5.5	183.3
Red clover	6.5	232.1	7.9	263.3
White clover	4.4	157.1	5.4	180.0

In the spring of productive years the contents of mineral and nitrate nitrogen under perennial fodder crops were very low and practically the same regardless to the plant species (i.e. grasses and/or clovers). Next growth in autumn, when the bigger decreasing of temperature was in late winter and the early growth of perennial fodder crops in spring decreased the content of mineral nitrogen in soil and also the possibility its leaching.

Table 2: Average contents of mineral nitrogen in soil in the spring of the 1st production year

	$N0_3$		N_{min}	
Variant	mg.kg^{-1}	%	mg.kg^{-1}	%
Grass mixture	1.3	100.0	2.2	100.0
Lucerne	1.6	123.1	3.5	159.1
Red clover	1.6	123.1	3.7	168.2
White clover	1.4	107.7	3.0	136.4

In years 2006 and 2007, the weather was cold for a long period in the spring and the subsequent onset of higher temperatures was relatively quick. When evaluating the content of mineral nitrogen content in fodder crops in the autumn, the lowest values were found out – similarly as in previous measurings – under grass stands; relatively low levels were measured also under alfalfa crops. Regarding the fact that clover stands after the second and following cuttings practically did not grow and dried out, the content of mineral nitrogen and, thus, the danger of its leaching into groundwater was higher in the autumn period.

Table 3: Average contents of mineral nitrogen in soil in the autumn of the 1st production year

	$N0_3$		N_{min}	
Variant	mg.kg^{-1}	%	mg.kg^{-1}	%
Grass mixture	0.5	100.0	0.9	100.0
Lucerne	2.3	460.0	3.3	366.7
Red clover	7.5	1,500.0	9.4	1,044.4
White clover	6.9	1,380.0	9.0	1,000.0

In the spring of the 2nd production year, the content of mineral nitrogen in clover stands was several times higher than that under grass but, in spite of this, it still did not represent any risk. The content of nitrate nitrogen showed similar trends as those in the content of total mineral nitrogen. Under clover stands, contents of nitrate nitrogen in soil were relatively high but only when compared with a very low content of nitrates in soil under grass stands.

Table 4: Average contents of mineral nitrogen in soil in the spring of the 2nd production year

	$N0_3$		N_{min}	
Variant	mg.kg^{-1}	%	mg.kg^{-1}	%
Grass mixture	0.2	100.0	2.0	100.0
Lucerne	1.7	850.0	3.0	150.0
Red clover	2.1	1,050.0	5.0	250.0
White clover	2.2	1,100.0	6.2	310.0

Table 5: Average contents of mineral nitrogen in soil in the autumn of the 2nd production year

	$N0_3$		N_{min}	
Variant	mg.kg^{-1}	%	mg.kg^{-1}	%
Grass mixture	3.5	100.0	5.3	100.0
Lucerne	5.8	165.7	8.8	166.0
Red clover	10.1	288.6	12.8	241.5
White clover	9.4	268.6	11.4	215.1

In the spring season, the content of mineral nitrogen in soil under fodder crops corresponded with levels recorded in previous years.

In the autumn of the 2nd production year, the content of mineral nitrogen was relatively high. The lowest values were found out under grass mixtures. Other fodder crops, i.e. clovers, responded mainly according to their resistance to draught, not according to their endurance. Yields obtained after clover stands were very low and stands dried out already after the first cutting so those greater amounts of organic matter were decomposed. Only the alfalfa crop produced second and further cuttings. In the second production year, also clover stands were sparser.
It can be concluded that well-established clover crops did not release into the soil much higher amounts of mineral nitrogen than grass stands in the production years; poor, dry stands and ploughed down stands from the ecological point of view represent a higher risk.

Acknowledgements
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EFFECT OF DIFFERENT SOIL TILLAGE ON YIELDS OF MAIZE

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Abstract
The effect of different soil tillage on maize grown for grain was evaluated on brown soil in the maize-growing region within the period of 2002 – 2007. Compared were three variants of soil tillage: Variant 1 – ploughing to the depth of 0.22 m; Variant 2 – shallow discing to the depth of 0.10 – 0.12 m; and Variant 3 – direct seeding of maize into non-tilled soil. The differences in maize grain yields among soil tillage varieties were relatively small and in a 6-year average not significant. The highest yield was obtained in Variant 1 (10.32 t ha^{-1}), followed by Variant 2 (10.20 t ha^{-1}) and Variant 3 (9.75 t ha^{-1}).

Keywords: maize for grain, soil tillage, yields

Introduction

For maize, there is wide selection of soil tillage technologies and methods of crop establishment. The selection of individual working methods should be performed with regard to site conditions, inclusion of maize into the crop rotation, condition of soil after the harvest of forecrop, technical equipment and machinery of farms and some other factors. When growing maize, it is possible to use not only conventional methods of soil tillage with ploughing but also different technologies of minimum tillage, i.e. mainly with a shallow and/or medium loosening of soil. The effect of a different intensity of soil tillage on yields of maize grain depends to a great extent on soil and climatic conditions. When using minimum tillage technologies under drier and warmer climatic conditions, the yields are usually the same and/or even higher while under colder and more humid conditions the yield response of maize crop to a reduced intensity of tillage is not so positive.

Materials and methods

Possibilities of the use of minimisation technologies of soil tillage when growing repeatedly maize for grain on one plot were evaluated in a long-term field experiment within the period of 2002 – 2007; maize crops were established in maize-growing region on plots with brown, loamy soil. At the experimental plot, the average annual temperature and the average temperature within the growing season were 8.9 °C and 15.6 °C, respectively. The annual sum of precipitation was 557 mm and that for the growing season was 358 mm.
Variants of soil tillage:
Variant 1: Ploughing to the depth of 0.22 m, spring dragging, soil loosening to the depth of 0.10 – 0.12 m prior to sowing, precise sowing with a simultaneous application of fertilisers to coulter boot, rolling.

Variant 2: Discing to the depth of 0.10 – 0.12 m, soil loosening prior to sowing, precise sowing with a simultaneous application of fertilisers to coulter boot, rolling.

Variant 3: No tillage, precise sowing with a simultaneous application of fertilisers to coulter boot, rolling.

Application of fertilisers was the same in all experimental variants:

N – 155 kg ha^{-1} prior to maize sowing
20 kg ha^{-1} to coulter boot
P, K – fertilization prior to the establishment of maize crop in the autumn of 2001 (100 kg of P_2O_5 and 60 kg of K_2O per hectare), 30 kg of P_2O_5 per hectare to coulter boot every year.

Plant protection:
Herbicide – pre-emergency application of Trichoplus, biological protection against European corn borer (ECB)

Hybrids: *Reseda* (FAO 400) in 2002; *Suarta* (FAO 400) in 2003 - 2005;
Ribera (FAO 420) in 2006 - 2007

Results

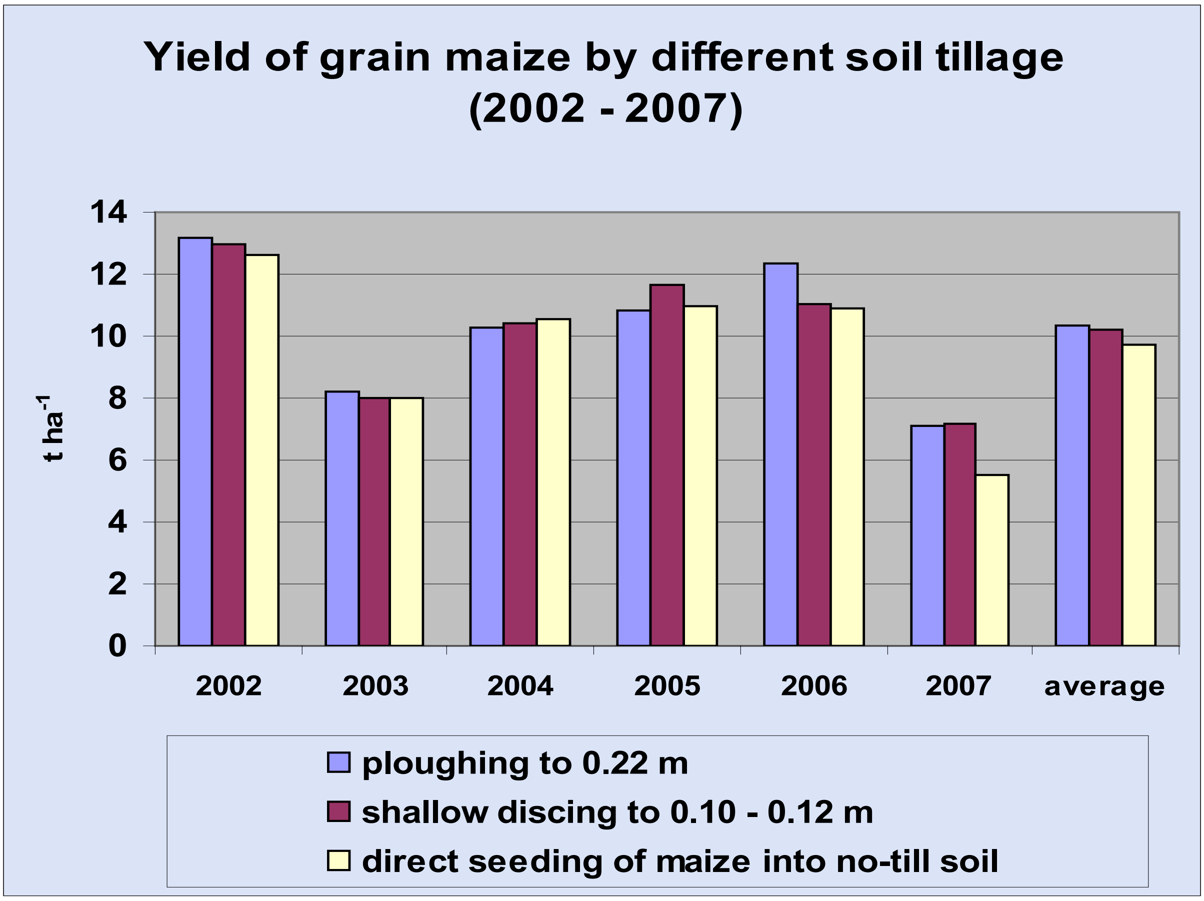
Within the six-year average, the differences in maize grain yields among individual variants of tillage were low and statistically non-significant. The highest average yield was obtained in Variant 1 – ploughing to the depth of 0.22 m (10.32 t ha^{-1}); followed by Variant 2 – shallow discing to the depth of 0.10 – 0.12 m (10.20 t ha^{-1}); and Variant 3 – direct maize sowing into non-tilled soil (9.75 t ha^{-1}).

In years 2002, 2003 and 2006, yields after ploughing (0.22 m) were higher than those obtained after minimisation technologies (sowing of maize into no-tilled soil and/or after shallow discing). In years 2004 and 2005, however, yields in Variant 1 (ploughing to the depth of 0.22 m) were lower while those after minimum tillage were higher. The year 2007 was dry and the obtained yields were generally lower. A marked yield decrease was recorded in Variant 3, mainly due to a low quality of established maize crop.

Ploughing to the depth of 0.22 m

Shallow tillage

Sowing into no-tilled soil



Variance analysis of effects of different soil tillage on grain maize yields

Source of variability	SS	d.f.	MS	F - value	Significance level
Soil tillage	1.0904	2	0.5452	0.10	0.9083
Residual	84.5082	15	5.6339	-	-
Total	85.5986	17	-	-	-

Conclusions

The obtained results indicate above all the possibility of the use of shallow soil tillage when growing maize for grain repeatedly on one plot with fertile brown soil in the maize-growing region. When sowing maize directly into non-tilled soil, there are problems with the quality of crop establishment due to higher amounts of organic residues on soil surface as well as due to an increased weed infestation. An increased occurrence of weeds is greatly dependent on a lower efficiency of pre-emergence herbicides caused by the coverage of soil surface with post-harvest plant residues.

Acknowledgement

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YIELD OF GRAIN MAIZE BY DIFFERENT SOIL TILLAGE

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Abstract

The impact of different soil tillage on yield of grain maize was evaluated in the field trial in year 2004-2007 in locality Žabčice (dry conditions, South Moravia region; Czech Republic). Grain maize was grown in 5-strip crop rotation with high concentration of cereals (spring barley, safflower, winter wheat, winter wheat, grain maize). It is a model crop rotation for farming without animal husbandry (all straw is cut and incorporated into the soil). Two different variants of soil tillage were used. Conventional tillage (CT) included stubble breaking after harvest of winter wheat and ploughing to the depth of 0.20 – 0.24 m in autumn. Minimum tillage (MT) consisted of stubble breaking after harvest of winter wheat and shallow loosening (to 0.15 m) in autumn. Seedbed preparation was performed before sowing of grain maize in spring. The four-year results showed non-significant differences between variants of soil tillage. Significant differences in yield were found among years. The highest yields were in 2006 (CT – 11.59 t ha-1 and MT – 11.77 t ha-1), in 2005 (CT – 11.40 t ha-1 and MT – 11.55 t ha-1) and in 2004 (CT – 9.34 t ha-1 and MT – 8.81 t ha-1). The lowest yields were in 2007 (CT – 7.17 t ha-1 and MT – 7.05 t ha-1). From results we can conclude that both variants of soil tillage are suitable for growing of grain maize, but none of them reduce annual changes in yield, which are influenced especially by amount of available water during vegetation period.

Keywords: grain maize, soil tillage, yield

Introduction

Grain maize (Zea mays) is warm-requiring crop growing in the Czech Republic for silage maize and for grain. The harvesting area of silage maize has decreased in recent years because number of cattle units has decreased. On the other hand the areas of grain maize have quite big development (for instance 47 000 hectares in 2000 and 84 000 hectares in 2006. Profitability of growing is influenced by suitable crop management practice which respects soil and climatic conditions of each locality. However, a lack of water in earlier growth stages can be a limiting factor of yields. For this reason it is necessary to adapt the crop management practices of maize to climatic and soil conditions by assuring sufficient supply of water to plants. The method of tillage represents one of the most important factors that could influence the water management of crops in the course of growing season.

Materials and methods

The impact of different soil tillage was evaluated in a field trial established in Žabčice in the four years 2004-2007. This locality (179 m above sea level, 49°01′ N, 16°37′ E) is situated 25 km southwards from Brno (South Moravia region, Czech Republic). It is a warm and dry region with average annual temperature and precipitation of 9.2°C and 480 mm, respectively July and January are the warmest and the coldest months with average daily air temperatures of 19.3°C and –2.0°C, respectively. June and March are the months with the highest and the lowest precipitation (68.6 mm and 23.9 mm, respectively; Table 1). The annual sum of solar irradiation ranges from 1.800 to 2.000 hours.

Table 1. Long-term temperature and precipitation standards (1961-1990)

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I-XII
Average temperature (°C)	–2.0	0.2	4.3	9.6	14.6	17.7	19.3	18.6	14.7	9.5	4.1	0.0	9.2
Sum of precipitation (mm)	24.8	24.9	23.9	33.2	62.8	68.6	57.1	54.3	35.5	31.8	36.8	26.3	480

According to the taxonomic system of soils of the Czech Republic, the soil in the Field Experimental Station in Žabčice is classified as clayey loam gleyic fluvisol which has developed on alluvial sediments of the Svratka river. These soils are without any marked diagnostic horizons and the parent substrate consisting of alluvial material is situated below a thin humus horizon. More marked symptoms of gley processes can be observed in the depth of below 0.6 m. In the course of the year, the groundwater level fluctuates between 0.8 and 2.5 m. As far as the soil texture is concerned, the soil is classified as heavy to very heavy.

The field trial was established in this locality as a model concept for farming without animal husbandry (all straw is cut and incorporated into the soil). The principle of this experiment is a 5-year crop rotation with a high concentration of cereals (spring barley, safflower, winter wheat, winter wheat, grain maize). The variant of conventional tillage consisted of stubble breaking after harvest and ploughing down to the depth of 0.20-0.24 m. The variant of minimum tillage included stubble breaking after harvest followed by a shallow loosening to the depth of 0.15 m.

Maize hybrid Ribera (FAO number 410) was sown at the rate of 80 000 germinating seeds per hectare. The experimental dose of fertilisers was 120 kg N ha-1 applied before seed preparation in urea form. For sowing there was used precise drilling machine Kleine Multicorn (four rows). The distance between rows was 0.75 m and depth of sowing 0.06 m. Experimental plots were harvested by a small combine harvester SAMPO 2010.

The impact of two variants of soil tillage on grain yield was assessed during four years (2004-2007). Results were statistically processed by the method of analysis of variance in the statistical software Statistica 7.0; the significance of differences of mean values was tested by means of the Fisher LSD (least square difference) test.

Results

The four-year results showed non-significant differences between variants of soil tillage. Significant differences in yield were found among years (Table 2, Figure 1). The highest yields were in 2006 (CT – 11.59 t ha-1 and MT – 11.77 t ha-1) and in 2005 (CT – 11.40 t ha-1 and MT – 11.55 t ha-1). Significantly lower yields were found in 2004 (CT – 9.34 t ha-1 and MT – 8.81 t ha-1) and the lowest in 2007 (CT – 7.17 t ha-1 and MT – 7.05 t ha-1). The yield level of grain maize is connected with sum of precipitation during vegetation period. Table 3 shows sum of precipitation from May to September. Higher yields in 2005 and 2006 were probably caused by higher sum of precipitation (330 mm in 2005 and 385 mm in 2006) in comparison with 199 mm in 2004 and 271 mm in 2007.

CONTENT

Table 2. ANOVA table

Source of variability	Degree of freedom	Mean square
Soil tillage	1	0.20
Year	3	150.39**
Soil tillage x year	3	0.86
Residuum	120	0.62

** Statistically highly significant effect (P = 0.99).

Figure 1. Yield of grain maize by different soil tillage (2004-2007)

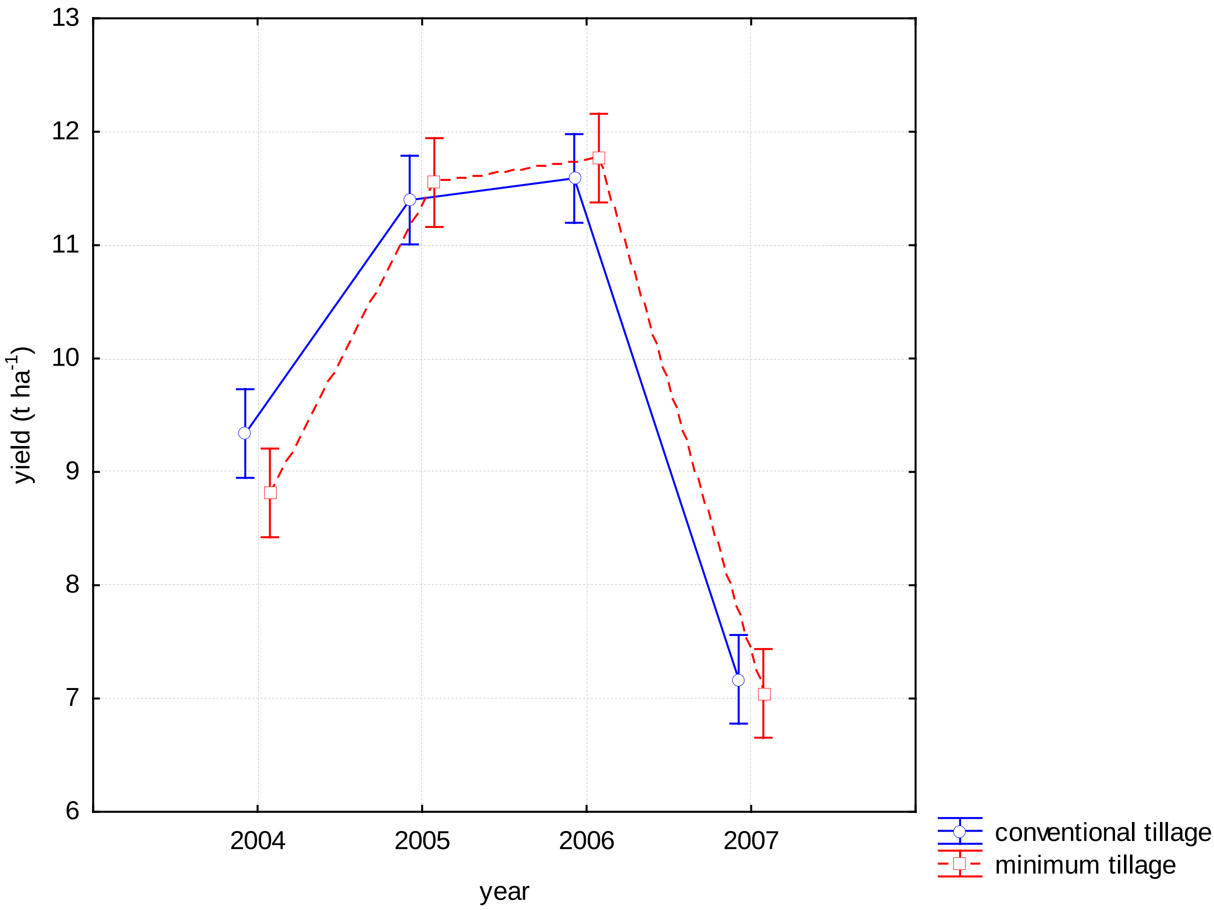

Table 3. Sum of precipitation during vegetation period (2004-2007)

Year	Month					V-IX
	V	VI	VII	VIII	IX	
2004	28	65	29	33	44	199
2005	67	46	103	81	33	330
2006	75	71	78	151	9	385
2007	25	72	32	40	104	271

Many authors notice favourable effect of soil tillage reduction on quality of soil environment. Minimum tillage is the proper way especially on the slopes where is higher risk of water erosion and nitrogen losses from surface soil layers into underground water. The impact of intensity of soil tillage on the yields of maize depends on soil and climatic conditions. The comparable yields are achieved in dry and warmer conditions. Some problems are described in locations in higher altitudes where lower soil temperature causes delay of sowing term, emergence and initial growth of maize. Yields can be decreased by higher weed infestation or if some pests occur on variants with minimum tillage. Crop residues which cover soil surface on variants with reduced soil tillage are often the cause of lower efficacy of preemergent applied herbicides.

Conclusion

The four-year results showed that yield of grain maize is not affected by the depth and intensity of soil tillage. Both technologies are suitable for conditions of heavier soils, especially in dry and warmer climatic conditions.

Acknowledgement

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EFFECT OF SOIL TILLAGE SYSTEMS ON QUALITY OF WINTER WHEAT GRAIN

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Abstract
The material for investigation was grain samples obtained from field experiment conducted 2005/2006 year in Pixendorf-Tuln with winter wheat cv. Capo. The examined factor was:
5 variants of soil tillage systems (conventional tillage, chisel plough, reduced tillage, ridge tillage and no tillage). Application of reduced and ridge soil tillage systems in comparison with conventional tillage had positive effect on the weight of 1000 grains and amount of biggest grain fraction (diameter of grain >2,8mm). Zeleny test value and gluten content were bigger for grain from no tillage variant. Higher water absorption was observed after conventional tillage. For the remaining farinogram traits differences were not significant.

Key words: soil tillage systems, wheat, grain quality

Introduction
Yield formation of winter wheat is influenced by cultivation locality, year, fore-crop and also by agronomical factors including soil tillage systems. Classical plough tillage system is the most energy and cost consuming. It cause that more often reduced tillage systems are used (Dzienia and Piskier 1999, Frant and Bujak 2005). The results obtained in different soil and climate conditions do not give the explicit answer how the reduction of soil tillage influence the productivity of wheat plants (Hammel 1995., Malicki et al. 1997). Most of the papers reports the effects on yield, yield components and soil properties, but quality of grain is investigated not very often. The aim of this work is to estimate the quality of winter wheat as affected by different soil tillage systems.

Material and Methods
The material for investigation was grain samples obtained from field experiment conducted 2005/2006 year in Pixendorf-Tuln with winter wheat cv. Capo. The examined factor was:
5 variants of soil tillage systems (conventional tillage - cultivator (chisel plow) or disc harrow after harvest + plow in late autumn, then seedbed preparation with rotary harrow or seedbed combination ; cover crops (plowed in late autumn), chisel plough - cultivator or disc harrow/chisel plow 2 x (1.after harvest + 2. late summer) + cover crops –mulchseed (with Roundup), reduced tillage - disc harrow late summer + cover crops - mulchseed (with Roundup), ridge tillage- conventional like 1 but ridges befor seeding in spring time for maize and no tillage - no tillage + cover crops - direct seeding (with Roundup)).
All variants are seeded with the same machines to have no mistake from the seeding (drillseed with Vaederstad, single space drill with Kuhn Planter 1). Climate: semiarid., average temperature 10°C, annual rainfall 600 - 650 mm.
Fore-crop for wheat was sunflower. Nitrogen fertilization level was130 kg ha^{-1}, applied in 3 doses (40 kg early spring, 60 kg BBCH 35, 30 kg BBCH 49). The following traits were estimated: weight 1000 grains, test weight, grain fractions, falling number by Hagberg-Perten, total protein content (calculated after determining N content, using Kjeldahl method, x 5,7), content and weakening of gluten, Zeleny test and farinogram properties (water absorption,

dough resistance, dough weakening and valorimeter value) using standard methods (Praca zbiorowa 1983). Number of replications -2. One factor analysis of variance was used to determine the significance ($P<0.05$) of main effects and interactions. The multiple range test (Tukey) was used to compare mean values.

Results and Discussion

Use of different tillage systems caused significant difference of weight of 1000 grains. (Table 1). Lower value of this trait was observed after conventional tillage system as compared to ridge, reduced and no tillage systems. Changes in share of grain fraction were also observed. Application of conventional system resulted in smallest amount of the thickest grain faction – diameter of grain more than 2.8 mm. Test weight values were on the same level. The results obtained by other authors are different. Blecharczyk et al. (1999) observed increase of 1000 grain weight after no tillage cultivation. Results obtained by Kuś (1999) showed that replacing of ploughing by reduced soil tillage decrease grain weight. Vavera et al. (2005) and Stankowski et al. (2007) indicated that different tillage systems had no influence on physical properties of grain

Table 1. Effect of soil tillage systems on physical properties of wheat grain

Trait	Tillage systems					$LSD_{0.05}$
	A*/	B	C	D	E	
Weight of 1000 grains (g)	39.1	41.9	41.9	43.0	42.9	1.75
Test weight (kg hl^{-1})	84.6	83.8	85.1	85.2	84.0	ns
Grain fraction (%)- <2.2 mm	3.5	2.9	2.2	2.4	2.2	1.20
2.2-2.5 mm	9.6	6.2	7.0	6.5	6.4	2.16
2.5-2.8 mm	28.4	19.9	23.0	19.6	20.0	1.78
> 2.8 mm	58.4	71.0	67.8	71.6	71.4	2.63

*/ A - conventional tillage, B – chisel plough, C – reduced tillage, D – ridge tillage, E- no tillage; ns – non significant difference

Application of investigated soil tillage (Table 2) changed some of quality traits of wheat grain. There was no difference in protein content, but for gluten content and Zeleny test bigger vales were observed for no tillage system. Weakening of gluten was very low and differences had not practical significance.

Table 2. Effect of soil tillage systems on quality traits of wheat grain

Trait	Tillage systems					$LSD_{0.05}$
	A*/	B	C	D	E	
Protein content (%)	15.9	15.6	15.5	15.7	16.3	ns
Falling number (s)	244	257	256	268	266	19.8
Gluten content (%)	34.9	36.2	36.7	36.6	38.8	1.73
Weakening of gluten (mm)	1.6	1.0	1.8	1.9	1.8	0.38
Zeleny test (cm^3)	42.2	41.9	42.6	43.0	44.7	1.91

*/ A - conventional tillage, B – chisel plough, C – reduced tillage, D – ridge tillage, E- no tillage; ns – non significant difference

Tillage systems investigated in this experiment changed water absorption, only (Table 3). Bigger value was noticed for conventional tillage than for the remaining systems. We can also indicate for higher valorimeter value obtained at ridge tillage and no tillage, but differences were not significant.

Table 3. Effect of soil tillage systems on farinogram properties of wheat grain

Trait	Tillage systems					$LSD_{0.05}$
	A*/	B	C	D	E	
Water absorption (%)	67.8	65.0	65.5	65.8	65.8	0.86
Dough resistance (min)	6.39	6.70	6.12	6.46	6.46	ns
Dough weakening (Bu)	20.0	32.5	22.5	27.5	20.0	ns
Valorimeter value	61.0	60.0	61.5	64.5	64.0	ns

*/ A - conventional tillage, B – chisel plough, C – reduced tillage, D – ridge tillage, E- no tillage; ns – non significant difference

Results obtained by Stankowski et al. (2007) indicated that different tillage systems (conventional, reduced and direct sowing) had no influence on most of the quality traits. Higher values were obtained for falling number, gluten content and water absorption when direct sowing was applied, but effects were small. Some other studies concerning protein content, a main trait connected with grain quality, as a function of tillage systems reporting no significant differences (Baenzinger et al. 1985, Cox and Shelton, 1992). In contrast Lopez-Bellido et al. (1998) and reported higher protein content and alveograph parameters for conventional tillage than for no tillage. He explained better results for conventional tillage due to the greater availability of soil N. In the other experiment (Lopez-Bellido et al. 2001) positive effect on grain protein was observed but there was no differences in dough quality as expressed by alveogram indices.

Conclusions

Application of reduced soil tillage and ridge systems in comparison with conventional tillage had positive effect on the weight of 1000 grains and amount of biggest grain fraction (diameter of grain >2,8mm).

Zeleny test value and gluten content were bigger for grain from no tillage variant.

Higher water absorption was observed after conventional tillage.

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EFFECT OF FORECROP AND ROW SPACING ON GRAIN QUALITY OF WHEAT

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Abstract
The material for investigation was grain samples obtained from field experiment conducted 2005/2006 year in Ceske Budejovice with winter wheat cv. EBI. The examined factors were: 3 variants of fore-crop (red clover, potato, spring barley) and 2 row spacing (12,5 and 25,0 cm). The cultivation was conducted in ecological way (without mineral fertilization). The different fore-crops had significant effect on quality traits of wheat. The best results were obtained after clover and the worst after barley. Increasing row spacing from 12,5 to 25 cm had inconsiderable effect on grain quality. When higher row distance was applied decrease of 1000 grain weight and shapeliness was observed.

Keywords: fore-crop, row spacing, wheat, grain quality

Introduction
Wheat quality is influenced by interaction of a number of factors, including cultivar, soil, climate and cropping practices (Randall and Moss 1990, Zentner et al. 1990, Blumenthal et al. 1991). Starczewski and Stankiewicz (1989), Stankowski et al. (2004) indicate that the main factor improving grain quality is nitrogen. In ecological farming where using most of mineral fertilisers is not allowed, crop rotation seemed to be a main factor of productivity. Crop rotation (including legumes and papilionaceous) may influence the protein content and breadmaking quality of wheat (Cox and Shelton 1992). On the other hand, there are not a lot of data available on the influence of the previous crop on quality of wheat grain.
The aim of this paper is to estimate the effect of different fore-crop and row spacing on grain quality of winter wheat.

Material and Methods
The material for investigation was grain samples obtained from field experiment conducted 2005/2006 year in Ceske Budejovice with winter wheat cv. EBI. The examined factors were: 3 variants of fore-crop (red clover, potato, spring barley) and 2 row spacing (12,5 and 25,0 cm). The cultivation was conducted in ecological way (without mineral fertilization).
The following traits were estimated: weight 1000 grains, test weight, grain fractions, falling number by Hagberg-Perten, total protein content (calculated after determining N content, using Kjeldahl method, x 5,7), content and weakening of gluten, Zeleny test and farinogram properties (water absorption, dough resistance, dough weakening and valorimeter value) using standard methods (Praca zbiorowa 1983). Number of replications -2. Analysis of variance was used to determine the significance ($P<0.05$) of main effects and interactions. The multiple range test (Tukey) was used to compare mean values.

Results and Discussion
Application as fore-crop 3 different plants (red clover, potato and spring barley had no significant effect on weight of 100 grains (Table 1), however tendency to obtain bigger value of this trait was observed when previous crop was red clover. Test weigh values observed in the experiment were similar independently to the plants used as a for crop. Share of different

grain fraction was influenced by this factor. Application of red clover and potato resulted in 47.4 and 48.2 of the fraction > 2.8mm, respectively. After barley amount of this fraction was about 3% lower. Increasing row spacing from 12.5 to 25.0 cm resulted in decreased weight of 1000 grains and smaller amount of the biggest in diameter of grain fraction. There was no interaction between fore- crop and row spacing.

Table 1. Effect of fore-crop (F) and row spacing (R) on physical properties of wheat

Trait	Fore-crop			Row spacing (cm)		$LSD_{0.05}$	
	A*/	B	C	12.5	25.0	F	R
Weight of 1000 grains (g)	37.2	36.9	35.2	37.4	35.4	ns	1.74
Test weight (kg hl^{-1})	75.4	75.3	75.7	75.6	75.4	ns	ns
Grain fraction (%):< 2.2 mm	3.6	3.2	4.9	5.0	4.0	0,90	0.40
2.2-2.5 mm	11.4	12.5	14.2	10.9	14.4	1.38	0.82
2.5-2.8 mm	37.6	34.4	36.1	34.5	37.7	1.67	1.00
> 2,8 mm	47.4	48.2	44.8	49.6	43.9	1.29	0.76

*/ A-red clover, B- potato, C- spring barley; ns- non significant difference

Protein content (Table 2) was significantly increased by using red clover in comparison with potato and barley. Favourable effect of red clover was also observed for gluten content and Zeleny test values. For Zeleny test was noticed higher value for potato as a previous crop with comparison with spring barley. Falling number and gluten weakening was not effected by different for-crops. Row spacing had no effect on every quality traits described in Table 2.

Table 2. Effect of fore-crop (F) and row spacing (R) on quality traits of wheat

Trait	Fore-crop			Row spacing (cm)		$LSD_{0.05}$	
	A*/	B	C	12.5	25.0	F	R
Protein content (%)	10.5	9.0	8.8	9.4	9.6	0.85	ns
Falling number (s)	126	132	154	142	133	ns	ns
Gluten content (%)	25.3	22.7	21.7	23.1	23.3	2.11	ns
Gluten weakening (mm)	0.72	0.74	0.99	0.72	0.91	ns	ns
Zeleny test (cm^3)	43.2	39.1	34.2	38.6	39.2	3.62	ns

*/ A-red clover, B- potato, C- spring barley; ns- non significant difference

Farinogram traits (Table 3) was significantly greater when previous crop was red clover. For two other variants of this factor (potato and spring barley) obtained values were lower and differences between them were not significant. Row spacing had no effect on farinogram traits. Reaction of wheat for fore-crops at different row spacing was similar.

Table 3. Effect of fore-crop (F) and row spacing (R) on farinogram traits of wheat

Trait	Fore-crop			Row spacing (cm)		$LSD_{0.05}$	
	A*/	B	C	12.5	25.0	F	R
Water absorption (%)	67.2	66.2	65.7	66.4	66.3	0.84	ns
Dough resistance (min.)	2.15	1.70	1.61	1.88	1.76	0.48	ns
Dough weakening (B.u)	48.7	68.7	66.2	62.5	60.0	10.4	ns
Walorimeter value	45.6	40.6	40.7	42.1	42.5	4.54	ns

*/ A-red clover, B- potato, C- spring barley; ns- non significant difference

Obtained in this experiment results indicated that red clover is the best fore-crop for wheat improving the quality of grain. Similar results, with legumes and papilionaceous, were obtained by Zentner et al. 1990, Borghi et al. 1995, Lopez- Bellido et al. 2001. Row spacing had only effect on physical traits of grain and did not change quality parameters of grain. Piech and Stankowski (1984) also indicate that row spacing has no significant effect on baking quality of wheat.

Conclusions

The different fore-crops had significant effect on quality traits of wheat.
The best results were obtained after red clover and the worst after barley.
Increasing row spacing from 12,5 to 25 cm had inconsiderable effect on grain quality.
Application of higher row distance decreased 1000 grain weight and shapeliness.

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CONTENT

PAPERS OF THE SECTION III

ISTRO

INFLUENCE OF DIFFERENT TILLAGE SYSTEMS AT YIELD AND QUALITY – RESULTS OF FIELD TRIALS IN LOWER AUSTRIA

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1. Abstract

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

From 1994 to 2007 eight different tillage systems were tested at three locations in Lower Austria. Five tillage systems were tested in Tulln – located 30 km from Vienna, beginning 2006 on more 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-till and ridge tillage was tested, also. The Institute of Hydraulics and Rural Water Management of the University of Natural Resources and Applied Science Vienna (Prof.A.Klik, Ph.D.) measured surface runoff, soil loss, nitrogen, phosphorus, and herbicide loss. Mycotoxins were analysed in an institute in Tulln. Between 1994 and 2007 the average soil loss at the three locations dropped from 6.1 t/ha/year (conventional tillage) to 1.8 t/ha/year with conservation tillage in cover crops, and to 1.0 t/ha/year with direct drilling systems. Nitrogen and Phosphorus losses showed similar tendencies. Herbicide loss declined by 3.1 % at the application rate in conventional tillage; 1.2 % in conservation tillage and 0.5 % in direct drilling systems.

2. Introduction and Problem Definition

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

- Lowering of production costs
- Fewer passes - less work time - less soil compaction
- Increased productivity - cultivation of larger area possible
- Reduction of fuel consumption
- Lower machinery use
- Prevention of wind - water – tillage erosion
- Increased humus content
- Improved water retention
- Better yields
- Lower CO_2 release from the soil (climate - and soil alliance, Kyoto - Agreement)

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

3. Material and methods

Different cultivation systems were examined at three locations in Lower Austria in the dry Hungarian climate (Pannonicum) and in the moderate transition climate. The climate is characterized by an annual precipitation amount of 500 mm in the Hungarian Climate (Pannonicum), 650 mm in the transition climate and by an annual average temperature of 8.5 °C – 10.5 °C.
Besides the conventional seed bed preparation with plow and chisel plow, different cover crops such as yellow mustard, California bluebell (Phacelia tanacetifolia), oil radish, clovers, green rye, buckwheat followed by mulch and direct seed were tested. Two tests of minimal cultivation using only a disk harrow and a No-Till variation were examined for yield achievement and the Mycotoxin content.
The conventional seeding was accomplished with use of a plow and cultivator plus harrow or rotary harrow for seedbed preparation. The mulch seeding was accomplished after two passes with the chisel plow followed with the cover crop. After mulch cultivation with a rotary harrow or seedbed combination implements, the direct drilling with cover crop management was just like the mulch seeding, yet the seedbed preparation was omitted (ZeroTillage). All three aforementioned systems were cultivated with a direct seeding machine.

4. Test results and discussion

4.1. Soil erosion tests

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

Table 1: Measured yearly erosion and yield 1994 – 2007 Mistelbach, Tulln, Pyhra (Klik 2007)

Cultivation method	Conventional Tillage	Mulch Seeding	Direct Drilling
Soil loss t/ha/Year Reduction	6.08	1.8 70 %	1.0 83 %
Nitrogen loss kg/ha/year Reduction	9.2	3.8 60 %	2.5 73 %
Runnoff mm/year 2007	23.5	21.1	18.3
$C_{organic}$ loss kg/ha	76.7	27.5	19.2
Phosphorus loss kg/h/year	4.7	1.3	0.7
Herbicide loss % sprayed active substance	3.1	1.2	0.5
Yield in % Conventional	100	102	103

As shown in Table 1, notable reductions in soil, nutrient C organic loss, and herbicide erosion are determined. The runoff could be reduced 2007 in the trials the first time. The yields do not differ significantly. Note that detailed results of registered yield reductions of 15-20 % with direct drilling of sugar beets are not represented. All other cultivated plants react to the changed cultivation yield-neutral, as long as the seeding machine slot in the course of the cultivation can be closed. Otherwise this can cause a problem if the soil is too damp or too dry. Implements such as rotary clod breaker or two sloping disks are necessary during planting in order for seeds to be covered with soil.

4.2. Cultivation tests Tulln

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

Next to the yield results in kg/ha 1999-2007 in Table 2, are the analysis of Microtoxin Desoxynivalenol (DON) and Zearalenon (ZON) level in µg per kg grain. The results from cultivated corn in the Tulln area from both trials are combined. Grains were picked for the crop rotation-corn for example- in 2000 soybeans were chosen.

Table 2: Cultivation test results Tulln 1999 – 2007

Tilling method	% yield	ZON		DON		DON		
	conventional	1999	2001	1999	2001	2004	2005	2006
culture		corn	corn	corn	corn	corn	corn	Summer Durum
Conventional Chisel Plow - Plow CT	100	28	79	505	2477	824	2400	600
Chisel Plow 2 x CP	97	12	514	323	2170	1257	5550	1200
Disc Harrow – Reduced Tillage1 x RT	92	12	20	302	1542	1080	730	1800
No Till NT	90	25	nn	600	519	374	850	1200
Conventional – Ridge Tillage corn RiTi	95	24	64	419	3229	387	4100	540

nd… not detectable

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

Mycotoxin guidelines for Europe:

DON: 200 – 1750 µg per kg grain
ZON: 50 - 200 µg per kg grain

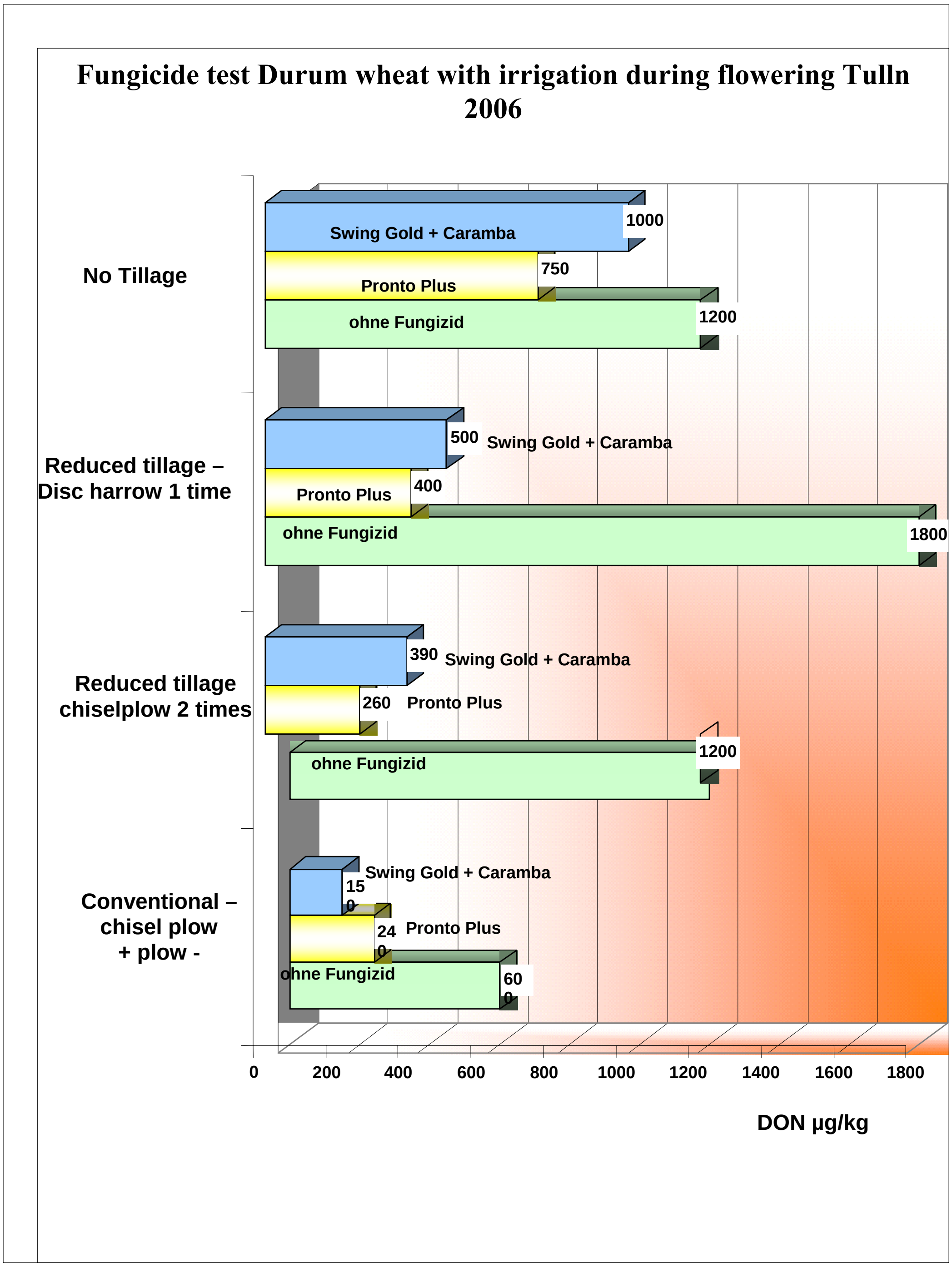
DON……Deoxynivalenol
ZON…….Zearalenon

The yields are significantly lower with minimum tilling. This setback is due to the cultivation of sugar beets. Problems arose by the closing of the seed-slots with No-Tilling, which led to a reduced number of sugar beet plants. Moreover, it was not possible to fight the arising field bindweed (Convolvulus arvensis) with the active substance Glyphosate. Similar difficulties with the locking of the seed-slots can also occur with the cultivation of corn.
Despite the shown problems it seems in practice possible to use these methods if certain principles are paid attention to such as minimum soil cultivation methods and the use of proven ecological advantages. According to practical data, profit losses are only in the first change-over years, reaching a normal level later, whereby the aforementioned advantages can be used.
Cover crop management is also very demanding. Successfully creating a cover crop results in being able to cultivate early, in August. Deep-root cover crops should be selected, in order to move nutrients from the lower-lying soil layers. The use of volunteer cereals should be considered to reduce "Green bridges". These bridges transfer yellow dwarf viruses from aphids to winter barley or soil-born diseases. Particularly with grain, straw residues from corn crop rotations are carefully worked into the ground before the cultivation of the cover crops to prevent the formation of Mycotoxin from Fusarium. If this is not carried out damp conditions must be acheived for the cultivated plant bloom which leaves a very high level of Fusarium risk, which is almost impossible to control chemically. The nuisance of a significant increase in Mycotoxin in the harvested crop is the end result. If the index values

are exceeded the harvested crop can not be sold for human or animal consumption, the only application options for the crop are composting or thermal energy.

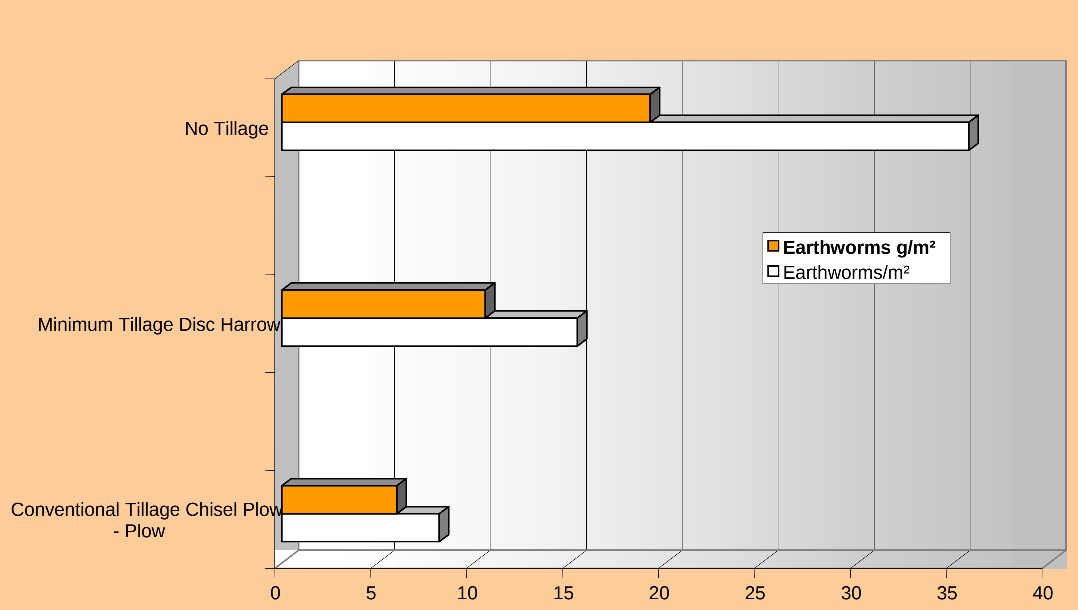
4.3. Fungicide tests

The European crop rotation sytem maize – cereals contains the risk of a fusarium infection, transmitted by ascopores, overwinteriung on infected stubbles. Is there a rainfall during the flowering of cereals an infection by fusarium sp. is probably. Spraying a fungicide within 48 hours after the rainfall can reduce an infection and a following mycotoxin creation. On 3 locations in Lower Austria 2006 and 2007 fungicide tests were applied. 2006 in Tulln Durum wheat was seeded and an infection provoked by irrigation during flowering. After 2 days a fungicide applikation occured. In the following Figure 1 the results are described.



In Figure 1 is a demonstration, that the effect of the fungicide application is effective, if it takes place within 2 days. Residual straw on the soil surface causes a higher risk of Mycotoxin production by Fusarium sp. nn the minimum – and No Till plots.

Figure 2: number and weight of Earthworms 0-30 cm 2004 - 2006



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

5. 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.
- 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 for a good development of the green manure.
- The production of Mycotoxins by Fusarium disease is to be interrupted by shallow soil tillage and a adopted crop rotation.
- A reduction of the costs is possible and necessary.
- A prescription is not possible and depends from the crop rotation and natural situation.

RUNOFF AND EROSION CONTROL WITH REDUCED AND NO SOIL TILLAGE ON CLAY-LOAM CHERNOZEM

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Abstract

In 2004 a specialized experimental site (chernozem soil type, clay loam soil) was established in the locality Klapy, about 60km NW from Prague, with three erosion-bounded plots; having a length of 75 m, 16 m width and about 10° slope. Runoff and soil losses were measured after erosion events. Three different tillage treatments were used: 1) conventional, 2) no tillage, and 3) minimum tillage. Maize for silage was grown in 2006. The results (assessment of measures, after the winter and vegetation erosion events), showed significant differences in both process and the consequences of water erosion of soils. The furrowed soil surface after ploughing and higher retention capacity of more-often loosened soil, is more effective protection against water erosion from melting snow than the relatively flat, even if by crop residues that covered the surface of untilled or minimum tilled soils. Frozen-through untilled soil has no retention capacity. On the other hand, the no tillage system with mulch very effectively prevents water erosion during the vegetation period, and it can decrease soil losses very significantly. Analysis of runoff water and soil sediment showed considerable decrease of nutrient and TOC losses due to conservation soil tillage use.

Key words: erosion; conventional tillage; conservation tillage; runoff; soil losses;

Introduction

Water erosion is the worldwide phenomenon that damages thousands of square kilometres especially soil cultivated year by year and from the localities of utilization billions tons of topsoil are removed. In Australian literature the calculation was published that this amount of soil loss comports with the total topsoil loss from those areas where wheat is grown in Australia. The potential production from lost from this area represents 9 million tons per year. The data from expert reports shows that if soil losses are larger than 2 tons/ha/year, and the full-value compensation of this amount has lasted 50 - 100 years at many places around the world (H o l ý, 1994). For instance, in Great Britain, about 40% of the farmland has been devastated by water erosion. According to competent estimates, 3 million tons of soil, mostly quality topsoil, is being scoured into drainage systems and rivers every year. Water erosion has a similar unfavourable effect upon farmlands in other European countries, as well. In the Czech Republic, about 54% of arable land is endangered by water erosion (J a n e č e k et al., 2002). Many experts dealing with agriculture, especially with soil management, seek applicable answers to the question of how to decrease these losses, caused by water erosion. Moreover, they are aware that a universal answer does not exist, but rather, it is necessary to take into account the natural conditions of specific endangered localities.
However, there exist methods to reduce considerably these erosion effects. For water erosion, it is necessary to: decrease the incidence of kinetic energy of rain drops impinging on the soil

surface, to increase water infiltration into the soil, to restrict the sediment function, and to ensure more harmless surface run-off diversions (H ů l a et al., 2003).
To achieve these objectives, anti-erosion measures are proposed. This is a list of organized, agronomical, and eventually construction arrangements which should be applied at plots, in compliance with concrete production-economic conditions, and in the interest of soil protection.
In the framework of agricultural measures, conservation tillage technologies of crop stand establishment are very important. Besides improvement of the economic parameters of crop production, water preservation in soil, soil structure enhancement, a favourable effect on soil fertility etc. (J a v ů r e k et al., 2006; T e b r ü g g e and D ü r i n g, 1999), conservation technologies have a significant impact on the decreased effect of erosion of soils (B a s i ć et al., 2004, S c h u l l e r et al., 2007, Z h a n g et al., 2007). To found the optimal technology of soil tillage for crop stand establishment from point of view of soil protection against water erosion effects and decrease soil and nutrient losses with relation to the local conditions was the aim of this research.

Material and methods

This field experiment was established at the Klapý site, about 60 km NW from Prague in 2004. This site is located in sugar beet production type chernozem, clay-loam soil, at an altitude of 230 m asl., monthly sum of rainfalls in Fig.3. For this project, three erosion bounded plots having 75 m lengths and 16 m widths and about 10° slope were laid-out. The tillage treatments are used as follows: 1. *conventional treatment - plough* (P) [i.e. mouldboard ploughing 0.2 m depth, usual seedbed preparation and sowing]; 2. *no tillage treatment* (NT) [i.e. direct drilling into untilled soil; the soil surface is covered with chopped straw of fore crop.]; 3. *Minimum tillage treatment (MT)* [i.e. shallow disking and straw and post harvest residues incorporated into soil.] From two possibilities (very large plots non-replicated versus small plots replicated) the first one has been chosen. Therefore no replication was set-up. All crop stands were established using the same sowing machine, precision drill machine Kinze 3600 with 12 two-disc drill coulters, to ensure comparable stand structures. In 2005 sunflower (var. Alexandra), and in 2006 maize for silage were grown. Usual doses of nutrients for high growing intensity were used and standard herbicides were applied depending on the intensity of weed infestation at each site. In the both conservation variants *glyphosate* is used as need may be. Special catchment device were installed for each of the erosion plots, in order to determine the amounts of runoff and soil sediments. Runoff water with soil particles collected along the bottom side of the plots is piped into the tanks imbedded in pits separately for each variant. All amounts of runoff water and soil sediments are measured from the whole area of each plot (1200 m^2). After each erosion events the samples of both runoff water and sediment were taken for analysis of N, P, K and total organic C content. Statistical evaluation of runoff and soil loss differences between individual treatments has not been done because of no replication, but results of nutrient analysis were statistically evaluated.

Results and discussion

It is necessary to preface that the texture of that soil at the experimental site was loamy clayey. This is the result of analytical analysis of the texture fraction distribution: sand = 4 % w/w, silt = 37 % w/w and clay 59 % w/w. It means that this soil is relatively resistant against water erosion because of higher cohesive impacts of high clay content in the soil. Likewise, the beginning erosion effect of rainstorms following longer dry periods is not intensive so much because relatively big amount of runoff water is spent in deep cracks which are generated during dehydration of these clayey soils.

The first erosion event with a measurable amount of runoff water was recorded in the middle of February 2006, which was followed by a further erosion event on March 10. Both of these events were initiated by a sudden warming after a previous frost with snow cover. Increases of daily temperature caused snow melting and infiltration reduced by frozen through topsoil started the erosion processes. The first erosion event was quantitatively larger than the second one because of a greater layer of snow.

The lowest runoff was found in P (100%), bigger in NT (138 %), and the biggest in the MT treatment (152%) - in both winter erosion events (Fig. 1). Statistically significant differences were not calculated because of no replications; however, differences of runoff between P and both conservation treatments are such great that there no doubt of their significance. In the second erosion event (winter), the relationship among treatments was the same as in the first case (i.e. in P the lowest and in MT the biggest runoff was found, but differences were insignificant). These proportions correspond to soil losses, as well (Fig. 2). It is evident that in the second case, more soil particles were transported per unit of water; meaning that erosion was more intensive because of the defrosting of the upper layer of soil. The different results from the erosion events mentioned above, were found after the erosion event during the vegetation period in June (34 mm of rainfall) (Fig. 1). As for the runoff, no significant differences were found among individual treatments; however larger runoff than in both conservation variants was recorded in the conventional treatment. This means that the soil in the conservation variants has more retention capacity for water than soil under conventional tillage. The highest soil losses (Fig. 2) were recorded in conventional treatment - P (100%); the lowest ones in the NT treatment (only 59.6%). No significant difference were found between the conventional and farm treatment (93.6%). Our findings correspond with the results of other authors concerning the impact of conservation soil tillage upon water erosion. These similar results include Schuller et al., (2007), where they conclude that no tillage practices, including crop residue management, reduce erosion from 100% to 57%, and therefore significantly decrease soil and nutrient loss. Bhatt and Khera, (2006) compared the erosion effects during monsoon seasons on plots under conventional and minimum tillage, combined with straw mulching. They found the high impact of min. tillage with mulch in reducing soil erosion losses. Basić, et al., (2004) also confirmed the favourable effect of the no tillage technology, that reduces erosion losses from maize and soybean crops 40 and 65%, compared to ploughing tillage.

Comparing the results from winter and vegetation erosion events, we found the basic differences in these erosion processes. Despite of higher amount of runoff water from melting snow (first event) the soil was less damaged than during June event because of less kinetic energy of erosion water and no destructive effect of rain drops. Lower erosional effects in winter, on soils under conventional technology than on conservation ones are caused by a rough soil surface after the autumn ploughing that blocks fast water flow along the slope; decreasing the water speed and its ability to transport soil particles. Freeze-through of the soil profile is a further significant factor, allowed only minor infiltration. The runoff waters only partly infiltrate into conventionally tilled soil, probably due to higher amounts of macropores without frozen water.

The nutrient and TOC analysis showed that there are substantial differences in nutrient content in runoff water and runoff soil. In runoff water the content is very low, practically immaterial. There were found no significant differences among tillage treatment in frame of particular erosion event. But from analysis of soil sediment is evident that erosion events in vegetation period are much more effective concerning nutrient and TOC losses (tab.1). The highest nutrient and TOC losses were recorded in variant under conventional tillage. In no tillage technology treatment, nitrogen loss was reduced by 83 % in min tillage treatment by about 34 %, phosphorus loss was reduced by 36 % in no tillage, resp. by 11 % in min tillage treatment and so on. TOC losses in no tillage and min tillage were decreased very significantly, as well (Fig. 3). The nutrient losses are an economic loss in the budget of growing technology, indeed. Thereto, it is necessary to add further harms such as soil degradation an soil fertility decrease through loss of humus and other important soil components and also environment damage by runoff of nutrients and pesticide residues into surface waters (Janeček et al., 2002). Statistical analysis show significant differences of nutrient and TOC losses between conventional and both conservation methods of soil tillage (Tab. 2).

Conclusions

In regions where the land freezes very deeply during winter, especially on clay soils, water erosion proceeds under other set of rules than in the vegetation period (after ploughing the furrowed soil surface). Higher surface roughness of ploughed soils and higher retention capacity, due to higher amounts of macro-pores (as a result of the more intensive loosening) play a significant role in the erosional effect mitigation during winter erosion events. Assessment of the erosion effect in the vegetation period has shown that the no tillage system with mulch can be a very effective defence against soil losses caused by water erosion.
Conservation agriculture technologies, especially no tillage technology significantly decrease nutrient and TOC losses caused by water erosion.

Acknowledgement
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FIGURES:

Figure 1: Total runoff volume, within three erosion events in 2006

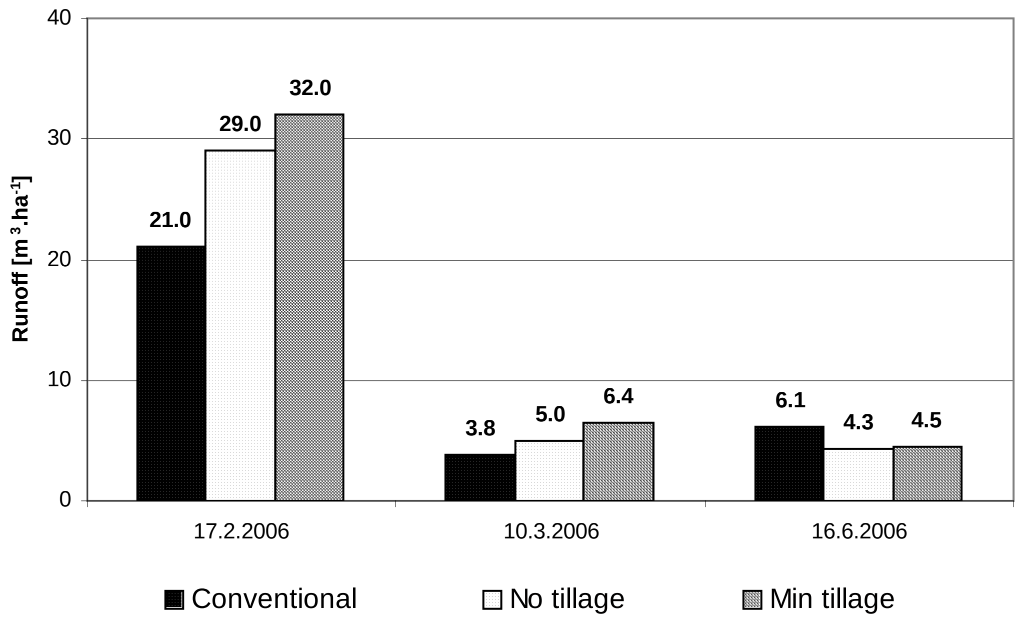


Figure 2: Soil loss, within three erosion events in 2006

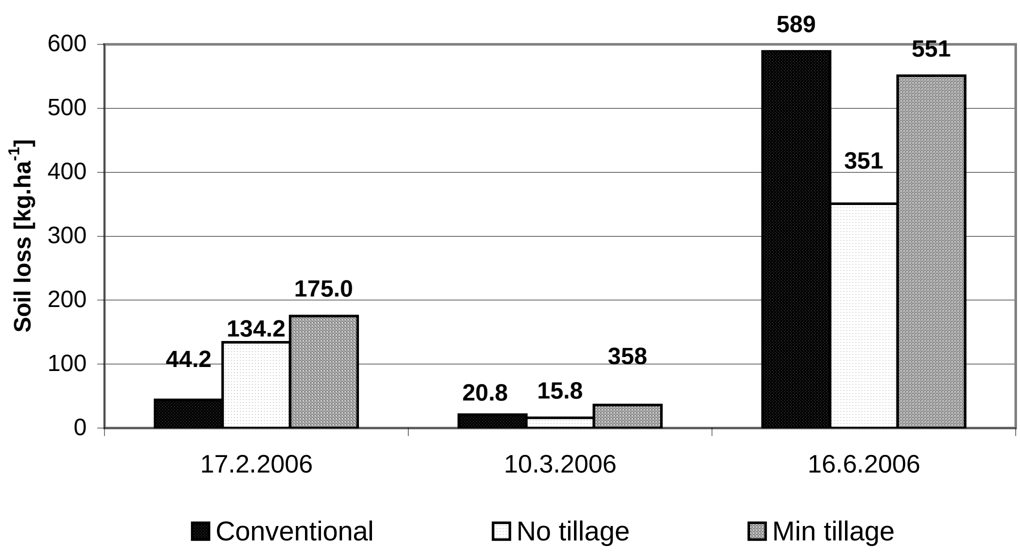


Figure 3. Monthly sums of precipitation at site Klapý

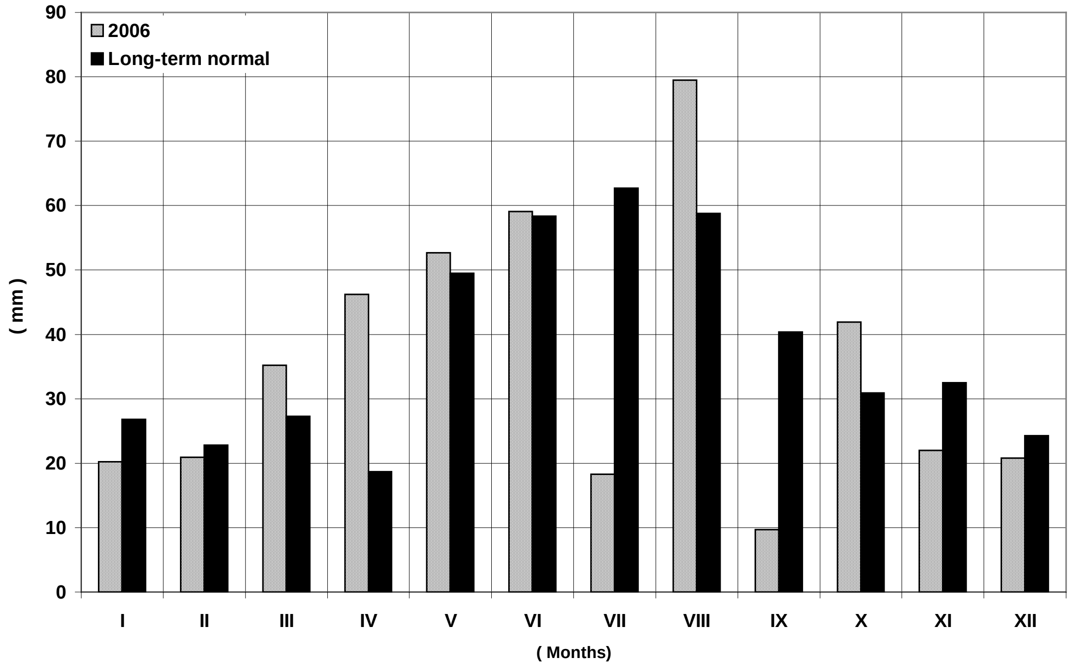
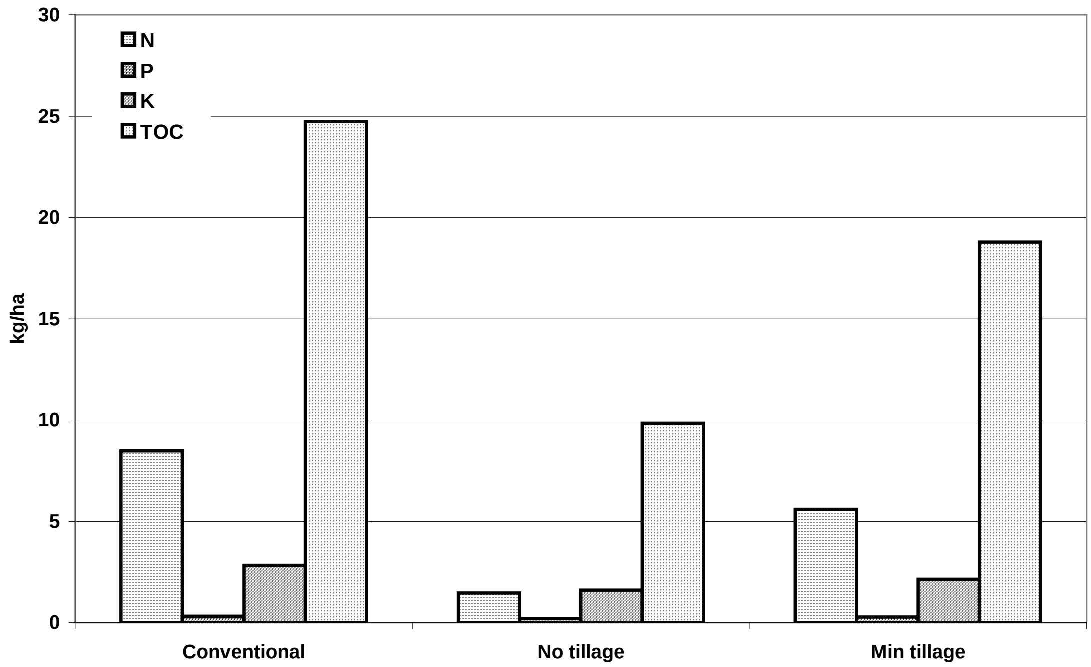


Figure 4: Nutrient and TOC losses during erosion at site Klapý in June 2006



CONTENT

Table 1: Nutrient and TOC losses during erosion events in July 2006

RUNOFF – Nutrient and TOC losses (g/ha)

Erosion event	CONVENTIONAL				NO TILLAGE				MIN TILLAGE			
	N	**P**	**K**	**TOC**	**N**	**P**	**K**	**TOC**	**N**	**P**	**K**	**TOC**
February 17, 2006	67,8	1,5	220,1	180,6	80,3	0	439,9	333,5	134,4	0	485,4	384,0
March 10, 2006	47,0	0	33,4	40,7	23,6	0	75,8	72,0	104,3	0	76,8	93,4
June 16, 2006	54,6	3,9	28,4	51,8	25,6	1,39	19,3	41,7	45,7	0	50,2	38,2

SOIL SEDIMENT – Nutrient and TOC losses (g/ha)

Erosion event	CONVENTIONAL				NO TILLAGE				MIN TILLAGE			
	N	**P**	**K**	**TOC**	**N**	**P**	**K**	**TOC**	**N**	**P**	**K**	**TOC**
February 17, 2006	349,2	91,3	168,3	2.957,6	456,3	86,9	536,5	8.763,2	560,0	98,3	691,4	10.541,2
March 10, 2006	54,1	10,7	67,4	506,3	48,9	8,4	69,0	428,9	107,4	20,5	154,2	1.327,9
June 16, 2006	8.472,5	318,6	2.820,6	24.725,0	1.458,8	204,6	1.605,0	9.828,0	5.597,9	285,3	2.153,9	18.775,0

TOC = total organic carbon

Table 2: Evaluation of difference significance among soil tillage treatments with help of LSD 0,05

Soil tillage	N (g/ha)	P (g/ha)	K (g/ha)	TOC (g/ha)
Conventional	8.472,5	318,6	2.820,6	24.725,0
No tillage	1.458,8	204,6	1.605,0	9.828,0
Min tillage	5.597,9	285,3	2.153,9	18.775,0
LSD $_{0,05}$	**1.009,7**	**42,4**	**483,3**	**3.146,1**

CONTENT

EFFECTS OF DIFFERENT SOIL TILLAGE SYSTEMS ON CHLOROPLAST PIGMENTS CONCENTRATION IN LEAVES OF WINTER WHEAT

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Abstracts
The scope of this research was to determine concentration and dynamic of chloroplast pigments in the winter wheat leaves. The research for winter-wheat after soybean crop rotation has been conducted at the North-eastern Croatia chernozem soil type during the period of 2001/2002–2003/2004, with following continuous soil tillage treatments: CT – conventional soil tillage, based on mouldboard ploughing; DH – multiple pass diskharrowing; and NT – no-tillage. The chloroplast pigments have been measured in four different phenophases after Feekes: 4.0, 8.0, 10.5.1 and 11.1. The concentration of chlorophil "a","b", karotenoids has been influenced by year, phenophase, interaction of year x phenophase and year x soil tillage on different significant level. The winter wheat grain yield at NT has been lower than CT and DH only in extremly dry year of 2003.

Keywords: Soil tillage, chloroplast pigments, winter wheat

Introduction

Croatia has very favorable agroecological condition for winter wheat growth, especially at the area of Slavonia & Baranya region. In crop production structure winter wheat is, together with maize, the most grown crop, covering area of around 200 000 ha each year. Although the reduced soil tillage systems in Croatia have been applied at small scale and very limited, last years there is real need for reduce of conventional soil tillage systems for crops, especially for winter wheat. The reasons for growth of the interest for reduced soil tillage have mostly economic, energetic and organizational characters, but the problems connected with physical, chemical and biological soil complex should not be diminished (*Jug, 2006*). Also, one should know that neither soil tillage system is not completely ideal, but there is occurrence of the problems in each one, which should be investigated. The growing number of researches is directly connected with winter wheat production in unfavorable weather and production conditions, with the main goal of increasing crop yield, with lesser production costs. The achieved yields are more and more connected with photosynthetic potential and photosynthetic plant activity (*Sabo et al. 2002*). The external factors with their variability and intensity significantly impact plant's growth and development, and yield quantity is determined not only by crop's genome, but also with different agroecological conditions and applied agrotechnology (*Vukadinović et al. 1989*). The photosynthesis is determined by numerous internal and external factor, such as: plant's development conditions, degree of adaptability to environmental conditions, water and nutrient supply, temperature, quality and quantity of the light, CO_2 and O_2 concentration, etc. Chloroplast pigments concentration in the winter wheat is inherited characteristic, moderated by numerous environmental factors (*Stanković, 1981*). Numerous researches have been pointing out dependency of chloroplast

pigments concentrations by growth and development of the crop, and pigment concentration and photosynthesis intensity are in close dependency with ontogenetic winter wheat growth. The large number of photosynthetic productivity factors has different impact at different genotypes in different agroecologic conditions (*Vidović*, *1998*). The most important for photosynthesis activity are light, nutrition, water supply and temperature. The interaction of each cultivar and agroecological factors are pointing out their huge inter-dependence, thus making needed investigations of each cultivar X soil tillage system interactions.
The main objective of this research was to establish the influence of different reduced soil tillage systems at the chloroplast pigments concentration during three very different years at the chernozem of the northern Baranya. This investigation should contribute toward better understanding of each soil tillage system on growth, development and yield of winter wheat.

Materials and methods

The field experiment

Soil tillage experiment was conducted at the north-eastern part of Croatia, in Baranya Region, at experimental field near Knezevo (N: 45°82′, E: 18°64′) for winter wheat (*Triticum aestivum* L.), cultivar Demetra, in crop rotation with soybean (*Glycine max* L.), cultivar Tisa, during three years (2001/2002, 2002/2003, 2003/2004). The main experimental set-up was a complete randomized block design in four replications, with three continuing soil tillage systems: CT – conventional tillage with ploughing up to the 30 cm as a primary tillage, followed by diskharrowing, sowing preparation and sowing with no-till driller John Deere 750A; DH – diskharrowing only up to the 15 cm and sowing as for CT and NT – No-tillage sowing without any primary tillage operation. The experimental site soil is classified as a calcareous chernozem on loess substrate (*FAO, 1990*). The soil analyses presented very favorable chemical properties (pH in H_2O = 8.1, pH in 1M KCl = 7.5; humus = 2.6%, $CaCO_3$ = 2.1%; AL-soluble P_2O_5 and K_2O = 18.7 and 28.4 mg $100g^{-1}$, respectively). The main experimental set-up was a complete randomized block design in four repetitions, with four continuing soil tillage systems. The size of basic experimental plot was 900 m^2 (*Jug, 2006*). The winter wheat cultivar "*Demetra*" (Agricultural Institute Osijek, Croatia) was sown at the planned rate of 700 germinating seeds m^{-2}, at the inter-row distance of 16.5 cm. The fertilization was uniform across treatments and years, and it consisted of $N:P_2O_5:K_2O$ = 40:130:130 kg ha^{-1}. The statistical analysis of single-year data has been made by Split-plot program with calculation of LSD values for $P<0.05$ and $P<0.01$ significance levels, whereas split-split-plot analysis has been made over multi-year data, with Year as the main level, Soil Tillage System as sub-level, and Phenophase as sub-sub-level treatments. Achieved grain yields were processed by two-way ANOVA for each year, whereas multi-year results were processed by split-plot ANOVA.

Weather characteristics

Weather characteristics were mainly specific in comparison with long-term means. For example, over-winter precipitation was 182 mm in 2002, 222 mm in 2003 and 332 mm in 2004 in comparison to the 30-year average of 266. Conversely, over-winter precipitation in 2002 only 171 mm. Total precipitations during the growing season was greater in 2004 year than the 30-yr average of 372 mm and ranged from 179 mm in 2003 to 434 mm in 2002. April-July were lower for 116%, and mean air temperatures were higher for 2.5°C in 2003 (*Table 1*).

Table 1. Total precipitation (mm) and temperature (º C) from September through February (winter) and the growing season (March through July) at Kneževo site during 2001/2002, 2002/2003, 2003/2004 and long-term means (LTM: 1965-2005).

	2002	2003	2004	LTM	2002	2003	2004	LTM
	Precipitation (mm)				Temperature (ºC)			
Winter season	171	281	330	272	6	9	6	6
March	10	4	35	41	9	6	6	6
April	64	9	120	46	11	11	11	11
May	86	33	77	60	19	20	17	17
June	49	19	114	92	22	25	20	20
July	61	61	41	61	24	23	22	21
Growing season	270	126	338	300	19	17	15	15

Sampling and laboratory analysis

The samples of w. wheat for chloroplast pigment analysis were sampled in four phenological stages (according to Feekes): 4.0 (tillering), 8.0 (jointing), 10.5.1 (heading) and 11.1 (milky ripening). The positions for leaf collection were chosen by the appearance and condition of the crop, with precautions needed for proper average sample collection. For chloroplast pigments analysis the 0.1 g of fresh weight of the most developed leaf was taken, whereas for the stage 11.1 the mass from flag-leaf was collected.

The concentration of chlorophyll a, chlorophyll b, chlorophyll a+b and carotenoids were determined spectro-photometrically (at wave lengths 662, 644 and 440 nm) from an acetone extract using the methods of Holm and Wettstain and expressed in mg/g of dry mass *(Sarić et al., 1986)*.

The winter wheat grain yield was achieved by weighing of the total grain mass from each plot (scale with d=1 kg t^{-1}). The final yield was recalculated for 1 ha area and standardized for 14% of the grain moisture.

Results and discussion

Concentration of chlorophyll a

By split-split-plot method it was determined that varying of chlorophyll a (*Table 2*) was strongly influenced by Phenophase (F=79.663**) and Year (F=9.220*). Very significant interactions were Year x Tillage (F=5.892**) and Year x Phenophase (F=3.365**). In all years the highest chlorophyll a concentration was recorded in heading, and the lowest in jointing. In years 2001/2002 and 2003/2004 at chlorophyll a concentration significant influence was expressed by Tillage and Phenophase. Similar results were reported by *Sabo et al., (2005)*. The chlorophyll a concentration at DH treatment in 2001/2002 was significantly lower in comparison with CT and NT treatments, whereas differences between CT and NT were not significant. In year 2002/2003 chlorophyll a concentration was under significant influence of the Phenophase, whereas Tillage and their interactions were not significant. In 2003/2004 chlorophyll a at CT treatment had significantly lower concentration if compared with other Tillage treatments, whereas there was not difference between DH and NT. Availability of soil moisture and nutrients for a longer period in moisture conserved plots, which resulted in increased chlorophyll synthesis. In water stressed plants, loss in chlorophyll is associated with a reduction in the flux of nitrogen into the tissue as well as alterations in the activity of enzyme systems such as nitrate reductase *(Begum and Paul, 1993)*.

Table 2. Chlorophyll a concentration for different soil tillage systems (A) for four phenophasis (B) in years 2001/2002, 2002/2003 and 2003/2004.

Feekes	CT (B_1)	DH (B_2)	NT (B_3)	Average
		2001/2002. year (A_1)		
4.0 (C_1)	1.859	1.711	1.699	1.756
8.0 (C_2)	1.686	1.646	1.927	1.753
10.5.1 (C_3)	2.676	2.246	2.536	2.486
11.1 (C_4)	2.117	1.930	2.390	2.146
Average	2.085	1.883	2.138	2.035
F-test	A*	B**		AxB
$LSD_{0.05}$	0.1958	0.2627		n.s.
$LSD_{0.01}$	0.2966	0.3547		n.s.
		2002/2003. year (A_2)		
4.0 (C_1)	1.739	1.649	1.582	1.657
8.0 (C_2)	1.345	1.252	1.211	1.269
10.5.1 (C_3)	2.339	2.349	2.185	2.291
11.1 (C_4)	2.136	2.319	2.222	2.226
Average	1.890	1.892	1.800	1.861
F-test	A	B**		AxB
$LSD_{0.05}$	n.s.	0.2428		n.s.
$LSD_{0.01}$	n.s.	0.3279		n.s.
		2003/2004. year (A_3)		
4.0 (C_1)	1.425	1.458	1.578	1.487
8.0 (C_2)	1.288	1.589	1.54o	1.472
10.5.1 (C_3)	2.049	2.101	2.139	2.096
11.1 (C_4)	2.082	2.179	2.180	2.147
Average	1.711	1.832	1.859	1.801
F-test	A**	B**		AxB
$LSD_{0.05}$	0.0474	0.1374		n.s.
$LSD_{0.01}$	0.0718	0.1856		n.s.

Source	A*	B	C**	AxB**	AxC**	BxC	AxBxC
F-test	9.220	1.502	79.663	5.892	3.365	0.633	0.542
$LSD_{0.05}$	0.1465	n.s.	0.1217	0.1354	0.2343	n.s.	n.s.
$LSD_{0.01}$	0.1465	n.s.	0.1601	0.1866	0.3284	n.s.	n.s.

Concentration of chlorophyll b

The ANOVA for AxBxC (Table 3) showed that at the chlorophyll b concentration the Year (F=30.477**), Phenophase (F=134.587**), and interaction Year x Phenophase (F=15.431**) had very significant influence.

The chlorophyll b concentration in 2001/2002 was significantly influenced by Phenophase and Tillage. The highest chlorophyll b concentration in w. wheat was recorded at CT in heading stage, whereas the lowest chlorophyll b concentration was recorded at DH in tillering stage. Statistical mean comparisons showed this tillering stage had very significantly lower chlorophyll b concentration in comparison with stages jointing, heading and milky ripening.

During the year 2002/2003 chlorophyll b concentration in w. wheat was under very significant influence of the Phenophase, whereas Tillage showed no influence.

The highest chlorophyll b concentration w. wheat had in the heading stage, whereas the lowest chlorophyll b concentration was recorded in jointing. Differences among phenophasis were highly significant. Chlorophyll b concentration in tillering and jointing was significantly lower if compared with heading and milky ripening, together with significant difference of chlorophyll b concentration between tillering and jointing stages.

At the variability of chlorophyll b concentration in 2003/2004 Phenophase had again very significant influence. The highest chlorophyll b concentration was recorded in milky ripening stage, and the lowest in tillering stage. All differences in chlorophyll b concentration were statistically very significant, except between jointing and heading, when that difference was only at P<0.05 level.

Table 3. Chlorophyll b concentration for different soil tillage systems (A) for four phenophasis (B) in years 2001/2002, 2002/2003 and 2003/2004.

Phenophase	CT (B_1)	DH (B_2)	NT (B_3)	Average
		2001/2002. year (A_1)		
4.0 (C_1)	0.407	0.356	0.313	0.358
8.0 (C_2)	0.458	0.454	0.530	0.481
10.5.1 (C_3)	0.770	0.625	0.726	0.707
11.1 (C_4)	0.662	0.558	0.685	0.635
Average	0.574	0.498	0.563	0.545
F-test	A*	B**		AxB
$LSD_{0.05}$	0.0618	0.0707		n.s.
$LSD_{0.01}$	0.0937	0.0955		n.s.
		2002/2003. year (A_2)		
4.0 (C_1)	0.495	0.484	0.451	0.476
8.0 (C_2)	0.395	0.384	0.380	0.386
10.5.1 (C_3)	0.782	0.796	0.782	0.787
11.1 (C_4)	0.644	0.673	0.663	0.660
Average	0.579	0.584	0.569	0.577
F-test	A	B**		AxB
$LSD_{0.05}$	n.s.	0.0685		n.s.
$LSD_{0.01}$	n.s.	0.0926		n.s.
		2003/2004. year (A_3)		
4.0 (C_1)	0.336	0.297	0.299	0.311
8.0 (C_2)	0.444	0.413	0.460	0.439
10.5.1 (C_3)	0.503	0.490	0.504	0.499
11.1 (C_4)	0.651	0.702	0.678	0.677
Average	0.484	0.475	0.485	0.481
F-test	A	B**		AxB
$LSD_{0.05}$	n.s.	0.0467		n.s.
$LSD_{0.01}$	n.s.	0.0631		n.s.

Source	A**	B	C**	AxB	AxC**	BxC	AxBxC
F-test	30.477	1.733	134.587	2.017	15.431	0.968	0.618
$LSD_{0.05}$	0.0244	n.s.	0.0351	n.s.	0.0676	n.s.	n.s.
$LSD_{0.01}$	0.0321	n.s.	0.0462	n.s.	0.0948	n.s.	n.s.

Concentration of chlorophyll (a + b)

The ANOVA for chlorophyll concentration (a+b) (*Table 4*) showed very significant impact of Year factor during experiment period (F=12.515**), together with Phenophase (F=105.615**). Very significant influence was recorded for interactions Year x Tillage (F=5.113**) and Year x Phenophase (F=5.498**). According to *Singh et al. (1985)*, continuous moisture stress leads to a decline in leaf chlorophyll and relatively wild stress would inhibit chlorophyll synthesis in wheat. During the year 2001/2001 chlorophyll concentration (a+b) was impacted significantly by Tillage and Phenophase. The highest chlorophyll concentration (a+b) w. wheat had at NT in the heading stage, and the lowest at DH in tillering stage. Chlorophyll concentration (a+b) at DH tillage treatment was significantly lower if compared with CT and NT. In 2002/2003 at chlorophyll concentration (a+b) very significant influence showed Phenophase. The highest chlorophyll concentration (a+b) was recorded in heading, whereas the lowest chlorophyll concentration (a+b) was recorded in jointing stage. Chlorophyll concentration (a+b) in tillering and jointing had significantly lower values than in heading and milky ripening stages. In 2003/2004 chlorophyll (a+b) was influenced by Phenophase and Tillage. The highest chlorophyll (a+b) concentration was at NT in milky ripening stage, whereas the lowest one was recorded at CT in tillering stage. Chlorophyll concentration (a+b) at CT was significantly lower in comparison with DH and NT, which were not different at P<0.05 level.

Table 4. Chlorophyll concentration (a+b) for different soil tillage systems (A) for four phenophasis (B) in years 2001/2002, 2002/2003 and 2003/2004.

Phenophase	CT (B_1)	DH (B_2)	NT (B_3)	Average
		2001/2002. year (A_1)		
4.0 (C_1)	2.266	2.067	2.012	2.115
8.0 (C_2)	2.144	2.099	2.457	2.234
10.5.1 (C_3)	3.446	2.871	3.261	3.193
11.1 (C_4)	2.779	2.489	3.075	2.781
Average	2.659	2.381	2.701	2.581
F-test	A*	B**		AxB
$LSD_{0.05}$	0.2561	0.3283		n.s.
$LSD_{0.01}$	0.3880	0.4434		n.s.
		2002/2003. year (A_2)		
4.0 (C_1)	2.234	2.133	2.033	2.133
8.0 (C_2)	1.741	1.636	1.590	1.656
10.5.1 (C_3)	3.121	3.145	2.967	3.078
11.1 (C_4)	2.780	2.992	2.886	2.886
Average	2.469	2.476	2.369	2.438
F-test	A	B**		AxB
$LSD_{0.05}$	n.s.	0.2689		n.s.
$LSD_{0.01}$	n.s.	0.3632		n.s.
		2003/2004. year (A_3)		
4.0 (C_1)	1.761	1.755	1.877	1.797
8.0 (C_2)	1.732	2.001	2.000	1.911
10.5.1 (C_3)	2.553	2.591	2.644	2.596
11.1 (C_4)	2.734	2.881	2.858	2.824
Average	2.195	2.307	2.345	2.282
F-test	A*	B**		AxB
$LSD_{0.05}$	0.0657	0.1551		n.s.
$LSD_{0.01}$	0.0996	0.2094		n.s.

Source	A**	B	C**	AxB**	AxC**	BxC	AxBxC
F-test	12.515	1.582	105.615	5.113	5.498	0.776	0.595
$LSD_{0.05}$	0.1171	n.s.	0.1438	0.1745	0.2770	n.s.	n.s.
$LSD_{0.01}$	0.1541	n.s.	0.1893	0.2404	0.3883	n.s.	n.s.

Concentration of karotenoids

The ANOVA showed that the karotenoids concentration (Table 5) was under very significant impact of the Phenophase (F=446.213**) and Year (F=6.511*), together with significant interactions Year x Tillage (F=3.794*) and Year x Phenophase (F=11.870**).

Karotenoids concentration in year 2001/2002 was under very significant impact of the Phenophase, whereas Tillage impact was not recorded. Karotenoids concentration was the highest in tillering, at the same time significantly higer than jointing at P<0.01 and milky ripening at P<0.05 significance level. As in the previous year, karotenoids concentration in 2002/2003 was under very significant impact of the Phenophase. The highest karotenoids concentration w. wheat had in the milky ripening stage, and the lowest concentration was in jointing stage. Karotenoids concentration in w. wheat leaf during milky ripening stage had higher value than other stages at P<0.01 level. Other differences in karotenoids concentration were not significant. In the year 2003/2004 karotenoids concentration was highly impacted by Phenophase and Tillage. The highest karotenoids concentration was recorded in milky ripening stage, the lowest in jointing stage. The karotenoids concentration in tillering and jointing were significantly lower if compared with concentration in heading and milky ripening.

Table 5. Karotenoids concentration for different soil tillage systems (A) for four phenophasis (B) in years 2001/2002, 2002/2003 and 2003/2004.

Phenophase	CT (B_1)	DH (B_2)	NT (B_3)	Average
		2001/2002. year (A_1)		
4.0 (C_1)	0.850	0.813	0.828	0.830
8.0 (C_2)	0.621	0.627	0.719	0.656
10.5.1 (C_3)	0.879	0.751	0.812	0.814
11.1 (C_4)	0.698	0.674	0.787	0.720
Average	0.762	0.716	0.787	0.755
F-test	A	B**		AxB
$LSD_{0.05}$	n.s.	0.0991		n.s.
$LSD_{0.01}$	n.s.	0.1338		n.s.
		2002/2003. year (A_2)		
4.0 (C_1)	0.688	0.645	0.588	0.640
8.0 (C_2)	0.448	0.457	0.461	0.455
10.5.1 (C_3)	0.738	0.643	0.649	0.677
11.1 (C_4)	0.892	0.953	0.889	0.911
Average	0.691	0.674	0.647	0.671
F-test	A	B**		AxB
$LSD_{0.05}$	n.s.	0.1206		n.s.
$LSD_{0.01}$	n.s.	0.1629		n.s.
		2003/2004. year (A_3)		
4.0 (C_1)	0.559	0.593	0.641	0.598
8.0 (C_2)	0.446	0.582	0.582	0.537
10.5.1 (C_3)	0.834	0.850	0.847	0.844
11.1 (C_4)	0.897	0.957	0.896	0.917
Average	0.684	0.745	0.742	0.724
F-test	A*	B**		AxB
$LSD_{0.05}$	0.0379	0.0558		n.s.
$LSD_{0.01}$	0.0574	0.0754		n.s.

Source	A*	B	C**	AxB*	AxC**	BxC	AxBxC
F-test	6.511	0.498	46.213	3.794	11.870	0.970	0.297
$LSD_{0.05}$	0.0466	n.s.	0.0528	0.0575	0.1016	n.s.	n.s.
$LSD_{0.01}$	0.0613	n.s.	0.0695	0.0793	0.1424	n.s.	n.s.

<u>Yields of winter wheat</u>

Based on three years research period, at winter wheat yield (*Table 6*) Year treatment influenced more than the Tillage. During the first and the third year of the experiment, achieved yields were appropriate, which can not be stated for yield in 2002/2003, extremely droughty year, when yields were lower for even 60%.

Table 6: Yields of winter wheat in period 2001/2002-2003/2004. year.

Year (A)	Soil tillage treatments (B)			Average (A)
	CT	DH	NT	
2001/2002 (A_1)	6.68	6.71	7.01	6.80
2002/2003 (A_2)	2.74	2.64	2.20‡	2.52‡
2003/2004 (A_3)	6.81	6.80	6.49	6.70
Average (B)	5.41	5.38	5.23	5.34
F-test	A		B	AxB
2001/2002	-		n.s.	-
2002/2003	-		9.659*	-
2003/2004	-		n.s.	-
2002-2004	629.586**		n.s.	4.660**

* significantly different at P<5%   ** significantly different at P<1%   n.s. non significant

‡ significantly different at P<1% according CT in the same year, and all years average.

Conclusions

1. At the concentration of chlorophyll a, chlorophyll b, chlorophyll a+b and karotenoids significant influence was recorded for Year and Phenophase, whereas Tillage influence was indirect, but visible through the interaction Year x Tillage.
2. Concentration of chloroplast pigments was in the average highest at NT treatment.
3. Average concentration of photosynthetic pigments was the highest in the year 2001/2002, and the lowest in 2003/2004.
4. Concentration of chloroplast pigments grew with development of the crops, showing the growth of the concentration from the lowest in jointing stage and the highest in heading stage.
5. Based at the three years results, it can be stated that treatment Year had higher impact at grain yield than Tillage treatment.
6. Average w. wheat yields are not reflecting real productivity of investigate area, due to extremely low yields in the second year, with exteme drought, which cut down yield for more than 60%.

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THE INFLUENCE OF SOIL TILLAGE AND BETA-LIQ PREPARATION ON THE ACTIVITY OF SELECTED SOIL ENZYMES

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Abstract

The research focused on assessment of activity of selected soil enzymes in the agroecosystem, while applying BETA-LIQ preparation and using different agricultural methods. Soil enzyme activity can reflect changes in soil environment and thus can be one of the soil-quality indicators. Over a three-year period the biochemical characteristics of soil were monitored out on small test-plots in Troubsko u Brna, Czech Republic. We implemented crop rotation involving winter wheat and spring barley. In two-month intervals during season, activity of acid and alkaline phosphatase, dehydrogenase, protease, nitrate reductase, urease and cellulase was monitored in 6 variants of agricultural methods. In statistically evaluated results we focused also on the effect of BETA-LIQ preparation. The evaluation showed the greatest statistical difference between the two following variants: spraying crushed straw with BETA-LIQ preparation and working post-harvest remains 12 to 15 cm into the soil, and that of working the crushed straw with a cultivator 12 to 15 cm into the soil and then ploughing to a depth of 22 cm. Significant difference was proven in the activity of dehydrogenase, nitrate reductase, urease, and acid and alkaline phosphatase. However, the variant with BETA-LIQ application did not statistically differ from other variants without this application, where the soil was also tilled 12 to 15 cm deep. Results of the research suggested that the applied BETA-LIQ preparation does not negatively affect microbial activity of soil, which is vital for efficient nutrient circulation and other soil processes, and can be used to start mineralization of post-harvest remains.

Keywords: soil, enzymes activity, crop rotation, tillage, BETA-LIQ

Introduction

In agriculture, the means of measuring and evaluating soil quality poses a major problem due to its considerable heterogeneity and variability of processes. Biological and biochemical processes (including soil enzymes activity) in soil are very sensitive to environmental stress, and therefore they can be used as one of the biological soil-quality indicators (Trasar-Cepeda et al., 1998). The activity of soil enzymes is also significantly affected by the method of soil management and fertilization (Diaz-Ravina et al., 2005; Melero et al., 2006; Dick et al., 2005; Marschner et al., 2003; Marinari et al., 2000; Martínez-Acosta et al., 2000).

In agroecosystem some studies recommend the use of various biopreparations to accelerate straw decomposition (Chen et al., 2002), while such preparations can also favourably affect changes in soil properties. For example, BETA-LIQ bioactive preparation is organomineral fertilizer based on beetroot molasses stillage which might, besides decomposition of organic matter, also influence soil enzyme activity (Procházková and Míša, 2005). We focused on this range of questions in our research, and in a crop-rotation sequence with a ten-year BETA-LIQ application we concentrated on studying its effect in a succession of crops grown under different soil tillage.

Materials and methods

Samples of soil had been taken from a small-plot experimental site in Troubsko near Brno, CZ, for three years. The studied area was divided into six experimental plots, on which different soil tillage and handling straw were used throughout the period of the trial:

T1 Working crushed straw with a cultivator to a depth of 12 - 15 cm, ploughing 22 cm
T2 Working crushed straw with a cultivator to a depth of 12 - 15 cm
T3 Stubble ploughing, sowing with a Horsch exaktor
T4 Harvesting straw, aeration to a depth of 12 - 15 cm
T5 Burning straw, aeration to a depth of 12 - 15 cm
T6 Spraying crushed straw with BETA – LIQ preparation, working it in with a cultivator to a depth of 12 - 15 cm

Winter wheat and spring barley were grown on monitored plots within the experimental period. In the last year of the experiment, spring barley was sown on all plots as a reference crop.
Soil samples for biochemical evaluation were repeatedly taken from the ploughed layer – from a depth of 0 - 15 cm.
To assess the activity of selected soil enzymes, the following methods were used:
The activity of phosphatases was assessed via methods adapted from Tabatabai and Bremner (1969), the activity of dehydrogenase was monitored using methods according to Ross (1970), to asses the activity of protease we used methods according to Ladd and Butler (1972). According to Tabatabai's and Bremner's methods (1972) we analysed the activity of urease, in assessing the activity of nitrate reductase the soil samples were incubated according to Abdelmagide and Tabatabai's methods (1987).
For the measuring of activity of cellulase we used methods according to Schiner and von Mersi (1990).
The dispersion analysis method of was used for statistical evaluation of the results, and a T – test (according to Tukey) and Spearman correlation for a more detailed assessment.

Results

During the three-year monitoring period, activity of soil enzymes (acid and alkaline phosphatase, dehydrogenase, protease, urease, nitrate reductase and cellulase) was regularly assessed on experimental plots with different soil tillage and different handling of straw.
In this experiment, we paid most attention to the variant of spraying crushed straw with BETA-LIQ preparation and then working the straw into the soil with a cultivator to a depth of 12-15 cm. A statistical comparison of T6 variant – spraying crushed straw with BETA–LIQ preparation and then working the straw into the soil with a cultivator to a depth of 12-15 cm with other variants within the experiment (T1 – T5) is given in tables 1 and 2.

Tab. 1 Comparing individual variants of soil processing with the variant of spraying crushed straw with BETA–LIQ preparation and working it in to a depth of 12-15 cm with a cultivator on plots with winter wheat (t-test)

	T1: T6	**T2: T6**	**T3: T6**	**T4: T6**	**T5: T6**
Acid phosphatase	0.071	0.259	0.381	0.312	0.182
Alkaline phosphatase	**0.002**	0.219	0.224	0.051	**0.043**
Protease	0.648	0.903	0.647	0.863	0.507
Nitrate reductase	**0.029**	0.085	0.156	0.244	**0.013**
Dehydrogenase	**0.039**	0.876	0.907	0.293	0.258
Urease	**0.008**	0.946	0.681	0.438	0.590
Cellulase	0.420	0.434	0.748	0.298	0.740

Tab. 2 Comparing individual variants of soil processing with the variant of spraying crushed straw with BETA–LIQ preparation and working it in to a depth of 12-15 cm with a cultivator on plots with winter wheat and spring barley (t-test)

	T1: T6	**T2: T6**	**T3: T6**	**T4: T6**	**T5: T6**
Acid phosphatase	**0.042**	0.205	0.898	0.325	0.103
Alkaline phosphatase	**0.018**	0.746	0.433	0.216	0.183
Protease	0.741	0.887	0.685	0.536	0.524
Nitrate reductase	**0.003**	**0.029**	**0.048**	0.090	**0.007**
Dehydrogenase	**0.002**	0.096	0.345	0.093	**0.004**
Urease	0.276	0.613	0.310	0.227	0.165
Cellulase	0.607	0.598	0.466	0.354	0.535

Note: values given in bold express statistically significant difference for $p < 0.05$

Evaluation showed that the most statistical differences occurred between the variant of spraying crushed straw with BETA–LIQ preparation and working the post-harvest remains in to a depth of 12-15 cm with a cultivator (T6) and the variant of working crushed straw in to a depth of 12-15 cm with a cultivator and then ploughing to a depth of 22 cm (T1). A remarkable difference was proven in the activity of dehydrogenase, nitrate reductase, urease, and acid and alkaline phosphatase. However, the variant with BETA-LIQ application did not statistically differ from other variants without such application, when the soil was worked to a depth of 12 – 15 cm (T2, T3, T4). A statistically proven difference to the benefit of the variant with application of BETA-LIQ was found in the activity of some enzymes (alkaline phosphatase, dehydrogenase and nitrate reductase) in comparison with burning straw and subsequential aeration to a depth of 12 – 15 cm.

Discussion and conclusion

Evaluation of selected biological and biochemical characteristics of soil on the site in Troubsko near Brno was based on a hypothesis that the BETA-LIQ organomineral fertilizer affects biochemical processes which can be expressed by the activity of soil enzymes, and thus favourably affects mineralization of organic matter contained in soil or brought to soil from the surrounding environment (Procházková and Míša, 2005).

In our research of soil enzymes activity in different soil tillage variants attention was mainly paid to the variant of spraying crushed straw with BETA-LIQ preparation and working it in to the depth of 12-15 cm with a cultivator. The statistical evaluation of the results proved most differences between this variant and deeper tilling of soil (to 22 cm) along with burning the straw. Minimisation technology, in comparison to conventional, does not cause in more cases a reduction in microbial biomass, and does not reduce its activity in the top soil layer (Diaz-Ravina et al., 2005). The non-ploughing management of soil, on the other hand, increases the content of soil organic matter (Angers et al., 1993; Roldan et al., 2003) which, as a source of energy positively affects microbial biomass and supports the enzymatic activity of soil (Melero et al., 2006). This was also proven in our monitoring, when in variants where post-harvest remains were worked into the surface, the level of activity was the highest. Neither a positive, nor negative effect of the BETA-LIQ preparation applied on a long-term basis was proven among these.
Differences between the described variants with BETA-LIQ application and those with ploughing mostly related to dehydrogenase, nitrate reductase, phosphatases and urease activity. According to Tabatabai (1972) dehydrogenases are an important part of the enzymatic system of all microorganisms and they belong to oxidoreductases, participating in oxidation of organic compounds. Nitrate reductase during the process of denitrification catalyzes a reaction during which nitrates in soil are reduced to nitrites (Abdelmagid and Tabatabai, 1987). The acidic phosphatase is brought to soil via root exudates, and therefore it is often used as an indicator of rhizosferic environment. Urease participates on hydrolysis of carbamide and thus makes nitrogen available for plants. In soil it represents a very stable enzyme, and is used in testing soil fertility (Frankenberger and Tabatabai, 1991). Urease activity is, besides soil temperature and pH, also affected by the method of soil management (Šarapatka, 2003). Differences in activity of dehydrogenase, nitrate reductase and alkaline phosphatase also showed in comparison of the variant with BETA-LIQ application and that of burning the straw.

Our research proved that the variant with BETA-LIQ application did not statistically differ from other variants without this application, where the soil was also tilled 12 to 15 cm deep. Results of the research suggested that the applied BETA-LIQ preparation does not negatively affect microbial activity of soil, which is vital for efficient nutrient circulation and other soil processes, and can be used to start mineralization of post-harvest remains.

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THE EFFECT OF SOIL TILLAGE ON DEVELOPMENT OF HARMFUL BIOTIC FACTORS

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Abstract

Soil tillage is an essential cultivation practice in many agricultural systems. It can be a powerful tool for managing many harmful biotic factors. Although soil tillage is closely associated with weed control, the various methods of tillage can also have important effects on plant fungi pathogens and insect pests. The effects of different methods of soil tillage (conventional, minimum and zero tillage) were evaluated in long-term field trials in the Czech Republic. The impact of tillage on incidence of other fungi pathogens (*Mycosphaerella graminicola* on winter wheat and *Pyrenophora teres* on spring barley) was significant only in interaction with soil tillage, forecrop and straw management. Reduced soil tillage resulted in increased occurrence of some pests, e.g. *Dasineura brassicae*, larvae of family *Elateridae* and *Ostrinia nubilalis*. The changes in technologies of soil tillage caused changes in actual weed infestation of many crops. Minimum tillage creates conditions that are suitable for lower number of weed species, therefore the diversity of species is decreasing. On the other hand the number of weed individuals is often rapidly increasing. The long-term effect of soil tillage influenced also quality and quantity of weed seedbank in the soil. The differences between conventional and reduced tillage are mostly in vertical distribution of weed seeds in the soil, seed viability and dormancy. Differences in seed burial depth can also have important implications for relative time of weed emergence, survival of weed seeds, and distribution of weed species.

Keywords: soil tillage, pests, diseases, weeds

Soil tillage is an essential cultivation practice in many agricultural systems. It can be a powerful tool for managing many harmful biotic factors. Although soil tillage is closely associated with weed control, the various methods of tillage can also have important effects on plant fungi pathogens and insect pests. The effects of different methods of soil tillage (conventional, minimum and zero tillage) were evaluated in long-term field trials in the Czech Republic.

Soil tillage and weeds

Tillage systems affect weed emergence, management and seed production. Changes in tillage practices consequently changes the composition, vertical distribution and density of weed seedbanks 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).

The impact of soil tillage on weeds was monitored in three field trials and on the selected plots of two agricultural enterprises. Actual weed infestation was evaluated in the newly established field trial in Branišovice (***short-term*** effect, established in 2000), where three variants of soil tillage were used, namely conventional tillage (CT), minimum tillage (MT) and zero tillage (ZT). The other place of evaluation was a ***medium-range*** field trial in Ivanovice na Hané (established in 1989), where the crops were grown in three crop rotations with different ratios of cereals (33.3 %, 50.0 % and 66.6 %). For the winter wheat and spring barley, four different variants of soil tillage were used, namely the variant with ploughing to depth of 0.22 m, the variant with ploughing to depth of 0.15 m, the variant with disk tillage to depth of 0.10 m and the variant with sowing into zero-tillage soil. The third ***long-term*** field trial with a monoculture of spring barley was established in 1970 in Žabčice. Two variants of primary soil tillage were used, 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 during years 2000-2004. The long-term effect of soil tillage on weed soil seedbank was evaluated in trial in Žabčice as well.
The impact of different variant of soil tillage on weeds was evaluated under operation conditions in two agricultural enterprises. On the plots of the cadastral area of Olomouc-Holice conventional tillage was used, while in the cadastral area of Bohuňovice minimum tillage was used. The method of phytosociological relevés was used for the evaluation of the spectrum of weed species. The obtained data were evaluated using analysis of variance (ANOVA) and the means were compared by the Fisher LSD test. The impact of the monitored factors on the individual species of weeds was evaluated by means of a multidimensional analysis of ecological data, using either Redundancy Analysis or Canonical Correspondence Analysis.

The ***short-term*** use of different variants of soil tillage resulted differences in weed infestation among crops and years. In the first years of observation, the variant with zero-tillage sowing of winter wheat showed the highest weed infestation, which then gradually decreased. This tendency was also apparent in the other variants of soil tillage in stand of winter wheat. In the stand of spring barley, weed infestation was fairly steady. It can be assumed that the decrease in weed infestation took place due to high quality chemical control. The species mainly occurred in the variant with zero-tillage sowing in the stand of spring barley were *Echinochloa crus-galli, Conyza canadensis, Lamium amplexicaule, Cirsium arvense, Viola arvensis, Tripleurospermum inodorum, Veronica polita, Stellaria media,* and in stand of winter wheat there were *Conyza canadensis, Capsella bursa-pastoris, Tripleurospermum inodorum* and *Veronica polita*. The variants with minimum tillage in stand of spring barley had the highest occurrence of *Descurainia sophia, Amaranthus sp., Veronica hederifolia,* while the winter wheat showed the highest occurrence of *Cirsium arvense, Descurainia sophia* and *Veronica hederifolia*. The species of *Chenopodium album, Chenopodium hybridum, Consolida regalis* and *Fallopia convolvulus* were mostly found in stands of spring barley with conventional tillage. *Consolida regalis, Fallopia convolvulus* and *Viola arvensis* were the most common weed species in winter wheat stands in the same variant of soil tillage.

The ***medium-range*** trial suggested certain trends in weed infestation. With the decreasing depth of soil tillage, the number of weed species also decreased, but the number of specimens increased. The reduced variants of soil tillage (disk tillage and zero-tillage) facilitate more favourable conditions for a higher occurrence of certain weed species. In stand of spring barley there were mostly late-spring species such as *Amaranthus sp., Echinochloa crus-galli* and *Chenopodium album* in particular. In stand of winter wheat it was *Capsella bursa-pastoris* and *Medicago sativa*. From these results it is apparent that reduced soil tillage is entirely unsufficient for the control of the pre-crop (lucerne). Weed infestation and species composition were significantly affected by the impact of weather conditions in each year, but also by the type of crop rotation.

As the results of the field trials showed, 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 results of weed seedbank in soil showed, that 30 years after establishment of spring barley monoculture, the higher number of weed seeds is on variant with minimum tillage (32237 pc m^{-2}) than on conventional tillage (47072 pc m^{-2}). Annual weed species *Chenopodium album*, *Amaranthus retroflexus* and *Melandrium noctiflora* were the most often on CT. Higher occurrence of *Convovulus arvensis* was on MT.
Areas where minimum tillage is used, showed the spreading of *Equisetum arvense* in general, in stand of spring barley it was the species *Avena fatua, Galium aparine, Poa annua* and *Veronica polita*, while in stand of winter wheat *Apera spica-venti* and *Fallopia convolvulus*. In most cases these are species which are difficult to control and which are capable of producing seeds or fruit very quickly.
In conclusion it can be said that the areas where minimum tillage is used, show those species in particular which produce seeds and fruit very quickly. Furthermore, these are species which are hardly controlled using herbicides. The occurrence of perennial weeds is apparently affected more by the quality of chemical control, which can overlap with the impact of the way of soil tillage. In addition, it is necessary to realise that the method of soil tillage affects the weed species as merely one of many factors, and also the fact that these act as a multifunctional factor in conjunction with many other factors.

Soil tillage and fungi pathogens

Reduced tillage leaves some crop residues on the soil surface and this is a cause for accumulation of disease inoculum. An increase in leaf diseases was reported in wheat in minimum tillage systems compared to conventional tillage (Sutton and Vyn, 1990; Brandt and Zentner, 1995; Krupinsky and Tanaka, 2001). But on the other hand Abrahamsen and Weiseth (1999) reported that no-tillage did not result in more disease than mouldboard ploughing.
The effect of some factors (soil tillage and straw treatment) on the incidence of *Pyrenophora teres* on spring barley and *Mycosphaerella graminicola* on winter wheat was determined in small-plot field trial during the years 2004-2007. The field trial was established in locality Žabčice as a model concept for farming without animal husbandry (all straw is cut and incorporated into the soil). This locality (179 m above sea level, 49°01′ N, 16°37′ E) is situated 25 km southwards from Brno (South Moravia region, Czech Republic). It is a warm and dry region with average annual temperature and precipitation of 9.2°C and 480 mm. The principle of this experiment was a 5-year crop rotation with a high concentration of cereals (spring barley, safflower, winter wheat, winter wheat, grain maize). The following two experimental factors were assessed: soil tillage (conventional or minimum tillage) and straw treatment with different fertilizers (variants A-D, see below). By winter wheat the third factor – pre-crop was evaluated (safflower – *Carthamus tinctorius* or winter wheat). The variant of conventional tillage consisted of stubble breaking after harvest and ploughing down to the depth of 0.20-0.24 m. The variant of minimum tillage included stubble breaking after harvest followed by a

shallow loosening to the depth of 0.15 m. Straw and crop residues of all crops were treated with four different liquid fertilizers (variants A-D); the aim of this treatment was to increase microbial activity and straw decomposition by nitrogen addition. The individual variants were as follows: Variant A involved the application of Beta-liq liquid fertiliser at the dose of 1 t ha^{-1}, Variant B the application of DAM 390 at the dose of 100 kg ha^{-1}, and in Variant C the fertiliser Unifert was applied at the dose of 230 kg ha^{-1}. All doses of fertilisers mentioned above corresponded to 30 kg of nitrogen ha^{-1}. The last variant, D, was used as control and it was without any fertilizer.

More detailed characteristics of fertilizers used:
A – Beta-liq – (a liquid molasses-based organo-mineral fertilizer containing 3% of N and 5% of K_2O); the applied dose was 1 t ha^{-1},
B – DAM 390 – (a nitrogen fertilizer solution composed of urea and ammonium nitrate, containing 30% N) – the applied dose was 100 kg ha^{-1}
C – Unifert – (liquid organo-mineral fertilizer on the base of alimentary waste products, containing 13% of N and 3% of K_2O) – the applied dose was 230 kg ha^{-1}
D – Control – without fertilizers
The spring barley variety Amulet and winter wheat variety Sulamit were sown at the rate of 4 million of germinating seeds (MGS) per hectare. The experimental dose of fertilizers for spring barley was 60 kg N ha^{-1} (applied prior to sowing as calcium ammonium nitrate, CAN, 27.5 %). The experimental dose of fertilizers for winter wheat was 120 kg N ha^{-1} (30 kg N prior to sowing as ammonium sulphate, 50 kg N in the spring for regeneration as calcium ammonium nitrate (CAN, 27.5 %) and 40 kg N till the end of tillering as DAM 390.
Experimental plots were harvested by a small combine harvester SAMPO 2010. Fungicide treatments were not applied.

The incidence of leaf spots caused by *Pyrenophora teres* was different on particular variants in all years. In the year 2004 variants treated with DAM were significantly less infected by this pathogen in comparison with untreated control and variants treated with Unifert. The influence of soil tillage was not proved in this year. On the contrary, in the year 2005 the influence of soil tillage was statistically significant, variants grown after reduced tillage were much more infected by *P. teres.* The influence of straw treatment was not proved in this year. In the year 2006 the influence of tillage was not significant, but differences between straw management variant were found. Variants with untreated straw were significantly less infected than variants treated by DAM and Beta-liq. As can be seen from these results, the incidence of *P. teres* in particular variants was influenced by the year and it can not be concluded, which soil and straw treatment is the best in the point of view of spring barley health status.
The effect of soil tillage, straw treatment and also pre-crops (safflower – *Carthamus tinctorius* or winter wheat) were evaluated on incidence of *Mycosphaerella graminicola* in the same field trial. We found different influence of particular factors on the incidence of this pathogen on winter wheat leaves. The statistically significant differences were found in factor pre-crop, in the years 2004, 2005 and 2007 variants after winter wheat were infected more than variants after safflower, but contrary, we found more infections on variants after safflower in year 2006. The factor soil tillage influenced also incidence of *Mycosphaerella graminicola.* Variant which were grown after reduced tillage were much more infected than variants after ploughing in years 2006 and 2007, but we can not find any differences in previous two years. Factor straw treatment did not influence the infection of winter wheat by this pathogen. We do not recommend to use reduced tillage for winter wheat if the pre-crop is also winter wheat.

Soil tillage and insect pests

Tillage strongly influences the essential conditions for insect fauna in fields. This is the case for both pests and beneficial organisms. Reducing the tillage influences different pest species in different ways due to different life strategies. A review of 45 investigations showed that 28% of the pest species increased with decreasing tillage, 29% showed no significant influence of tillage, and 43% decreased with decreasing tillage (Stinner and House, 1990).
Currently with implementing of different methods of reduced soil tillage, soil protection and plants founding is the question, how *Arthropoda* react will, which lives in the soil and on the surface. That includes the pests and also some groups of beneficial insects. In last years there was evaluated the influence of different soil cultivation on occurrence of pod midge (*Dasineura brassicae*), wireworms (larvae of family *Elateridae*) and European corn borer (*Ostrinia nubilalis*).
The differences in occurrence of pod midge were observed between variants of conventional (CT) and minimum tillage (MT) in winter oilseed rape. The traps were fit in place into stand of winter wheat (pre-crop was winter oilseed rape) in spring before emergence of this pest. These traps were transparent boxes from PVC painted with adhesive inside (Chemstop Ecofix). The surface of the box was 500 cm^2. There were three variants of soil tillage: CT – stubble breaking into the depth of 0.12-0.15 m (straw was incorporated into the soil) and followed by ploughing to the depth of 0.22 m, MT 2 – stubble breaking into the depth of 0.12-0.15 m (straw was incorporated into the soil) and MT 3 – stubble breaking into the depth of 0.12-0.15 m (straw was harvested). The obtained results are in Table 1.

Table 1. Influence of different soil tillage on number of pod midge in 2002 and 2003

Variants	Number of pod midge on 4 traps		Number of pod midge per m^2	
	2002	2003	2002	2003
CT	17	9	85	40
MT 1	77	52	385	260
MT 2	80	41	400	205

The results in table 1 showed big differences in numbers of pod midge in observed variants. The occurrence of pod midge was 4.5 – 6.5 times higher on variants with reduced tillage (variant MT 1 and 2) in comparison with conventional variant (CT).
The impact of two variants of soil tillage on occurrence of wireworms was evaluated in the field trial for farming with animal husbandry in locality Žabčice in 2004-2007. The principle of this trial is 7-year crop rotation with 2-year lucerne (lucerne - 1. year, lucerne - 2. year, winter wheat, silage maize, winter wheat, sugar beet, spring barley). CT – conventional tillage includes stubble breaking after harvest, ploughing to the depth of 0.20-0.24 m (depending on crop). NT – no tillage is a variant with direct sowing without any soil tillage, only before sowing of maize and sugar beet seedbed preparation is used on the depth of sowing.
The occurrence of wireworms was observed in winter wheat grown after lucerne using soil traps in spring. The results are given in Table 2. The differences in number of wireworms among years were observed, the lowest occurrence of wireworms was in 2005 (only 1 on variant NT and 3 on variant CT). The four years results show, that the number of wireworms was higher on NT variant (68 wireworms per m^2) than in CT (9 wireworms per m^2).

Table 2. Influence of different soil tillage on number of wireworms in winter wheat - Žabčice 2004 – 2007

Year	Number of wireworms genus *Agriotes* per m^2	
	CT	NT
2004	0	12
2005	3	1
2006	6	43
2007	0	12
Total	9	68

The impact of conventional tillage (CT) and minimum tillage (MT) on occurrence of larvae of European corn borer was evaluated in 5-year crop rotation with high concentration of cereals (description of this trial is already above mentioned). Comparable observation was done in grain maize monoculture. No kind of protection against *Ostrinia nubilalis* was used. During the assessment the whole plants were picked up, the stems and cobs were cut and the number of hallways and larvae per plant was counted. Broken plants (over and below cobs) were counted before harvest (200 plants from each variant in total). The results are in Table 3. The ratio of attacked plants 37.5 % - 80.0 % was on variants of conventional tillage and 62.5 % - 96.7 % on minimum tillage. Also the number of hallways, larvae and the ratio of broken plants were higher on variants with minimum soil tillage.

Table 3. Influence of different soil tillage in grain maize on occurrence of European corn borer in 2004 – 2006

year	Variant of soil tillage	Ratio of attacked plants	Total number of hallways per 10 plants	Number of larvae per 10 plants	Ratio of broken plants
2004	CT	37.5	*	4	5.2
	MT	62.5	*	8	9.8
2005	CT	80.0	17	8	3.0
	MT	96.7	28	14	6.0
2006	CT	43.3	17	4	3.0
	MT	66.7	36	8	7,3

Acknowledgement

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MEASURING CART DEVELOPMENT FOR SOIL BIN TEST

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Abstract
The environment-friendly tillage methods get more emphasis in the European Union thanks to the economical production and the environment load of tillage and its harmful effects. As the impact of climate change is getting more and more obvious nowadays. Soil profile or soil redistribution after tillage operation is important in several aspects such as incorporating manure, crop residues, protecting soil from wind or water erosion. The analysis of soil profiles and soil redistribution by tillage has progressed slowly due to its complexity which involves many factors, such as soil types and properties, types of tillage tools and their operational parameters. A soil tillage system which is based on a primary tillage with heavy-duty and field cultivator results in practical advantages. The duck hoe has several advantages as opposed to the ploughing. The perspective of the field cultivator tillage can be evaluated on the evidence of soil conservation directives of EU and on national interests. In this paper we will introduce the methods of the soil bin study
Keywords: soil, hoe, disturbance, erosion, tillage, cultivator, soil profile

Introduction
Soil profile or soil redistribution after tillage operation is important in several aspects such as incorporating manure, crop residues, protecting soil from wind or water erosion. The analysis of soil profiles and soil redistribution by tillage has progressed slowly due to its complexity which involves many factors, such as soil types and properties, types of tillage tools and their operational parameters.
For these phenomena the best solution is the cultivator, which can improve survival and growth of plants by reducing competing vegetation, increasing nutrient availability, improving planting quality, and improving the physical properties of the soil. Progressive soil degradation due to tillage operations affects crop production and its yield uncertainty, soil erosion by wind and water and gas emission.
A soil tillage system which is based on a primary tillage with heavy-duty and field cultivator results in practical advantages. The duck hoe has several advantages as opposed to the ploughing. The perspective of the field cultivator tillage can be evaluated on the evidence of soil conservation directives of EU and on national interests.
With the cultivating actually we can improve the process of pouring and weed control. Beside of the soil cutting, depend of the angle of attack, it can poring the soil. The tools have two important parameters: the 2γ front angle and the β angle of the wings.
The displacement of the soil parts depends on the main angles, in a stationary velocity. Accelerating the soil segment generates significant sculpturesque soil deformation, that produces cropping and poring. We should emphasize the accompanying deformations of the cutting process, because the volume of soil resistance factor can be insufficiently defined. The volume of this factor can change in a wide range depending on the cultivator tool properties. In this paper we will introduce the soil bin study measurement and it's materials and methods.

Materials and methods

<u>The soil bin</u>

The subject of the measurement is to compare the sweeps geometry in the soil bin. (Comparison resistance of the soil.)
The construction of the measuring cart:

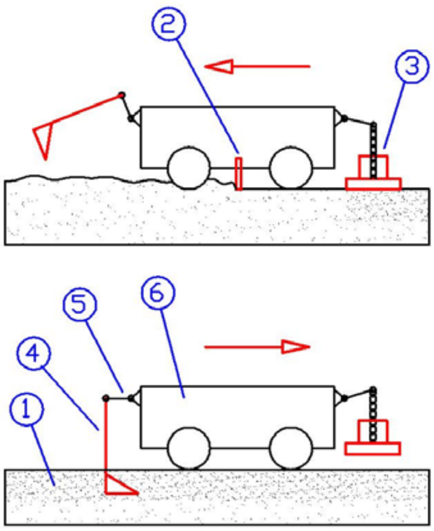

Fig. 1 Laboratory soil bin and measuring cart

1. Sand
2. Smoother
3. Compacter
4. Sweep (duck hoe)
5. 3-point suspension
6. Power machine

wing

- dynamic effects caused to tilling tools by the soil, specification of their components
- the effects of cultivation depth and cultivation speed to the power requirement and resulted soil condition,
- testing of various tilling tools, measuring their energy consumption,
- testing and measuring the constructional components of tilling tools,
- analyzing the structure of rubber tires, measuring wheel slip of different constructions.

Dimensions of the soil canal: Length of soil canal: 50m;Width of soil canal: 1,95m ;Type of soil: sand.

<u>The soil conditioning system</u>

Soil preparation:
The soil preparation is made up 3 actions:
1. Smoothing, 2. Compacting, 3. Moistening

Target: To produce the homogenous soil structure be practically the same as the field quality, and the maitenance the soil cohesion.
Smoothing:
The smoothing occured with the mounted smoother plates, which worked the horizontal surface. On the following figures we can view the vertical and horizontal adjustable smoother plates in yellow coloure. (Fig.2.-3.) We accomplished the soil surface to be compacted and moistured a number of pass.

Fig.2. Smoother mechanism

Fig.3. Original surface

Compaction:

The compaction occured with the mounted compacter device (Fig.4.).The device compacted the top surface of the soil vith excentric vibrator which we put 100 kg owerweight. By this means we calibrate the density of the soil, that controlled by penetrometer. We can find it on the following figure without owerweight.

Fig.4.. Compacter device

Fig.5. Soil moistening

Fig.6. The suitable soil

Moistening:

We fill up with water the soil bin after the smoothening and compacting (Fig.5.) as long as we can made the requested moisture contain. After the water absorbed int he soil, we controlled the moisture content, with TDR (Field Scout TDR 300).

The final state of the soil:

After the three operations we got the suitable soil. (Fig.6):

Result and discussion

The soil conditioning system

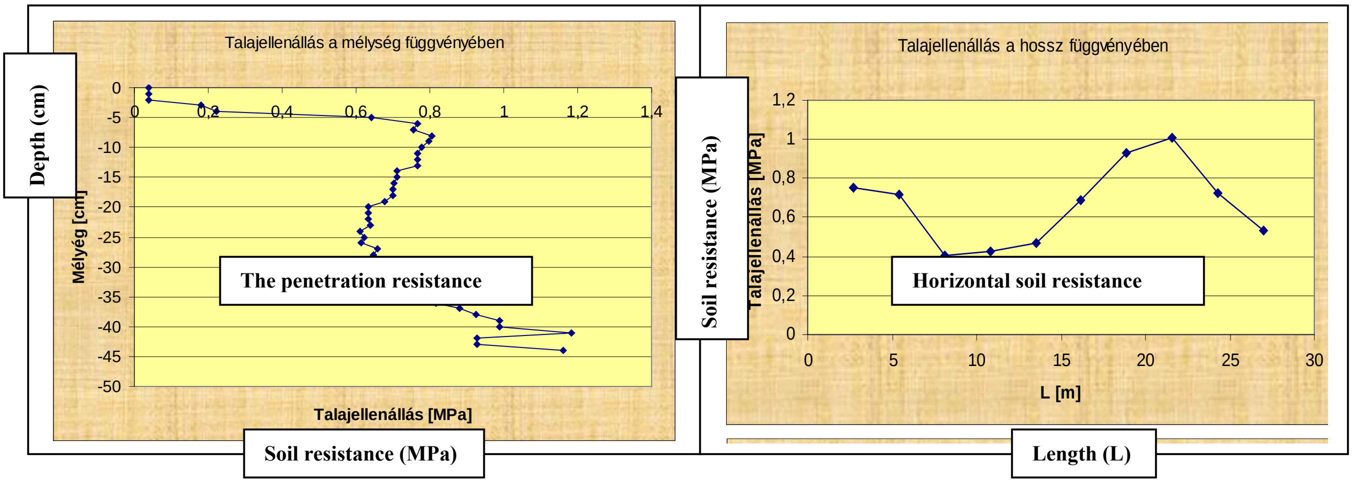

Fig.7. Soil vertical penetration and moisture content

As we can see on the figure 7, that the soil vertical penetration is increasing to 10 cm deep., than fixed to a constant value.It could be occused by the resonator tool.. The L values, thats could be read from the charta re the distances from the start of the soil bin. Averaging the values of the different measurement points and then we illustrated the horizontal soil resistance depend on the distance.

The testing shank

The simplest method to measure the traction force, if we stamp the sweep shank with tensometer stamp. At first we have to plan the positions of the tensometers. And this four tensometer we have to link in Wheatstone Bridge.

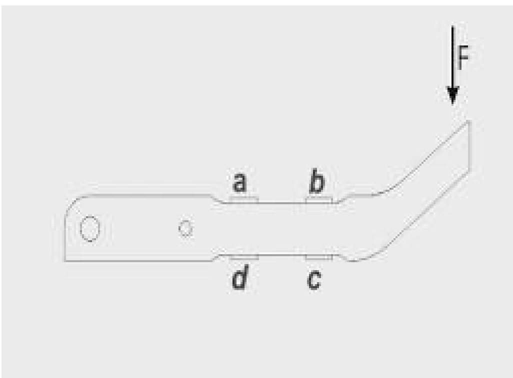

Fig.8. The position of the tensometer

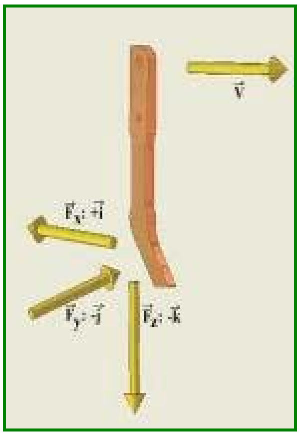

Fig. 9. The sweep shank coordynate system

On the planed sweep shank we modelled the effect of tracton resistance, that make mechanical stress and displacement. At first we have to define the force coordinate system. And we tested that the effect of the different traction resistance how large will be the extension in the planned sites.

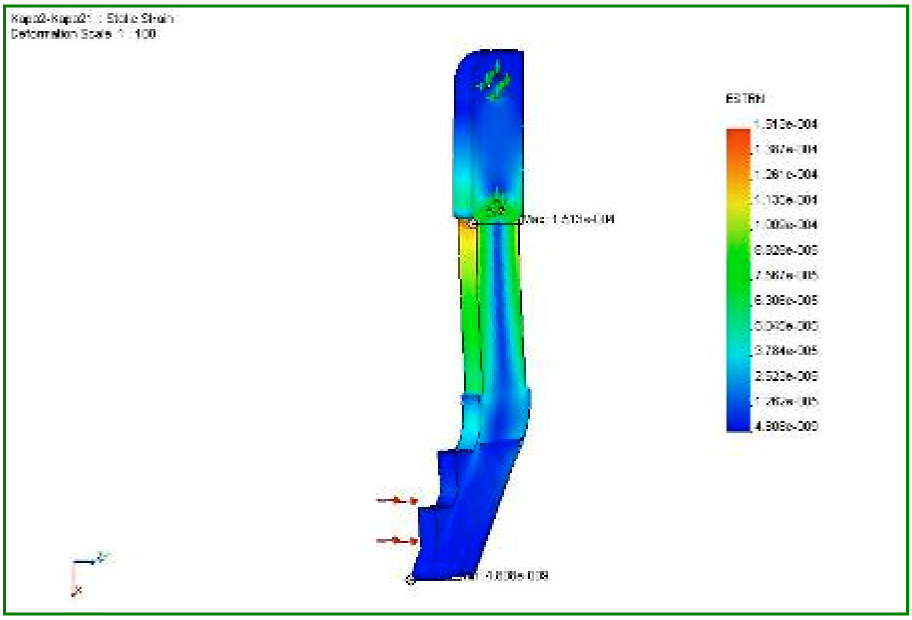

Fig. 10. The originated extension

The resulted deformation and strains on the tensometers site sin the effect of load.

Data acquisition system

In the measurement we use the Spider-8 based data acquisition. The Spider8 is a multi-channel PC measurement electronics for parallel, dynamic measurement data acquisition using a computer. With Spider8 everything needed for measurement is accommodated in a compact housing no bigger than a notebook.

The Spider8 offers a simple and economic alternative to systems based on PC plug-in modules. Contrary to such systems, the quality of measurements using Spider8 is independent of the electromagnetic conditions inside the PC which can hardly be computed in advance. Furthermore, this requires neither additional installations for connection and wiring nor high configuration effort.

The system verification

In the calculations E=210 kN/mm2 elastic modulus-value and k=2,05 value

A computed volume of extension:

Table 1.

The volume of resulted extension in the measure sites

F	ε_a	ε_b	ε_c	ε_d
[N]				
981	0,000109490	0,000061127	-0,000061216	-0,000108340
1962	0,000218980	0,000122250	-0,000122430	-0,000216690
2943	0,000328470	0,000183380	-0,000183650	-0,000325030
3924	0,000437960	0,000244510	-0,000244870	-0,000433380
4905	0,000547540	0,000305630	-0,000306080	-0,000541720

The main factor of the tensometer is the Gage factor, this is the conversion factor that give the proportional resistance change for the proportional extension.

$$k = \frac{\frac{\Delta R}{R}}{\frac{\Delta l}{l}} = \frac{\frac{\Delta R}{R}}{\varepsilon}$$

The output voltage of the tensometers, that linked in Wheatstone-bridge show the next equation.

$$U_{ki} = U_{be} * \left[\frac{R_a + \Delta R_a}{(R_a + \Delta R_a) + (R_b + \Delta R_b)} - \frac{R_d + \Delta R_d}{(R_d + \Delta R_d) + (R_c + \Delta R_c)} \right], [V]$$

The bridge input power is: Uin=1V.

The tensometer stamps which positioned to the output lines of the bridge the resistance change will define the next equation:

$$\Delta R = R * \varepsilon * k, [\Omega]$$

To substitute the extention value the effect of the load we get the output voltages.

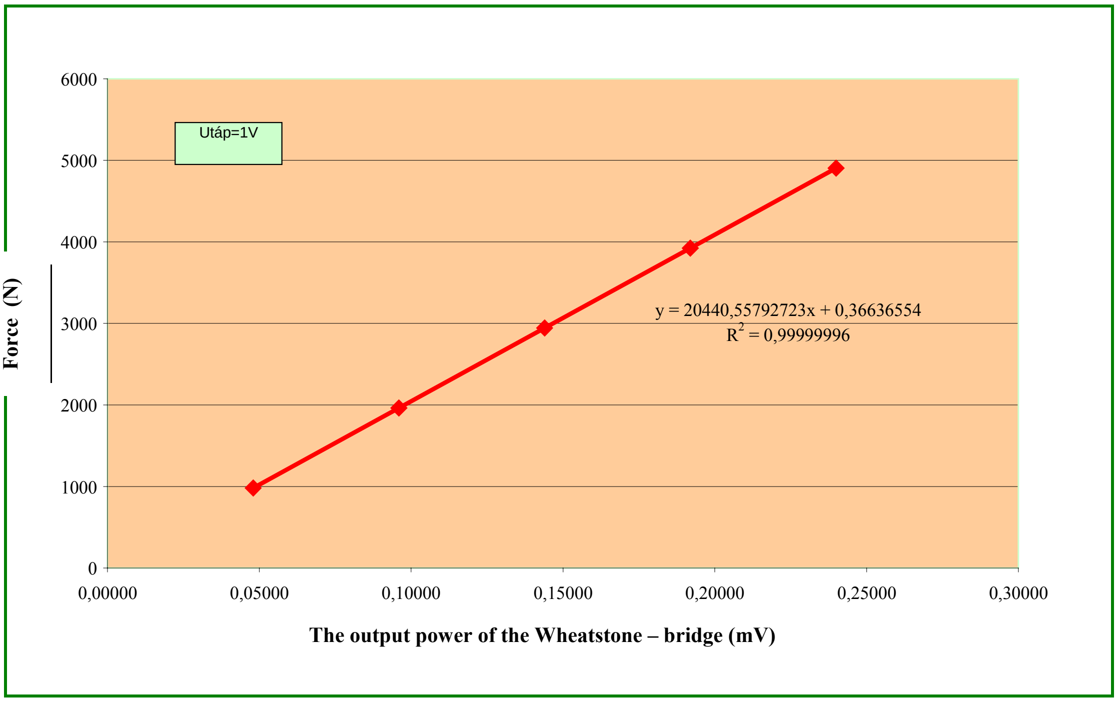

Fig.11. Output power

The steepness of the obtained calibrate factor in the course of the modelling:

$$m = 20440 \frac{\frac{N}{mV}}{V}$$

Conclusions

A soil tillage system which is based on a primary tillage with heavy-duty and field cultivator results in practical advantages. The duck hoe has several advantages as opposed to the ploughing. The perspective of the field cultivator tillage can be evaluated on the evidence of soil conservation directives of EU and on national interests.
The displacement of the soil parts depends on the main angles, in a stationary velocity. Accelerating the soil segment generates significant sculpturesque soil deformation, that produces cropping and poring. We should emphasize the accompanying deformations of the cutting process, because the volume of soil resistance factor can be insufficiently defined. The volume of this factor can change in a wide range depending on the cultivator tool properties. In this paper we will introduce the soil bin study measurement and it's materials and methods. The soil preparation is made up three actions: Smoothing, Compacting, Moistening. Target: To produce the homogenous soil structure be practically the same as the field quality, and the maitenance the soil cohesion. The simplest method to measure the traction force, if we stamp the sweep shank with tensometer stamp.
Eventually we can reveale, that the measuring cart is ready for the soil bin test. In the next we'll have to collect the sweeps.

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SOIL TILLAGE AGAINST EXTREME MOISTURE REGIMES

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Abstract
Soil as the largest potential natural water reservoir in the Carpathian Basin has increasing importance under conditions of predicted climate change resulting in increase of probability of extreme hydrological events. Soil management changes soil structure and has a major effect on soil water, heat and nutrition regimes. In this study the effect of four tillage treatments in combination with catch crop management was studied on soil hydraulic properties and water regime under semi-arid conditions. It was concluded, that both, the tillage systems used in the experiment and the application or absence of catch crops had strong influence on soil structural status and on soil water regime. Quantification of the soil water balance elements, however, would be required to decide which management system created the most favourable for the plants soil conditions.

Keywords: extreme moisture regime; (available) moisture content; infiltration; water storage; tillage treatments.

Introduction
The increase in atmospheric CO_2, along with increase in other greenhouse gases, is believed to be changing the earth's energy balance (Haskett *et al.* 2000). There has been recent confirmation of anthropogenic changes in earth's climate related to this increase (IPCC 2007). According to forecasts the probability, frequency, duration and intensity of extreme hydrological events and soil moisture situations (flood, waterlogging, overmoistening versus drought, sometimes in the same year, in the same place) will be increasing in the future because of climate change, and its consequences.

Under such conditions, as in Hungary, situated in the deepest part of the hydrogeologically practically closed Carpathian Basin – it is an important fact that soil is the largest *potential* natural water reservoir and a great part of the atmospheric precipitation can be stored in the 0–100 cm layer of the soil and this water storage *may* reduce hydrological stresses (Várallyay, 2005). This potential water storage capacity, however, cannot be used efficiently, because of the following reasons:

– infiltration is prevented or limited by full water saturation (as a consequence of a previous water supply) („filled bottle effect"); frozen topsoil („frozen bottle effect"); a compact, hardly permeable soil layer on or near to the soil surface („closed bottle effect");

– the infiltrated water is not stored within the soil in plant available form because of low water retention or high wilting percentage ("leaking bottle effect").

For an efficient soil moisture control and for the reduction of surface runoff (soil erosion), evaporation and filtration losses all efforts have to be taken to help infiltration, and to increase the water storage capacity of soil and the available moisture range. In this respect soil tillage practices have special importance (Várallyay, 2004).

Mechanical disturbance of soil changes soil structure and pore size distribution in the tilled layer and below. From this aspect, soil tillage has direct (through mechanical disturbance) and indirect (e.g. through its effect on root growths, biological processes, soil organic matter content etc.) effects on soil structure and, consequently, on soil water retention and infiltration

properties (Farkas, 2004). Stable soil structure is an important property of soil from both agricultural and environmental aspects (Dexter and Birkás, 2004). When soil structural degradation occurs, seedbeds can collapse and become anaerobic and unsuitable for crop growth (Watts et al., 1996). Soil degradation also has harmful effects on the soil water regime and on aeration (Štekauerová, 1999). Hence, sustainable tillage techniques that conserve moisture are important for increasing crop yields and limiting the devastating consequences of drought. Soil holds moisture mostly on the basis of texture, although plant available water can be modified by soil organic matter content because of the way soil particles aggregate. Application of catch crops and mulching can improve soil structure (Whiteley and Dexter, 1982) and influences soil water retention and infiltration properties as well as soil temperature (Radke et al., 1988). However, it was shown, that the decision on whether to use catch crops is based heavily on the prevailing conditions (Ujj, 2004ab), including soil type, rainfall amount, perennial weed type, time of catch crop harvest and type of catch crop. Consequently, investigation of various soil tillage systems and of adaptation possibilities of catch crops under semi-arid conditions of the Carpathian Basin calls for further attention.
The objective of the current study was to investigate the combined effect of four tillage variants and catch crop on soil hydrophysical properties and soil water regime of a Chernozem soil in Hungary for the selection and recommendation of site-specific, soil and moisture conserving soil management systems.

Material and methods

Experimental site. The investigation was carried out in the long-term soil tillage experiment of the Szent István University, established in 2002 (Birkás and Gyuricza, 2004a). The Józsefmajor Experimental Station (altitude 110 m, latitude: 47°40' N, longitude 19°40' E) is located nearby Hatvan, Hungary, 60 km north-east from Budapest on the northern edge of the Carpathian basin. The year average temperature is 7.9°C, the annual and growing season precipitation amounts are 580 and 323 mm on average, respectively. The prevailing soil type is Calcic Chernozem, developed on loam and is moderately sensitive to soil compaction. The soil has a slightly acidic reaction (pH H_2O is 6.38 and pH KCl is 5.43); the sand, silt and clay contents of the upper 20 cm layer are 23%, 42% and 35%, respectively. The organic matter content is 3.2% and 2.5%; the total N, P_2O_5 and K_2O contents of the 0–20 and 20–40 cm layers are 0.13 and 0.082%; 270 and 214 ppm and 110 and 85 ppm, correspondingly. The experiment was set up on 13 m x 150 m experimental plots with four replicates in a split-plot design. The tillage variants comprised mouldboard ploughing (P, 26–30 cm); disking (D, 16–20 cm); loosening + disking (L+D, L: 40–45 cm, D: 16–20 cm), and direct drilling (NT) (Birkás and Gyuricza 2004b). The crop sequence – winter wheat (*Triticum aestivum* L.) – maize *(Zea mais*, L.) during years 2001–2003 was improved by catch crops (mustard, rye and pea). In 2003 maize, sawn in winter wheat mulch was the main crop grown, after which rye (*Secale cereale* L.) was sown as a catch crop in half of the territory of each tillage treatment. Since the farm has livestock, the purpose of the rye production was double: to protect the soil and to produce green-mass for forage. For this reason, the rye was harvested rather late, in the beginning of June (Ujj, 2004). The crop residue was implicated into the soil by a cultivator, except or the direct drilling where the residue was treated using chemicals. After rye harvest, pea was sown to improve soil conditions and for forage. Detailed description of various treatments, examined in this study is given in Table 1.

Soil sampling, analyses and monitoring. In May 2004, disturbed samples and undisturbed soil cores of $100 cm^3$ volume were collected from each tillage treatment/catch crop combination in 3 replicates. Samples were taken from 5 to 10-, 15 to 20- and 45 to 50- cm layers, representing the soil surface, the cultivated layer, the pan and the non-tilled layers, respectively. Samples were wetted from bellow and further drained to water suctions, h, of 1, 2.5, 10, 32, 100 and 200 hPa using the hanging water column method (Várallyay 1973) and to 500, 2500 and 15850 hPa by the osmotic method (Várallyay 1973). The water contents were then measured gravimetrically by drying the samples at 105°C until no changes in their weight was observed. Bulk density was calculated from dry soil weights (105 °C, 48h) and the volume of undisturbed samples. Soil texture was determined, using the pipette method.

Table 1*. Description of treatment varieties in the Józsefmajor experiment between September 2003 and September 2004

	Tillage treatments							
	Ploughing		Direct drilling		Disking		Disking + deep loosening	
Notation	**P_0**	**P_1**	**NT_0**	**NT_1**	**D_0**	**D_1**	**LD_0**	**LD_1**
Date	22 August, 2003							
Depth (cm)	25-30				16-20		16-20 and 40-45	
	Crop rotation							
Date	25 August, 2003							
Mulch	winter wheat straw and root							
Catch crop	no	Rye	no	Rye	no	Rye	no	Rye
Date	15 June, 2004							
Mulch	no	Rye straw, root	no	Rye straw, root	no	Rye straw, root	no	Rye straw, root
Crop	Pea for forage							

Codes _0 and _1 refer to no catch crop and catch crop treatments, respectively.
* After Birkás and Gyuricza (2004a,b)

In each of the 8 treatments, 3T-System type capacitive probes (Szőllősi, 2003) were installed up to 80 cm depth with 10 cm increment to ensure continuous measurement of soil temperature and soil water content. Measurements were performed four times a day from September 16, 2003 until September 9, 2004. Daily average values for a period between days 70 and 240 were used for the calculation of total soil water contents of the upper 20, 50 and 80 cm soil layers. Soil water content dynamics as a function of depth was evaluated for a selected shorter period.

Results and Discussion

The main soil hydrophysical properties, determined for different treatments are given in Table 2. In the ploughing treatment, soil bulk density was lower in the treatment without catch crop, compared to the P_1 treatment. Also the saturated soil water content was higher. However, according to Ujj (2004b), no differences between the penetration resistances of the P_0 and P_1 treatments were observed in May 2004 in the upper 50 cm layer, even thought the soil water contents were almost identical. This indicates that the pores of the topsoil were filled with live roots in the P_1 treatment, which influenced the bulk density and saturated water content measurements. Moreover, the presence of crops during the winter period had a favourable effect on soil structure and caused and increased in the water holding capacity of the soil. Consequently, the potential amount of plant available water (PAW) increased in the 5-10 and 15-20 cm layers of the P_1 treatment compared to the P_0 by 9.6 and 8.3 v%, respectively.

Table 2. Soil hydrophysical properties, measured in different treatments (Józsefmajor, 2004)

	TREATMENTS							
	P_0	**P_1**	**NT_0**	**NT_1**	**D_0**	**D_1**	**LD_0**	**LD_1**
	5-10 CM SOIL LAYER							
BD (G CM^{-3})	**1.12**	**1.49**	**1.43**	**1.36**	**1.23**	**1.29**	**1.31**	**1.36**
□$_{SAT}$ (V%)	**57.7**	**43.9**	**45.9**	**48.7**	**51.3**	**53.5**	**50.6**	**48.6**
□$_{FC}$ **(V%)**	**28.7**	**37.3**	**37.1**	**38.7**	**36.7**	**32.5**	**38.7**	**39.3**
□$_{WP}$ **(V%)**	**11.7**	**10.7**	**12.2**	**12.2**	**13.1**	**12.3**	**13.4**	**13.3**
PAW (%)	**17.0**	**26.6**	**24.9**	**26.5**	**23.6**	**20.2**	**25.3**	**26.0**
	15-20 CM SOIL LAYER							
BD (G CM^{-3})	**1.17**	**1.39**	**1.39**	**1.39**	**1.38**	**1.37**	**1.38**	**1.37**
□$_{SAT}$ (V%)	**59.2**	**47.6**	**47.6**	**47.7**	**47.8**	**48.3**	**48.0**	**48.3**
□$_{FC}$ **(V%)**	**29.8**	**37.5**	**34.1**	**34.3**	**32.6**	**33.1**	**32.9**	**35.0**
□$_{WP}$ **(V%)**	**12.8**	**12.2**	**13.2**	**11.4**	**11.9**	**13.5**	**13.8**	**13.4**
PAW (%)	**17.0**	**25.3**	**20.9**	**22.9**	**20.7**	**19.6**	**21.1**	**21.6**

Where: Bd – bulk density; □$_{SAT}$, □$_{FC}$ and □$_{WP}$ are the saturated soil water content, the field capacity and the wilting point, expressed in volume % and PAW is the plant available water.

Soil water retention curves, measured in the upper 20 cm soil layer in all the treatments are presented in Figure 1.
Valuable differences between the soil water content values corresponding to different water potentials could be observed in the low suction range, while no differences could be found in the high suction (above 1000 cm H_2O) range. The shape of the soil water retention curves reflected dual porosity soil structure in some of the treatments (e.g. in D and L+ D treatments).

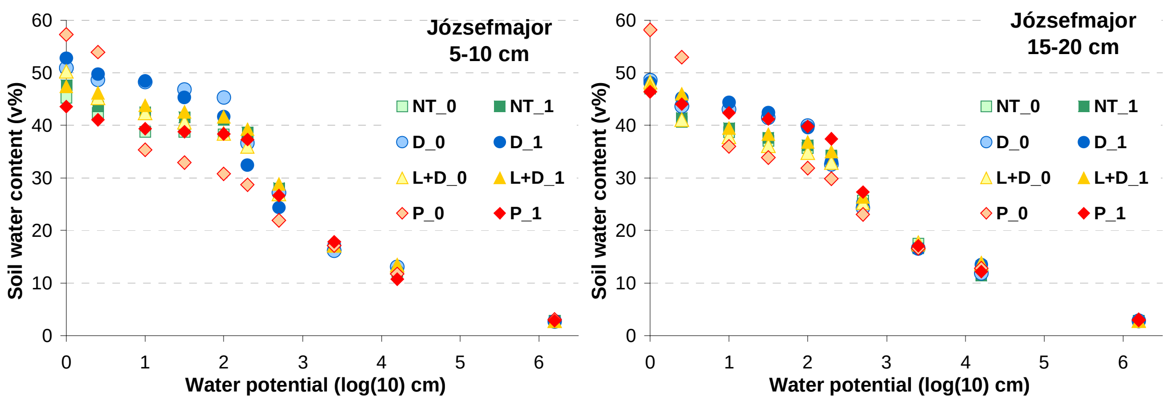

Figure 1. Soil water retention curves, measured in different treatments (Józsefmajor, 2004)

We concluded, that both, the tillage systems used in the experiment and the application or absence of catch crops had strong influence on soil structure, which could significantly effect the water and heat regimes of soil.

The total amount of water (TSW), stored in the upper 20-, 50- and 80cm soil layers is shown in Figure 2. For the whole root zone, the catch crop treatments were generally dryer in all tillage varieties except disking treatment due to rye water consumption. The range of TSW among the tillage systems was as follows: P < L+D < NT <D. As it was reported by Ujj (2004b), the total biomass of rye in the P treatment was significantly higher than in the other treatments, so most probably the crop water uptake dried the soil out. In the NT soil retained more and less water in the upper 20 and 80cm layer, respectively, compared to D treatment, which indicates, that NT provided more equilibrated soil water distribution within the profile.

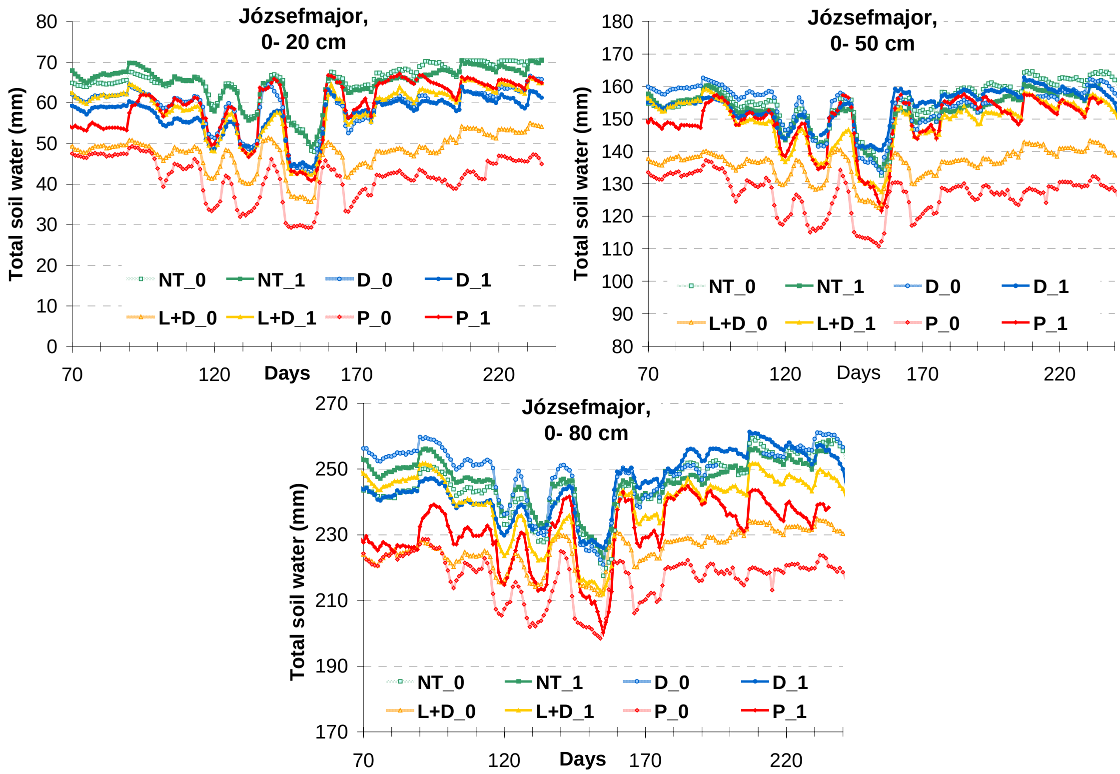

Figure 2. Total amount of water (TSW) in different soil layers (Józsefmajor, 2004)

Figure 3 demonstrates the soil water content dynamics recorded in various treatments during a selected period. The depth of tillage treatments is indicated with red lines. The driest conditions during the 70-day period starting from early spring were recorded in the ploughing treatment. The soil water content distribution in the P_0 treatment indicates, that the formation of plough pan around 30 cm depth limited the infiltration of water to the deeper layers, resulting in increased evaporation losses and drier conditions in both, the topsoil and the subsoil. Application of catch crops changed the soil water regime in the P treatment significantly – water could penetrate below the below the plough pan layer, most probably due to improved soil structure and root channels.

The influence of catch crops was also valuable in the L+D treatment, resulting in higher and lower soil water contents in the topsoil and subsoil, respectively. There were no significant differences in the measured soil characteristics under the various tillage treatments, but they show characteristic seasonal dynamics during the vegetation period, especially the actual moisture content and the available water range.

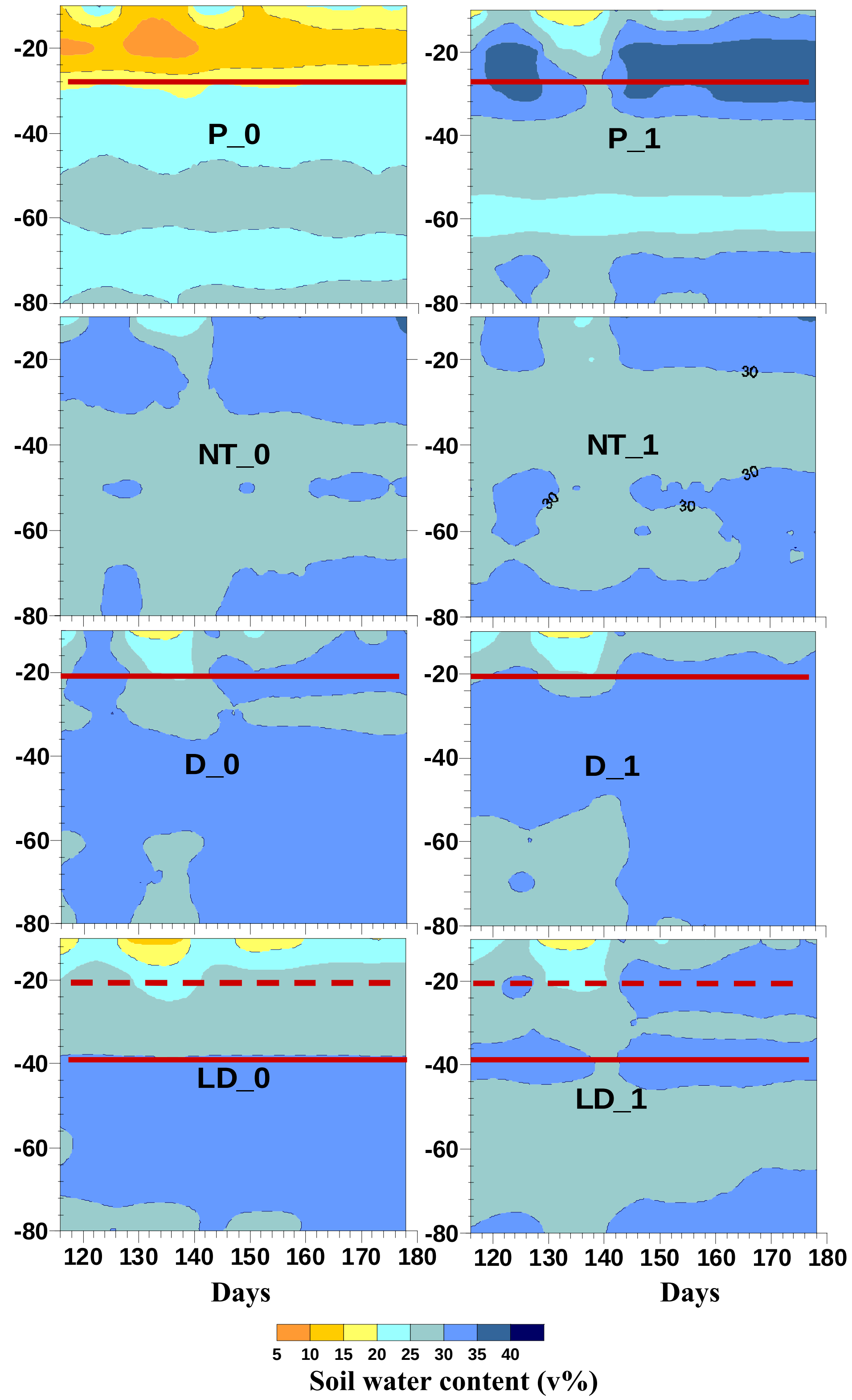

Figure 3. Soil water content dynamics as a function of soil depth derived for a chosen period from EH_2O probe measurements in different treatments

However, it is difficult to decide, which soil/crop management system provided the highest amount of plant available water for the rye, since high soil water content could mean that rye roots could not reach the wet soil layers, or could not uptake the water from the soil for various reasons. Consequently, quantification of the soil water balance elements (including plant water uptake and transpiration) and water use efficiency calculations would be needed to range the studied soil management systems with respect to moisture conservation.

Conclusions

The main conclusion from the experiment is that under such (or similar) ecological conditions, the uniform and „over-standardized" adaptation of tillage methods for soil moisture conservation is rather risky, their application needs special care and the future is for site-specific precision technologies. These are, in combination with catch crop application can be efficient measures of environment protection (prevention of soil degradation processes; control of biogeochemical cycles of elements: plant nutrients and pollutants; maintenance of favourable biodiversity, etc.) as well.

We concluded, that quantification of the soil water balance elements (including plant water uptake and transpiration) and water use efficiency calculations would be needed to range the studied soil management systems with respect to moisture conservation

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EFFECTS OF PLANT RESIDUE MANAGEMENT ON LABILE ORGANIC MATTER AND WATER-STABLE AGGREGATION OF A LOAM DEGRADED CHERNOZEM AND A CLAYEY LOAM GLEYIC FLUVISOL

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Abstract
The objective of the present studies was to evaluate the effects of three plant residue management practices on water-stable aggregation and distribution of labile forms of soil organic matter (SOM) in two arable soils. These practices included: straw harvesting, straw incorporation into a depth of 0-20 cm, and straw burning with a subsequent its incorporation into the depth of 0-20 cm. There was only a trend towards a greater increase in amount of water-stable aggregates in soils with the straw incorporation treatment, compared to other ones, possibly as a result of higher accumulation of SOM and its labile forms. The straw incorporation also led to a greater accumulation of labile forms of SOM and to a substantial increase in soil basal respiration. The straw burning treatment resulted in the highest amount of microbial biomass carbon in the clayey loam Fluvisol. In contrast, the loam degraded Chernozem contained the highest content of microbial biomass carbon at the straw incorporation treatment.

Keywords: management practices, organic matter, aggregation

Introduction
Soils as key components of agro-ecosystems are responsible for such important ecological functions as biochemical and geochemical cycling, accumulation and distribution of water, nutrients and heat, buffering, providing biodiversity of living organisms (De Kimpe and Warkentin, 1998; Swift, 1994). Soil quality is a basic requirement for a sustainable environment and biodiversity maintenance (Karlen et al., 1997). An effective organic matter and plant residue management is essential for maintaining soil quality and sustainability due to the self-recovery of favourable water-stable aggregation after detrimental impacts. Therefore the need for soil aggregation research is to study the effects of different management practices on labile forms of soil organic matter (SOM) in order to evaluate their functional roles in soils. In the studies of key indicators of the soil quality and sustainability a priority is given to interdisciplinary microbiological, biochemical and biophysical studies (Anderson, 2003; Marriott and Wander, 2006**;** Väisänen et al., 2005; Six *et al*., 2004). Such studies enable to carry out a reasonable selection of robust soil indicators to distinguish trends in the improvement and deterioration of soil quality and sustainability in various agro-ecosystems around the world (Nortcliff, 2002; Shaxson, 1998).
The plant residues, roots and root hairs can be involved into a formation of soil structures which are very sensitive to the effects of agricultural treatments and erosion processes (Six et al., 2004; Bossuyt et al., 2001; Balashov and Bazzoffi, 2003). Therefore the importance of plant residues for the structural complexity of soils should be taken into account if there is a need for evaluating the effects of different management practices on soil sustainability. However, a little information is still available on the quantitative contribution of plant residue management practices to the recovery of soil structure (i.e. water-stable aggregation) in soils with different genesis and texture.

The objective of the present studies was to evaluate the effects of three plant residue management practices on water-stable aggregation and distribution of labile forms of SOM in two arable soils.

Materials and methods

Disturbed soil samples were taken in October of 2002 from the ploughing horizons in fields with different management treatments for monoculture of barley cultuvated in Ivanovice and Zabcice - experimental stations of the Mendel University of Agriculture and Forestry Brno. Field experiments in Ivanovice and Zabcice were established in 1965 and 1970, respectively. In Ivanovice, samples of a loam degraded Chernozem (Luvic Chernozem, FAO classification) were taken from a depth of 0-20 cm in the fields with conventional tillage (to a depth of 20-22 cm) and with such management treatments as straw harvesting (removal), straw incorporation (into a depth of 0-20 cm), and straw burning (with a subsequent incorporation into the depth of 0-20 cm). In Zabcice, samples of a clayey loam gleyic Fluvisol (Fluvi-gleyic Phaeozem) were collected from the depths of 0-20 cm (conventional tillage) on plots with such treatments as straw harvesting, straw incorporation (into the depth of 0-20 cm) and straw burning (with a subsequent incorporation into the depth of 0-20 cm).

Air-dried soil samples were sieved through a set of sieves with a diameter of openings of 0.25, 0.5, 1.0, 2.0, 5.0 and 10.0 mm in order to determine a distribution of size fractions of dry-stable aggregates. Afterwards the distribution of size fractions of water-stable aggregates (WSA) was determined by placing the samples (50 g) of the dry-stable aggregates on top of a set of the above-mentioned sieves, immersing directly in water, and oscillating for 1 min (40-50 mm stroke length, 10 cycles min^{-1}).

SOM content in bulk soil samples and total fractions of WSA was measured by a conventional wet combustion method. Basal respiration in the bulk soil samples and WSA was determined by a gas chromatograph "Chrom–5" after an 1-day incubation of moistened (field capacity) samples at 30 ^oC. Measurements of substrate-induced respiration in the bulk soil samples and WSA to calculate a microbial biomass carbon (MBC) content were carried out using a gas chromatograph according to a method of Anderson and Domsch (1978). All the measurements of soil properties were made in three replicates. The results were subjected to an analysis of variance (ANOVA), and the means and standart deviations were determined at a confidence limit of up to 95%.

Results and discussion

Plant residues management practices are usually regarded as rather effective tools for a satisfactory organic C sequestration and water-stable aggregation in arable soils (Chan et al., 2002). The organic C sequestration in soils generally means that a fresh organic matter derived from plant residues and manures will be included with time within micro- and macroaggregates (Golchin et al., 1995; Knicker and Skjemstad, 2000). However, the extent of SOM changes in response to tillage and plant residue management varies between climatic conditions, soils and crops.

Our experimental data showed that there were no significant differences in the total amount of WSA in the straw harvesting, incorporation and burning treatments at conventional tillage of the loam degraded Chernozem (51,9-54,1%) and clayey loam Fluvisol (60,9-64,3%). However, there was a trend towards a slightly greater increase in WSA in both soils mainly at the straw incorporation treatment, compared to other ones (Fig. 1a, b). In the most cases, our results demonstrated a higher increase in amount of 1,0-10,0-mm fraction of WSA in the straw incorporation treatment, as compared to the straw harvesting and burning treatments. Fractions of 1,0-2,0 to 5,0-10,0-mm WSA played an almost similar role in the management-induced changes of water-stable aggregation of the clayey loam soil.

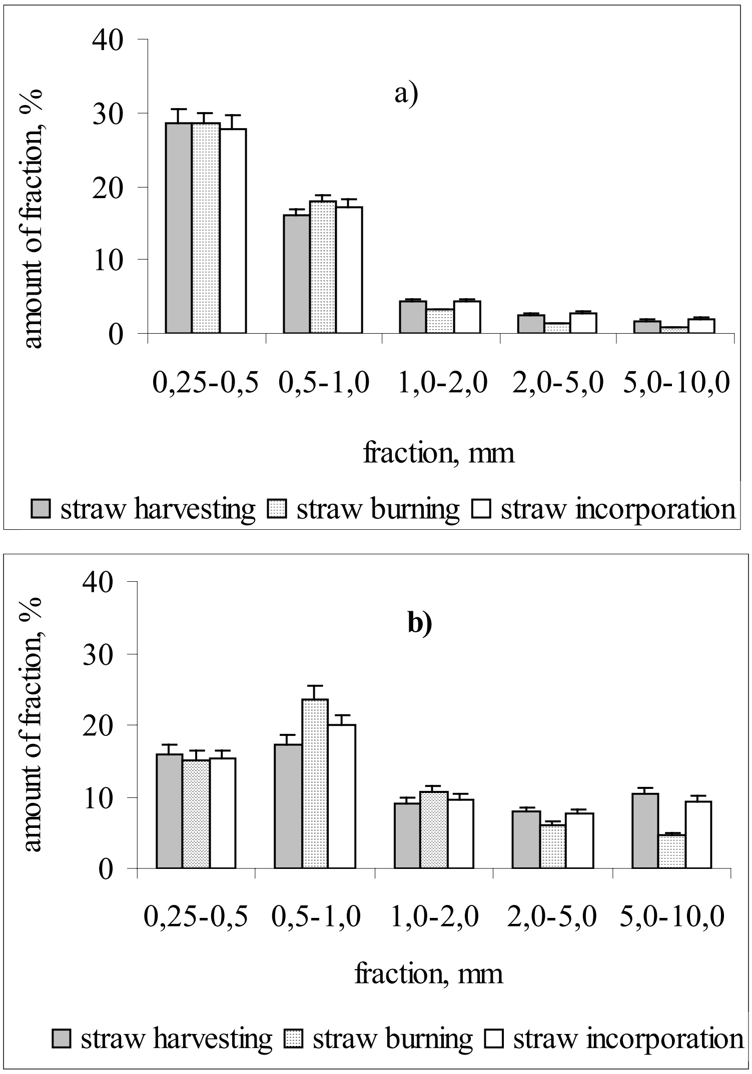

Fig. 1. Distribution of size fractions of water-stable aggregates in a loam degraded Chernozem (a) and a clayey loam Fluvisol (b) at different plant residue management practices (bars are standart deviations at P<0,05, n = 3)

In contrast, the straw burning treatment contributed to a greater increase in amount of 0,25-1,0-mm WSA, mainly 0,5-1,0-mm WSA in both soils. Burning of plant residues is known to lead to a formation of aromatic components (for instance, benzenepolycarboxylic acids) associated with clay minerals (Glaser et al., 2000). In the straw burning treatment, such aromatic components might be active binding agents in the observed greater formation and self-recovery of smaller WSA.

The observed trend of a more favourable action of the straw incorporation treatment on WSA amount could be due to a greater contribution of this treatment to an accumulation of SOM in the loam soil - 18,0 g C kg^{-1} soil (bulk samples) and in the clayey loam soil - 15,7 g C kg^{-1} soil (bulk samples), compared to other treatments. An accumulation of SOM in WSA was higher than that in bulk samples at the straw incorporation and burning treatments. For instance, SOM content in WSA of the loam soil was equal to 19,1 g C kg^{-1} soil at the straw incorporation and straw burning treatments. In the clayey loam soil, the only straw incorporation treatment contributed to a slightly higher accumulation of SOM (16,2 g C kg^{-1} soil) in WSA, as compared to bulk samples. However, the treatment-induced differences in accumulation of organic C did not result in any significant changes of soil water-stable aggregation. Therefore the SOM content can be regarded as an insensitive indicator for a valid assessment of changes in water-stable aggregation of the studied soils.

Basal respiration is a sum of respiration by microorganisms at a current content of available organic C and N. In the present studies we supposed that the straw harvesting, incorporation and burning treatments would affect the mineralisable (i.e. labile) forms of SOM in soils. It was also assumed that the burning of barley straw did not lead to the death of soil microorganisms as temperatures in the top layers of soils may be not lethal to microorganisms as recently reported by Wuethrich et al. (2002).

Among the studied treatments, the use of straw incorporation one also led to a greater accumulation of easily available forms of SOM, and, as a result, to a higher basal respiration in bulk samples of the loam degraded Chernozem (21,6 mg CO_2-C kg^{-1} soil h^{-1}) and clayey loam Fluvisol (19,3 mg CO_2-C kg^{-1} soil h^{-1}). However, we observed a trend towards a higher basal respiration in WSA than in bulk samples at any plant residue treatments. For instance, values of basal respiration in WSA of the loam degraded Chernozem varied from 28,7 mg CO_2-C kg^{-1} soil h^{-1} (straw harvesting) to 35,0 (straw burning) mg CO_2-C kg^{-1} soil h^{-1}. Basal respiration in WSA of the clayey loan Fluvisol reached lower values - 25,0 mg CO_2-C kg^{-1} soil h^{-1} (straw burning) - 28,8 mg CO_2-C kg^{-1} soil h^{-1} (straw incorporation). On the basis of these results we can conclude that basal respiration was a rather sensitive indicator of changes in the status of labile organic matter and WSA.

Substrate-induced respiration is being measured to calculate a content of MBC, i.e. an amount of C in the living non-resting microbial biomass of soil (Anderson and Domsch, 1978). MBC is being currently used as a sensitive soil quality indicator (Anderson and Domsch, 1989; Beyer, 1995; Franzluebbers et al., 1997).

Our results showed that the straw incorporation treatment contributed to a higher accumulation of MBC in the loam degraded Chernozem (Fig. 2).

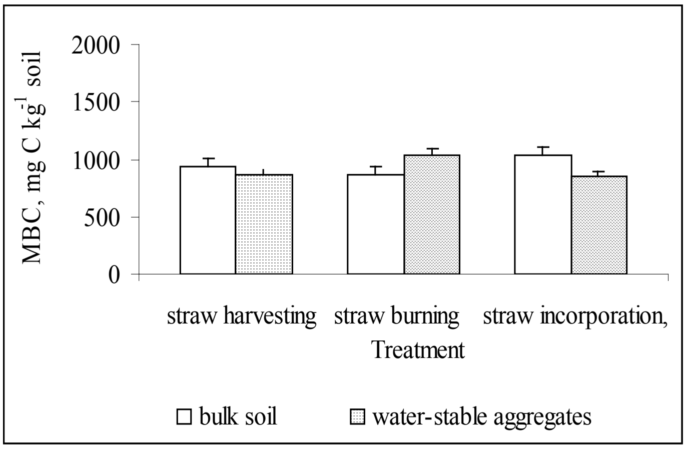

Fig. 2. MBC content in bulk samples and water-stable aggregates of the loam degraded Chernozem at different plant residue practices (bars are standart deviations at P<0,05 and n=3)

However, we observed that the only straw burning treatment contributed to a higher accumulation of MBC in WSA of this soil. This was likely due to that living conditions for soil microorganisms, in terms of quantity and quality of available forms of SOM, were more favorable in WSA of the soil at the straw burning treatment for this soil. The straw burning could improve availability of nutrients and soil pH for microorganisms as well (Chan et al., 2002).

The MBC content in the clayey loam Fluvisol was higher than that in the loam degraded Chernozem because of differences in soil texture. There was a greater contribution of the straw incorporation treatment to the accumulation of MBC in WSA, compared to effects of other treatments (Fig. 3).

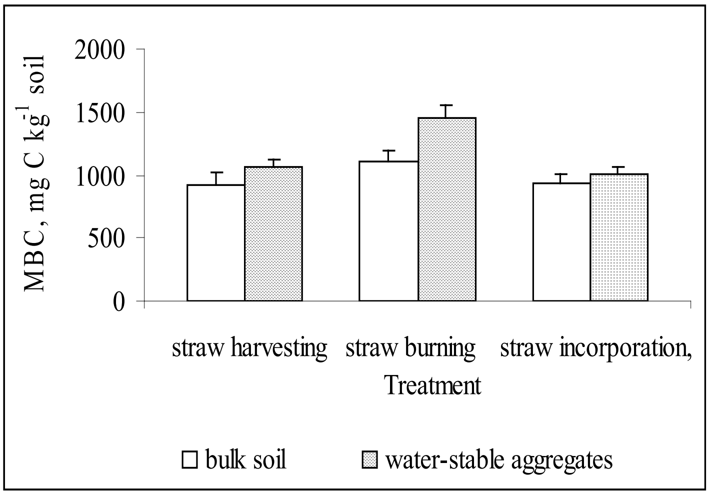

Fig. 3. MBC content in bulk samples and water-stable aggregates of the clayey loam Fluvisol at different plant residue practices (bars are standart deviations at P<0,05, n=3)

In contrast to the loam degraded Chernozem, a greater accumulation of MBC was observed in WSA of the clayey loam Fluvisol at any of the studied plant residue treatments. However, the highest content of MBC was in WSA at the straw burning treatment. Hence, this treatment was the most favourable one for accumulation of MBC in WSA of both soils. Perhaps the above-mentioned increase in amount of 0,25-1,0-mm WSA was caused by the highest accumulation of MBC in WSA at the straw burning treatment for both soils.

Conclusions

The straw harvesting, incorporation and burning treatments did not result in significant differences of total amount of WSA in the clayey loam Fluvisol and loam degraded Chernozem. The straw incorporation treatment, compared to other ones, showed a greater contribution to an improvement of water-stable aggregation of both soils. This treatment also led to a greater increase in amount of large (1,0-10,0-mm) WSA, whereas the straw burning one led to a higher increase of small (0,25-1,0-mm) WSA in both soils.

The straw harvesting, incorporation and burning treatments also did not result in significant changes in SOM content in both soils. However, in terms of accumulation of MBC and relevant water-stable aggregation, the straw burning treatment can be regarded as a more favourable one for the clayey loam Fluvisol. In the loam degraded Chernozem, the straw incorporation and burning treatments showed a favorable influence on the MBC accumulation.

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WEED SPECTRUM CHANGE WITH NO TILL TECHNIQUE

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Abstract
The no-till technique brings about new challenges and odds for researchers and farmers. Our field trial has shown that it creates a new physical environment for plant characterized by higher soil compaction due to rainfall and natural soil compaction when not disturbed. These new conditions have changed the weed spectrum as well. Usual weeds like: Amaranthus retroflexus, Chenopodium album, Setaria glauca, Digitaria sanguinalis that are confined to a loosened soil disappeared and other species appeared: Erigeron canadensis, Cynodon dactylon, Crepis foetida and others.
The paper presents an assessment of weed spectrum in no till treatment in comparison with plow.

Introduction

The last decades have recorded a huge interest in conservation agriculture techniques, due to their paramount advantages:
- fuel savings
- soil fertility preservations.

The less disturbance of soil involves changing in its physical, chemical and biological properties, which need long term experiments and determinations (B.D. Soane, 1993). Elliot E.T. and Colleman D.C. (1988) show that the corn plant growth is severely impeded over 1.55 g cm^{-3} bulk density. This fact means that, generally, the plants need a specific soil bulk density for proper root growth. In this manner they can be grouped in low and high soil bulk density requirements. Within the first group there can be mentioned *Polygonum aviculare*- common knotgrass, *Hordeum murinum*- mouse barley as weeds and *Lolium perene*-ryegrass as crop. The loosened soil is occupied by specific weeds as: *Amaranthus retroflexus* – redroot pigweed, *Setaria glauca*- yellow foxtail, *Chenopodium album* – fat hen. Almost all crops are adapted to loosened soil. Fewer disturbances during the drilling operation is advisable in order not to determine the weed seed to emerge (Sprague M and Triplett G., 1986)
When we first try to crop using no till and have no crop residues upon the soil surface, there is formed a shallow layer of compacted soil because of the wet winter season. This layer is more compacted than the soil below that keeps its natural structure. Due its higher compaction status the soil is occupied by specific weeds. This conditions lead to total failure of the crop because the water from below migrates upward in the shallow, more compacted soil where it simply evaporates in function of the atmosphere water vapor deficit.
Plant residue layer presence upon the soil surface determines the lowering of the soil bulk density due to the better contact between the soil and the water. In such conditions the water drops do not hit the soil directly. In addition, more water into the soil conducts to the intensification of the bacterial activity which has as a consequence the better soil structuration. It means that the presence of the residue layer upon the soil surface is compulsory. Its composition can increase or decrease the nutrient availability for the crop root, especially in function of the nitrogen content.

Material and method

The experiment unfolded at the Research Station of the University of Craiova, Faculty of Agriculture on a sandy soil with the corn crop having the following treatments: no till, shallow plow (up to 20 cm), normal plow (22-25 cm), paraplow, chisel, disc, deep plow (25-30 cm). The surface of a plot was 63 m^2. The basis tillage were made during the fall and the seedbed preparation before planting (5-7 April). The corn planting was performed in the second half of the April with a special seeding machine for no till treatment and by conventional seeding machine for the other treatments. For the tillage plots there was used herbicide Guardian (acetochlor), 1.5 liters ha^{-1} and for the no till variant Icedin (2,4 D and dicamba). The determination of the weeding degree was performed after the corn plants emerged and before harvesting. The plant residues for the no till treatment were chopped using a mechanical chopper and left upon the soil surface. Because of the low quantity of plant and weed residues the surface was not entirely covered in the second or in the third year. Nevertheless, during the third year of the experiment the residue layer has accumulated on 75% of the soil surface and has determined positive results for the corn plants (Dobre M., 2002).

Results

The weeding degree was not high due to herbicides applying. This fact was recorded both for tillage variants and for no till variant.

With the tillage treatments the highest average values were recorded by *Xanthium italicum* (cocklebur) a very easy to control species by dicamba herbicides in corn crop. The presence of this weed is because it can not be controlled by Guardian (acetochlor) herbicide. The postemergent applying of Icedin (dicamba + 2,4 D) has solved the problem. Other recorded weeds in tillage variants were: *Digitaria sanguinalis, Chenopodium album and Amaranthus retroflexus*. However, their number did not impede the normal growth of the crop.

With the no till variant, due to the changed physical conditions the recorded weeds were almost completely changed, too. In this manner, the upward mentioned species for the loosened soil were replaced within the no till variant by: *Crepis foetida, Trifolium arvense, Taraxacum officinale and Erigeron Canadensis*. The only species that survived to the new environment, more compacted was *Cynodon dactylon*.

These new species were all killed by the postemergent herbicide Icedin (dicamba + 2,4 D). The herbicides that can be applied to the corn crop in postemergence have a very wide controlling spectrum; they can kill not only dicots like the above species but monocots like *Sorghum halepense* and *Cynodon dactylon* that were menacing the corn crop not long ago. Moreover, the genetically modified corn for using glyphosate can be grown in many countries and despite local quarrels it will be grown all over in the future.

For the time being this kind of corn can not be grown in Romania although it could be grown legally few years ago!!!

The next table shows the number of the weeds per treatment and the average. It also comprises the participation (P%) to the total weed number as well as the constancy (K%) that means in how many treatments a certain weed was present.

Table 1

The weeding degree recorded at 23 of June at the corn crop
in several tillage treatments

Species	Phase/ Height	Biol. cat.	Treatments						Average	P%	K%
			1	2	3	4	5	6			
Erigeron Canadensis	B/25	Adw	5	-	-	-	-	-	0.8	0.8	16
Sysimbrium Sophia	D/30	Adc	3	-	-	-	-	-	0.5	0.5	16
Crepis foetida	B/15	Adw	54	-	-	-	-	-	9	9.6	16
Cynodon dactylon	B/15	Pmw	12	22	-	25	-	-	6	6.0	48
Xanthium strumarium	B/25	Adw	5	75	58	53	24	36	42	42.3	100
Digitaria sanguinalis	B/15	Amw	-	12	14	24	16	21	14.5	14.6	84
Setaria glauca	B/15	Amw	-	21	9	15	8	10	10.5	10.5	84
Sonchus arvensis	C/30	Pdc	-	6	-	5	-	-	2	2	33
Trifolium arvense	D/20	Adc	25	-	-	-	-	-	4	4	16
Chenopodium album	B/25	Adc	-	13	6	4	7	5	6	6	84
Amaranthus retroflexus	B/25	Adw	-	8	2	4	5	6	4	4	84
Total			104	157	99	131	60	78	99.3	100	

Conclusions

1. The new environment created by the no till technique determines the changing of the almost all weed spectrum.
2. The species adapted for the loosened soil, Digitaria sanguinalis, Chenopodium album, Amaranthus retroflexus, Xanthium strumarium, Setaria glauca are replaced by species that are adapted for more compacted soil as: Crepis foetida, Trifolium arvense, Taraxacum officinale and Erigeron Canadensis.

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STATUS OF EARTHWORM POPULATIONS AFTER DIFFERENT COMPACTION IMPACTS AND VARYING SUBSEQUENT SOIL MANAGEMENT PRACTICES

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Abstract

In a field trial on a deep cambisol (20% clay, 26% silt, 1.4% org. C) in Zurich-Reckenholz, Switzerland, compaction treatments with differing subsequent mechanical soil loosening were installed to investigate the importance of soil management practices on the extent of structural regeneration. The aim of this field trial is to study the functional relationships between soil structure, soil environment and the amount, composition and activity of soil organisms.

For this purpose three main treatments were installed: 1) one single compaction at the start of the experiment and 2) annually repeated compaction, both followed by natural regeneration without mechanical loosening, and 3) one single compaction at the start of the experiment followed by annual plough tillage.

Each of these treatments is managed under actual weather conditions as well as with irrigation in order to identify consequences of compaction more clearly. The crop sequence is maize, wheat, barley and ley.

Earthworm populations were investigated in the third year of the field trial, i.e. 1) three years after a single compaction and 2) after three years with annually repeated compaction, both without mechanical loosening, and 3) three years after a single compaction and subsequent annual ploughing and seedbed preparation. Earthworms were sampled by hand sorting in the topsoil and formalin extraction in the subsoil. Earthworm biomass and abundance of earthworm species as well as the affiliation to ecological groups were determined.

Earthworm biomass in the topsoil did not differ between treatments, but earthworm biomass extracted from subsoil and total biomass did. Abundance of earthworm species as well as of ecological groups differed between the treatments. More differences could be identified by comparing subplots under actual weather conditions and with irrigation.

1 Introduction

Arable land use by mechanised management systems may enhance the risk of soil compaction. This is due on the one hand to intensive wheeling of soils with heavy and powerful machinery and, on the other hand, by the use of deep reaching or intensively rotating tillage implements in the soil, both possibly under weak soil conditions. In order to maintain a good soil structure with a good soil tilth regardless of occasional compaction events, the activity of structure forming processes has to be supported. Only by enhanced regeneration capacities soil structure – and therefore soil quality as well - can be maintained in a good state, making the support of structure forming processes an important part of sustainable soil management.

Soil compaction results in the killing of many earthworms and the destruction of their tunnel structure by direct physical impact (Whalley et al. 1995). The full recovery of a damaged earthworm population may need several years (Syers and Springett 1984).

In a laboratory experiment Joschko et al. (1989) investigated the influence of *L. terrestris* on soil bulk density in compacted soil columns. The cast of this earthworm species had significant lower bulk density than the compacted soil. The ability of earthworms to burrow in compacted soils is very important for plant growth because roots can use these biopores to reach deeper layers (Bieri & Cuendet 1989, Syers & Springett 1984, Whalley et al. 1995). However, in a compacted soil the activity of earthworms is affected (Jégou et al. 1998, Langmaack et al. 1999b, Söchtig & Larink 1992). Because in compacted soils the burrowing activity requires more energy and at the same time oxygen supply is reduced, the earthworms reduce their activity in order to save energy (Langmaack et al. 1999b).

In a long-term field trial on a deep cambisol in Zurich-Reckenholz, in the north-eastern part of Switzerland, compaction treatments with differing subsequent mechanical soil loosening were installed to investigate the importance of soil management practices on nutrient cycling, microbial soil properties and the extent of structural regeneration.

In the autumn of 2007, three years after the implementation of the compaction treatments, earthworm populations were assessed in the experimental plots. The aim of this study was to investigate the medium-term influences of soil structures with different compaction status on earthworm populations and to study the relationships between soil structure and the size and composition of earthworm populations.

2 Materials and methods

2.1. Site characteristics, treatments and experimental design

Details of the experimental design and the applied treatments can be found in Weisskopf et al. (2006). The field trial COREBA (COmpaction, REgeneration and Biological Activity) was installed in 2004 at Agroscope Reckenholz-Tänikon Research Station ART in Zurich-Reckenholz on 443 m above sea level. The soil is a deep gleyic cambisol with a loamy texture and a low stone content (2 vol.%); table 1 shows the principal characteristics of the experimental site.

Table 1: Site characteristics of the experimental field COREBA

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

Weather characteristics	2004	Long term mean[1)]
Precipitation [mm]	976	1042
Temperature [°C]	9.6	8.5

[1)] average for 1961-1990

On the field plots seven experimental compaction/regeneration-treatments were installed by combining mechanical impacts and tillage/seeding techniques. The intention was to create a field experiment in order to monitor the impact of single and multiple compaction events and subsequent mechanical and natural regeneration respectively on soil physical and microbial properties and on soil environmental conditions. Within the four-year crop rotation maize, wheat, barley and ley were cultivated. Three main treatments were established with a single or annually repeated compaction of the whole surface by wheeling the plot track by track using a tractor-trailer combination. The aim of this procedure was to create a homogeneous distribution of the mechanical impacts on the whole plot area and to restrict compaction to the topsoil layer. The compaction treatments were combined with exclusively natural or with both mechanical loosening (plowing and rototilling) and natural regeneration using standard agricultural procedures and machinery (tab. 2). No-till equipment was used as seeding technique to install crops on all experimental plots without mechanically disturbing the structural state of a previously compacted soil. Each of these main treatments was carried out under actual weather conditions as well as with irrigation in order to increase the effect of

altered physical soil properties on the soil environment and to facilitate the detection of soil environmental conditions limiting biological activity.
The field experiment COREBA started in 2004 on an arable field with silage maize (*Zea mays L.*) as first crop on plots without any specific compaction. The differentiation between the compaction/regeneration treatments started in autumn 2004 after the harvest of maize. After installation of the treatments, winter wheat (*Triticum aestivum L.*) was sown as main crop for 2005. With the exception of the specific experimental procedures “compaction” and “tillage/seedbed preparation”, the agricultural management of the experimental plots was identical, especially regarding fertilization, crop protection and harvesting operations.
The experimental design consists of seven treatments without field repetitions but with two subplots in each treatment plot for repeated measurements and samplings.

Table 2: Experimental treatments in the field experiment COREBA.

Treatment code	Compaction[A)]	Regeneration[B)]	Irrigation[C)]
C0	none	mechanically and naturally	no
C1	once[1)]	mechanically and naturally	no
C1i	once[1)]	mechanically and naturally	yes
C2	once[1)]	only naturally	no
C2i	once[1)]	only naturally	yes
C3	every year[2)]	only naturally	no
C3i	every year[2)]	only naturally	yes

A) whole surface, track by track, multiple passes
B) “mechanically” = ploughing and seedbed preparation; “naturally” = by physico-chemical processes, roots, soil organisms
C) during vegetation period under drying conditions (soil moisture above field capacity)
1) at the beginning of the experiment after harvest of maize 2004
2) every year after harvest in late summer/autumn

2.2 Characterization of physical properties, extraction and determination of earthworms
Three to four times per year (spring, early summer before harvest, late summer after harvest/compaction, autumn after sowing the next years main crop), structural properties of the top- and the subsoil were investigated in the soil layers 9 to 15 and 34 to 40 cm. Macropore volume, total pore volume and bulk density are determined from the same cylindrical soil samples of 100 mm diameter and 60 mm height. Macropore volume was analysed conventionally by weighing the soil samples after saturation and following desorption to 60 hPa matric potential; total pore volume was calculated from determined particle density and bulk density values; bulk density was determined gravimetrically after drying at 105°C for 24 hours.
In the autumn of 2007, i.e. in the third year of the field trial with ley growing on the plots, earthworms were sampled in an area of 50 cm x 50 cm, first in the topsoil down to 20 cm depth by hand-sorting, subsequently in the subsoil by extraction with 0.5 % formalin-solution according to ISO 23611-1. Four samples were randomly taken per treatment, the whole sampling procedure was completed within 4 days. Adults were determined to species level, juveniles to ecological groups (Cuendet, 1995; Graff, 1953; Herr & Bauchhenss, 1987). For each taxonomic group abundance and biomass were determined.
Data were analyzed statistically with the Software STATISTICA (Version 7; StatSoft Inc., Tulsa, USA) using the non-parametric methods “Kruskal-Wallis ANOVA and Median test” to compare treatment means of abundances (tab. 4), ANOVA and Tukey HSD test to compare means of biomasses (fig. 1) and the “Spearman rank correlation” to correlate variables. Because of the high variability of earthworm data significances with $p < 0.1$ are indicated too.

3 Results

3.1 Soil physical properties

Table 3: Physical properties in the topsoil (9 to 15 cm) of the treatments in the field experiment COREBA 2007.

	C1i	C1	C3i	C3	C2i	C2	C0
Bulk density [g/cm^3]	1.51	1.51	1.65	1.68	1.61	1.59	1.42
Total pore volume [Vol.%]	42.8	42.9	36.9	35.9	39.3	39.3	46.1
Macropore volume pF1.8 [Vol.%]	8.5	9.8	1.6	2.6	4.3	3.5	8.4

Physical properties of the topsoils (tab 3) showed clear effects of the different compaction/regeneration- treatments. Bulk density was highest in the yearly compacted treatments (C3i and C3) and a little lower in the treatments with one single compaction and without tillage (C2i and C2). In the uncompacted control treatment (C0) bulk density was lowest, but in the treatments which were compacted once and afterwards tilled annually (C1i and C1) bulk density was still clearly increased. Total pore volume and macropore volume indicated analogous results to bulk density, with macropore volume showing the most distinctive differences between treatments.

Figure 1: Total biomass [g/m^2] for top- and subsoil (1a) as well as biomass [g/m^2] of ecological groups (adults + juveniles) (1b) in the different treatments with statistical significance of differences between treatments (1c).
Error bars represent standard deviation; significance level: $p < 0.05$.

Fig. 1a

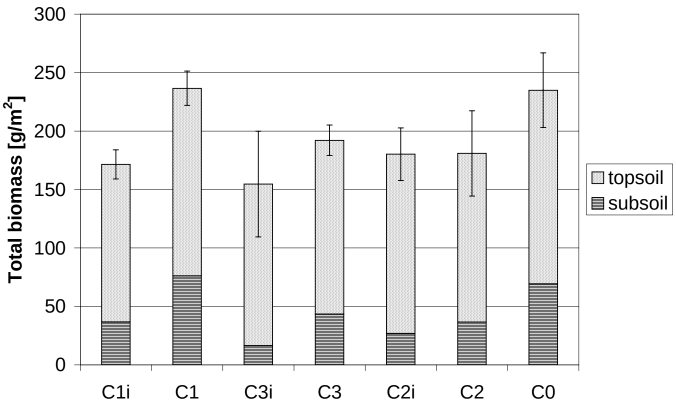

Fig. 1b

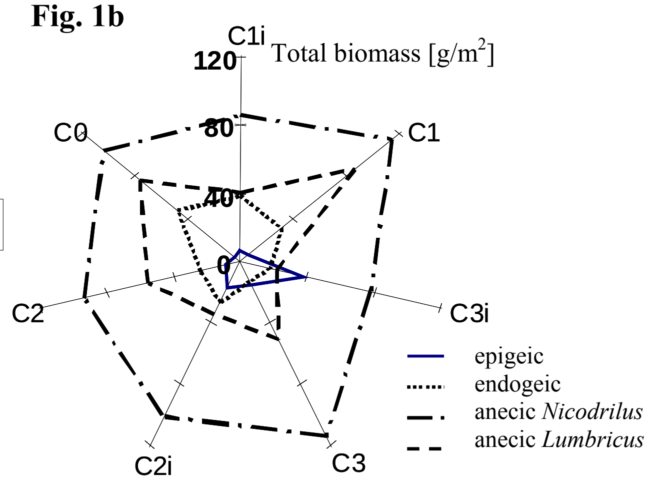

Fig. 1c	C1i	C1	C3i	C3	C2i	C2	C0
epigeic	b	b	a	ab	ab	b	b
endogeic	ab	abc	c	c	bc	bc	b
anecic *Nicodrilus*	a	a	a	a	a	a	a
anecic *Lumbricus*	bc	a	c	abc	c	abc	ab
biomass topsoil	a	a	a	a	a	a	a
biomass subsoil	abc	a	c	abc	bc	abc	ab
total biomass	bc	a	c	abc	abc	abc	ab

3.1 Abundance and composition of earthworm populations in the different compaction treatments

The highest total earthworm biomass was determined in treatments C1 and C0, the lowest in C3i and C1i (fig. 1). Differences between treatments found in the earthworm biomass hand-sampled in the topsoil were not statistically significant, but the earthworm biomass of the subsoil, which was extracted by Formalin and consisted mainly of *L. terrestris*, showed similar significant differences between the treatments as total earthworm biomass (fig 1). In total 10 earthworm species were found. The abundances of several species and of ecological groups differed between treatments (tab. 4), as well as the biomass of ecological groups (fig. 1). The biomass of single species showed the same tendencies as the abundances (data not shown) with statistically significant differences in some cases.

Table 4: Abundance [individuals/m^2] of ecological earthworm groups and species in different treatments of the field experiment COREBA in 2007.

Ecological group, „age" and species	Abundance (individuals m^{-2})						
epigeic	C1i	C1	C3i	C3	C2i	C2	C0
Lumbricus rubellus	8^{a}	4^{a}	**22**$^{\mathbf{a}}$	9^{a}	**14**$^{\mathbf{a}}$	7^{a}	4^{a}
Lumbricus castaneus	7^{ab}	8^{ab}	**49**$^{\mathbf{a}**}$	**21**$^{\mathbf{ab}}$	9^{ab}	8^{ab}	2^{b**}
Adults total	15^{ab}	12^{ab}	**71**$^{\mathbf{a}**}$	30^{ab}	23^{ab}	15^{ab}	6^{b**}
Juveniles total	15^{a}	31^{a}	**70**$^{\mathbf{a}}$	32^{a}	47^{a}	17^{a}	19^{a}
Sum of epigeic	30^{a}	43^{a}	**141**$^{\mathbf{a}}$	**62**$^{\mathbf{a}}$	**70**$^{\mathbf{a}}$	32^{a}	25^{a}
endogeic	C1i	C1	C3i	C3	C2i	C2	C0
Nicodrilus caliginosus calig.	**53**$^{\mathbf{a}**}$	23^{ab}	27^{ab}	9^{b**}	29^{ab}	12^{ab}	32^{ab}
Aporrectodea icterica	8^{a}	13^{a}	2^{a}	3^{a}	5^{a}	10^{a}	31^{a}
Aporrectodea rosea	3^{a}	1^{a}	1^{a}	3^{a}	5^{a}	4^{a}	2^{a}
Aporrectodea chlorotica	16^{a*}	0^{b*}	8^{ab}	2^{ab}	6^{ab}	1^{ab}	4^{ab}
Octolasion cyaneum	1^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}
Adults total	81^{a**}	37^{ab}	38^{ab}	17^{b**}	45^{ab}	27^{ab}	69^{a**}
Juveniles total	125^{a*}	109^{ab}	47^{ab}	41^{b*}	109^{ab}	97^{ab}	123^{a*}
Sum of endogeic	**206**$^{\mathbf{a}*}$	146^{ab}	85^{b**}	58^{b*}	154^{ab}	124^{ab}	**192**$^{\mathbf{a}**}$
anecic *Nicodrilus*	C1i	C1	C3i	C3	C2i	C2	C0
N. nocturnus	18^{a}	17^{a}	11^{a}	22^{a}	9^{a}	6^{a}	14^{a}
N. longus longus	14^{a}	8^{a}	13^{a}	5^{a}	6^{a}	3^{a}	6^{a}
Adults total	32^{a}	25^{a}	24^{a}	27^{a}	15^{a}	9^{a}	20^{a}
Juveniles total	59^{b*}	133^{ab}	82^{ab}	141^{ab}	145^{a*}	127^{ab}	93^{ab}
Sum of anecic Nicodrilus	91^{a}	128^{a}	106^{a}	168^{a}	160^{a}	136^{a}	113^{a}
anecic *Lumbricus terrestris*	C1i	C1	C3i	C3	C2i	C2	C0
Adults	10^{ab}	14^{ab}	4^{b*}	10^{ab}	6^{ab}	8^{ab}	**16**$^{\mathbf{a}*}$
Juveniles	5^{b*}	26^{ab}	6^{ab}	10^{ab}	15^{ab}	29^{a*}	14^{ab}
Sum of anecic *L. terrestris*	15^{ab}	**40**$^{\mathbf{a}**}$	10^{b**}	20^{ab}	21^{ab}	37^{a**}	30^{ab}
	Significance level: $^{*} = p < 0.1$; $^{**} = p < 0.05$						
	low abundance			**high abundance**			

The abundance and biomass of epigeic species was high in treatments C3i and C3 which were compacted every year as well as in treatment C2i. In contrast the abundance and biomass of endogeic species showed lowest values in the annually compacted treatments C3i and C3. Dominant species of this ecological group were *N. caliginosus caliginosus* and *A. icterica.* Some species of the endogeic group showed no or only slightly differences between treatments, therefore the dominant species were the main reason for the differentiation between treatments. Likewise juveniles of endogeic species were rarely found in C3i and C3 compared to other treatments. In the anecic group only *L. terrestris* showed significant

differences between treatments: *L. terrestris* adults were most frequent in C0 (control treatment) and C1 (single compaction), whereas only 4 individuals m^{-2} were found in treatment C3i (tab. 4). Biomass of *L. terrestris* (including juveniles) was highest in treatment C1 and lowest in C3i (fig. 1).
Additionally abundance and biomass data are suggesting that irrigation of the experimental plots had specific impacts on earthworm species compared to non-irrigated plots. Total earthworm biomass generally was higher in non-irrigated than in irrigated plots (fig. 1a). In detail, abundance (tab. 4) and biomass (data not shown) of *L. rubellus, N. caliginosus caliginosus, A. chlorotica* and *N. longus* were higher in irrigated-plots, whereas *A. icterica* and *L. terrestris* values were higher in non-irrigated-plots; however, these are trends without statistical significance.

3.2 Correlations between earthworm populations and parameters of soil structure
Correlation between earthworm biomass and soil bulk density in the topsoil (9 to 15 cm) was clearly (and mostly significantly) positive for epigeic adults and juveniles (tab. 5). No clear correlation was found for *N. nocturnus, A. rosea and A. chlorotica,* whereas the biomass of all the remaining species was negatively correlated with bulk density in the topsoil; however, only data of *A. icterica* and endogeic juveniles were statistically significant (tab. 5). All these correlations between earthworm biomass and bulk density can also be found - with a similar absolute value of the correlation coefficient - for macropore volume and total pore volume respectively, but of course with the opposite prefix (data not shown).
Correlation between total earthworm biomass and yield data 2007 was significantly positive (p < 0,05). Furthermore, correlations between earthworm biomass of single ecological groups and the yield data 2007 showed a significantly positive correlation for *L. terrestris* adults (p < 0.05) and a significantly negative correlation for epigeic adults. Biomass of endogeic adults as well as of anecic *Nicodrilus* were positively correlated with yield data, but without statistical significance.

Table 5: Correlation between soil bulk density in the topsoil (9 to 15 cm) and earthworm biomass [g/m^2].

Adults	
Lumbricus rubellus	**+0.79****
Lumbricus castaneus	**+0.71**
Aporrectodea icterica	**-0.86****
Nicodrilus nocturnus	**0.00**
Lumbricus terrestris	**-0.57**
epigeic	**+0.86****
endogeic	**-0.89****
Juvenils	
epigeic	**+0.82****
endogeic	**-0.93****
Significance level: ** = p < 0.05	

4 Discussion

The results of the physical soil analysis in the treatments of the COREBA field trial confirm considerable effects of the different compaction/regeneration-treatments on soil structure. This situation allows to investigate the consequences of these differently compacted soils on biological soil properties.
The track to track-topsoil compaction of the whole plot area in the model experiment COREBA showed adverse effects on total earthworm biomass in the repeatedly compacted treatment (C3), especially combined with irrigation (C3i). On the other hand the treatment with single compaction at the start of the experiment, regular tillage in the following years and without irrigation (C1) showed almost the same earthworm biomass as the regularly tilled control treatment without intentional compaction (C0). However, irrigation of this treatment with single compaction and repeated tillage (C1i) reduced earthworm biomass significantly. At the moment we can only hypothesize about the reasons for this observation. According to our data on soil structure the effect of irrigation on earthworm biomass may be an indirect one, caused by the unfavourable influence of irrigation on the soil environment. In the irrigated treatments situations with very low O_2- and high CO_2-concentrations in the soil air

are more frequent than in the compacted but not irrigated treatments (Weisskopf et al. 2006). Biomass and abundance of all earthworm groups and species indicated that three years after a single compaction all these populations were not disturbed or did already regenerate. These results suggest that a single compaction followed by careful soil cultivation does not necessarily lead to medium-term damages of the earthworm populations. In a 3 year experiment with one compaction event in the first experimental year Langmaack (1999a) investigated the evolution of earthworm populations. It was only in the year of compaction that he found a significant reduction of earthworm abundances in the compacted treatment. In the following years, as in our field trial, no differences to the uncompacted control could be determined anymore, suggesting an elevated potential of earthworm populations to regenerate after a single compaction incidence.

A closer look revealed that the treatments affected ecological earthworm groups and earthworm species differently. High abundance and biomass especially in the repeatedly compacted plots as well as positive correlation with soil bulk density indicate that epigeic species benefited from the increased compaction level of soil structure. In contrast most of the endogeic species as well as *L. terrestris* were adversely affected by the permanently compacted topsoil. One reason for this effect may be the interspecific competition for food: The low abundance of *L. terrestris,* especially in treatment C3i, probably reduced the competition for organic matter, resulting in relative advantages for epigeic species and accordingly in higher frequencies (Lowe and Butt 1999). Another reason could be that in these treatments the rooting zone was concentrated in the top 5 cm of the soil, the living space of the epigeic species.
However, the correlations between earthworm biomass and parameters of soil structure which were found in this study cannot reveal causality: High earthworm biomass in plots with low bulk density may be attributed on the one hand to the potential of earthworms to regenerate a compacted soil structure (earthworms as actors), or on the other hand it may simply be an indication of a more favourable environment for the earthworms, which was caused by other processes (earthworms as indicators).

It is well known that earthworms may have effects on plant growth in many different ways. The plant roots can benefit directly from the burrowing activity of earthworms by growing in their tunnels, allowing them to penetrate easier and more deeply into the soil (Syers and Springett 1984). In this study plant yield was higher in treatments with high biomass of earthworms, whereupon *L. terrestris* had the greatest influence. But again it is not clear if these are only incidental statistical correlations or whether these correlations are reflecting true causal relationships: Whether both roots and earthworms are benefiting from favourable soil structures, or whether roots and earthworms (especially *L. terrestris*) have contributed separately or interactively to the improvement of the soil structure in this field trial, cannot be decided based on these data.

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BIOPREPARATIONS AND THEIR INFLUENCE ON THE YIELD AND OTHER CHARACTERISTICS OF WINTER WHEAT UNDER DIFFERENT STAND ESTABLISHMENT

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Abstract

Three soil tillage practices were used in four-year field experiments: a) *conventional tillage*, b) *no-tillage,* c) *minimum tillage*. Biopreparations used in small parcel experiments were as follows: Supresivit (with effective fungus *Trichoderma harzianum*), Ibefungin (effective bacteria *Bacillus subtilis*) and Polyversum (with effective fungus *Pythium oligandrum*). The biopreparation above mentioned applied as a seed treatment or as fertilizer fungi (mixture of biopreparation and ammonium nitrate) were compared with control variant where the seeds were treated by chemical dressing Celest Extra. The influence of biopreparation use on grain yield of winter wheat in individual soil tillage treatment was statistically evaluated. No significant yield differences were recorded among method of stand establishment owing to biopreparation application. The results obtained from testing of Supresivit homogenized with the seed in form of seed-treatment were statistically significant comparing to non-treated control.The application of biopreparations caused not only increase of yields but also improved of the health state of the plants observed. The biofungicides, which were used in this experiment, depress phytopathogenic fungi, especially the genus *Fusarium* and due to this property of the active component the health state of winter wheat plants was better.

Key words: winter wheat, different soil tillage, biopreparations, yield

Introduction

In the current conditions of market economy the effective cultivation of field crops needs such cropping methods which lead to sufficient incomes and to desired quality production as well. The use of biofungicides is one of the possibilities how to get closer to this goal because these preparations, which except positive effect on health state of stands, improve the nutrients supply and increase effectiveness of the application mineral fertilizers into the soil. The basic principle of the biofungicides use is to depress parasitic soil microflora by natural impacts of antagonistic microorganisms. To contribute to crop production enhancement in conservation growing systems and increase the soil quality by the way of biopreparation effectiveness against soil-borne phytopathogenic fungi was the aim of our study. Debode et al. (2005) discovered the mechanisms of *Verticillium* control in soil by means of microbial antagonists which were supported by crop residues and lignin incorporation. The positive effect of the combination on grain yield, stability of grain quality and improvement of plant health were recorded. The combination also contributed to better nutrient management in case of mineral nutrients simultaneously applied.

Good health state of crop stands leads to good yield level, less costs for growing technology and higher profitability of crop production (Javůrek et al, 2005, Hýsek et al., 2005). Tambong et al. (2005) was engaged in similar problems. He studied populations of *Pythium* in

compacted and non compacted soil by PCR method and he found out that *Pythium* number increased in compacted soils.
Many published results show the possibilities of non chemical methods utilization for inhibition of soil-borne diseases with contemporary decrease of chemical fungicide use. Our study should append further knowledge to this problems.

Material and methods

The data have been acquired from four-year field trial established at experimental site located in the sugar beet production-type on luvisol, medium-heavy soil. This experiment was established as a rotation of three crops: pea, winter wheat, and spring barley. The important up-to-date soil tillage methods in the Czech farming practice were used in field experiments:

a) conventional tillage technology (including ploughing, current seed-bed preparation, sowing)
b) no tillage technology (including drilling into non-tilled soil covered with mulch)
c) minimum tillage technology (i.e. mid-deep (10–12 cm) loosening and chopped straw of pre-crop incorporation into the soil).

All variants were sown by John Deere 750A drill machine. Variety Ebi of winter wheat was used.

Biopreparations used in small parcel experiments were as follows: Supresivit (with effective fungus *Trichoderma harzianum*), Ibefungin (effective bacteria *Bacillus subtilis*) and Polyversum (with effective fungus *Pythium oligandrum*).

Two different ways of biofungicides application were used: on the one hand the biofungicides were homogenized directly with the seed (seed-treatment) and on the other hand the biofungicides were mixed with mineral fertilizer ANL (ammonium nitrate with limestone). The variants evaluated were included in the block of conventional soil tillage technology (ploughing, seed-bed preparation, sowing by John Deere 750 seed-machine).

The various fungi were determined from soil extracts which were cultivated on agar medium. We verified the impacts of the microorganisms chosen, contained in the biopreparations used: *Trichoderma harzianum* in Supresivit, *Pythium oligandrum* in Polyversum and *Bacillus subtilis* in Ibefungin. The above-mentioned microorganisms were applied as a seed-treatment and as a mixture with nitrogen fertilizer. The biopreparations (containing microorganisms) were mixed with ANL for winter wheat fertilization.

Variants of winter wheat were as follows:

1. Control with seed-treatment with Celest Extra
2. Celest Extra + fertilizer fungi (ANL + 3 g Polyversum .kg $^{-1}$ of fertilizer)
3. Celest Extra + fertilizer fungi (ANL + 10 ml Ibefungin .kg $^{-1}$ of fertilizer)
4. Celest Extra + fertilizer fungi (ANL + 1 g Supresivit .kg^{-1} of fertilizer)
5. Seed-treatment with 3 g Polyversum .kg^{-1} of the seed
6. Seed-treatment with 10 ml Ibefungin .kg^{-1} of the seed
7. Seed-treatment with 1 g Supresivit .kg^{-1} of the seed

All plots were fertilized by the same dose 100 kg N per ha (divided into 3 doses 40+30+30). The dose of Celest Extra was 1.5 ml.kg^{-1}of the seed. Grain yield of winter wheat and its parameters were determined as well as qualitative characteristics of winter wheat (nitrogen compounds content, volume weight, sedimentation test, viscosity test, falling number).
For statistical evaluation the method of determination of the lowest significant difference for the individual factors was used. Assessment of the impact of different biopreparations on

plant health and the subsequent effects on grain yield, stability of yield components and quality parameters of winter wheat grown in conditions of different soil tillage were the aim of this field experiments.

Results and discussion

In the variants of conventional tillage technology on average of experimental years we found out depression of phytopathogenic fungi, namely the genus *Fusarium*. In comparison with non-treated variants we ascertained the number of micromycetes decrease in soil by about 10-15 % in the variants with biopreaparation treatment.
In the variants established by direct sowing into non-tilled soil with mulch from the straw and post-harvest residues of pre-crop (pea) higher incidence of *Fusarium* pathogens was recorded, especially on plant roots.
In the variants with shallow tillage and organic matter incorporation the highest effect of the biopreparations applied was recorded. The preparations Supresivit in the form of seed-treatment agent (in the mixture with the seed) considerably influenced *Fusarium* occurrence.

In the table 1. grain yield results of winter wheat on average of 4 experimental years were included. The data show the influence of different technologies used, (e.g. conventional soil tillage treatment on the contrary with both types of conservation tillage technology). It is evident that different establishment of stands caused non-significant yield differences (only +0.4 %, resp.+2.5 % yield increase in comparison with conventional tillage treatment).

In the average of the years we found out the highest yield of grain (to 8.05 t. ha^{-1}) in the variant with Supresivit + fertilizer and simultaneously also the highest yield increase in comparison with the variant fertilized and treated only with Celest Extra (0.41 $t.ha^{-1}$, e.g.+ 5.4 %). From the data presented in the table it is evident (regardless of application and tillage method) that the highest yield increase was caused by Supresivit + 5.3.0% followed by Polyversum + 3.4% and Ibefungin + 3.4% compared with fertilized variants but non-treated with biopreparations (only Celest Extra). The effect of biofungicides in the form of fertilizer fungi (var. 2-4) and in the form of seed-treatment (var. 5-7) emerged by grain yield increase (+ 4.0 – 4.1%). Yield differences were also identified among different tillage technologies. If the conventional variant is 100%, then yield in the no tillage variant (2) was 98.1% and in minimum tillage (3) was 97.3 %.

The data obtained were statistically processed with help of analysis of variance and LSD values were determined. From the following table it is visible statistical significancy of individual measured biopreparations on grain yields of winter wheat after different application ways.
In frame of study of biopreparation impact on health state of winter wheat we assessed some qualitative parameters (nitrogen matter content, volume weight, sedimentation test, viscosity test, falling number). On the base of long-term experiments it is visible that in variants with reduced and no soil tillage there was found higher level of nitrogen compounds (14.27 %) as compared to conventional soil tillage (13.15%). The similar results were recorded in gluten content (conventional technology 33.1%; no tillage 38.0 %; shallow tillage 36.8 %). Other parameters were not significantly influenced by different stand establishment.
Comparing reached economic results in studied years, health state of stands, price relations of evaluated biofungicides and incomes of growing technologies of winter wheat stands we calculated the economic effectiveness before the use of particular biofungicides. Their price including application (as seed-treatment agent or in the mixture with mineral fertilizer ANL)

was compared with control chemical seed-treatment of the preparation Celest Extra. Receipts for the addition of grain yields of winter wheat on the variants treated with biopreparations were entirely balanced (and in the year 2007 after rise in market price of winter wheat grains were overstepped), namely in the biopreparations Supresivit and Polyversum. In the last experimental years the economic effect of biofungicide Ibefungin was not significant.

In all variants of field trials the quantity and the spectrum of phytopathogenic fungi in soil and on surface of harvested grain of winter wheat were evaluated. In the variants where biofungicides were applied we found out lower number of fungi of the genus *Fusarium*, except the species *F. oxysporum*, which number non-regularly varied.

On the basis of results obtained we can conclude that the use of chosen biofungicides based on effective antagonistic fungi or bacteria in mixture with seed (in form of seed dressing or in mixture with mineral fertilizer ANL) influenced favourably level of grain yield of winter wheat. The mean yield increase due to application of evaluated biopreparations varied from 4.6 to 5.4%. Regardless of different soil tillage technology of winter wheat we can explain by conclusive depression of soil transferred phytopathogenic microorganisms, especially microscopic fungi infestation of plant roots. On the contrary with non-treated variants we recorded approximately 10 – 15% decrease of CFU number (colony forming units) in the soil. High significance appeared in reduction of the occurrence of phytopathogenic fungi of the genera *Drechslera, Fusarium, Pseudocercosporella* and *Septoria* maintaining their infection potential on plant roots and in soil in the form of conidia and mycelium which cause diseases of plant roots. Namely the genus *Fusarium* survives on plant residues in soil and it is strong depressed by antagonistic fungi and bacteria and its pathogenic effect is strong limited. Before depression of root infestation by above mentioned fungus plant damage was lower and at the same time mycotoxin level in the soil as well. The occurrence of phytopathogenic fungi of the genus *Septoria* on the leaves treated with biofungicides was approximately by 8-10% lower in comparison with non-treated control. By these ways treated and more healthy stands give higher and more quality grain production. Except of favourable economic view there is the most important access for farming practice of these applications of biofungicides the depression of important pathogenic fungi and following maintaining of good health state of cultural plants. The highest increase of yield was in variant 5 (combination ammonium nitrate & limestone with biofungicide Supresivit), comparing with control variant 2 (without biofungicides).

The weight of 1000 kernels was very similar and ranged from 48.9 to 51.3 g. The highest volume weight of winter wheat grain was found in the conventional technology variant (depending on biofungicides 775.2 – 795.6 $g.l^{-1}$), and the lowest one in the direct drilling treatment (depending on biofungicides, as well 741.2 - 783.8 $g.l^{-1}$).

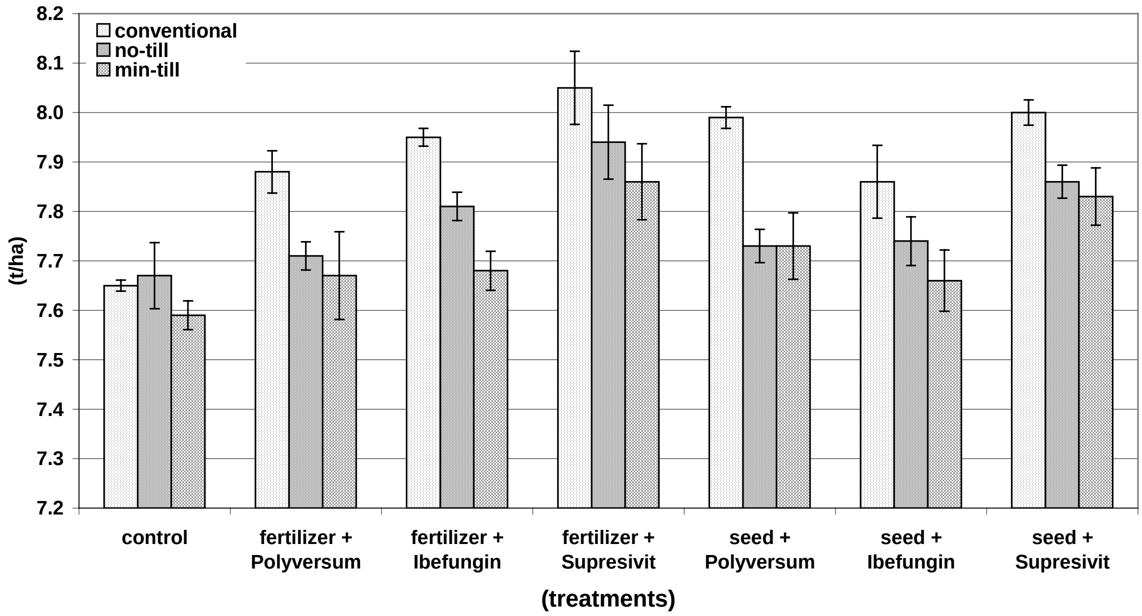
Tab. 1: The grain yields of winter wheat from evaluated variants (4 year average)

Variant		Ways of stand establishment 1 x		2 xx		3 xxx	
		($t.ha^{-1}$)	(%)	($t.ha^{-1}$)	(%)	($t.ha^{-1}$)	(%)
1.	control – Celest Extra, ANL	7.64	100.0	7.50	100.0	7.44	100.0
2.	ANL + Polyversum	7.88	103.1	7.71	102.8	7.67	103.1
3.	ANL + Ibefungin	7.94	103.9	7.81	104.1	7.68	103.2
4.	ANL + Supresivit	8.05	105.4	7.94	105.9	7.86	105.6
5.	seed + Polyversum	7.99	104.6	7.73	103.1	7.73	103.9
6.	seed + Ibefungin	7.85	102.7	7.74	103.2	7.66	103.0
7.	seed + Supresivit	8.00	104.7	7.86	104.8	7.83	105.2
Mean grain yield:		**7.91**		**7.76**		**7.70**	
The effect of biopreparates:			**104.1**		**104.0**		**104.0**
The effect of stand establishment:		**100 %**		**98.1%**		**97.3%**	

x) Methods of stand establishment for winter wheat:

1. Conventional tillage
2. No tillage - direct sowing into untilled soil, covered with mulch
3. Minimum tillage - sowing into shallow tilled soil, with chopped of pre-crop straw incorporated

Fig. 1: The influence of soil tillage and biopreparation applied on grain yield of winter wheat (average of years 2004-2007)



In the fig.1 it is visible lower yield of the control with fertilization in comparison with the variants of biopreparations and fertilizer mixtures and seed treatment with biopreparations (about 4 %).

The lowest significant difference

* identifies significantly different pairs. Homogenous sub-groups are in vertical columns

Group	Cases	Average	1	2	3	4	5	6	7
Control (1)	48	7.5260		*	*	*	*	*	*
Seed + Ibefungin (2)	48	7.7504	*					*	*
Fertilizer + Polyversum (3)	48	7.7515	*					*	*
Fertilizer + Ibefungin (4)	48	7.8075	*						*
Seed + Polyversum (5)	48	7.8160	*						
Seed+Supresivit (6)	48	7.8969	*	*	*				
Fertilizer + Supresivit (7)	48	7.9502	*	*	*	*			

Minimum difference: 0.152

For grain yield; devided by soil tillage

* identifies significantly different pairs. Homogenous sub-groups are in vertical columns

Group	Cases	Average	Min-till	No-till	Conventional tillage
Minimum tillage	112	7.6935			*
No-tillage	112	7.7537			*
Conventional tillage	112	7.9094	*	*	

Minimum difference: 0.083

Our results with biofungicides documented that these preparations could have significant influence on stand health of field crops in protection systems of crop growing under conservation soil tillage technologies where the risk of infection can be far higher than in conventional ploughing system of plant production.

The application of biopreparations (Supresivit, Polyversum and Ibefungin) caused suppression of fungi of the genus *Fusarium*. There is only little knowledge about this topic. Different ways of soil tillage technologies specifically influenced the composition of soil mycoflora. In the variant with direct drilling the highest number of the genus *Fusarium* was found out. Reduction of fungal occurrence of the genus *Fusarium* and *Rhizoctonia* showed big importance for the maintaining their infection soil potential in the forms of conidia and mycelium, which occur on plant roots, invading the roots and causing t disease (Hýsek, Vach, Javůrek, 2005). The decrease of occurrence was found after the infection with phytopathogenic fungi *Pyrenophora* and *Septoria* - their species caused leaf area damaging. We confirmed the fact that antagonistic fungi help to depress the populations of phytopathogenic fungi and maintain quantitative equilibrium of saprotrophic and phytopathogenic fungi.

From research results and experience from farming practice it is known that conservation tillage technologies of crop growing save the direct costs, decrease fuel consumption, labour costs and abbreviate the sequence of working operations for stand establishment of field crops. In some cases these advantages and savings can be eliminated by higher requirement of fungicides due to higher occurrence of plant diseases. Utilization of biofungicides, which are able to suppress some significant pathogenic fungi, could improve the economic balance of conservation soil tillage methods for field crop growing and could be more friendly to the environment.

Conclusions

1. The research results on utilization of chosen biofungicides for winter wheat protection in conditions of conventional, minimum and no till methods of soil tillage for stand establishment showed the favourable significant influence on health of treated stands.
2. Better health state of plants influenced on higher grain yield of winter wheat was in treated variants.
3. As for winter wheat the highest yield effect was found in combination ANL + Supresivit (+ 5.6 % comp. to control). Differences among treated variants and control were statistically significant.
4. Utilization of efficacious biofungicides could partial substitute the expensive chemical disease control and consequently it could improve economic balance, especially of conservation soil tillage technologies where the infection probability was far higher through organic matter supply on soil surface or shallowly incorporated.
5. Decrease of chemicals application due to biopreparation use in growing technologies of field crops conduces to environment improvement.

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THE IMPACT OF LONG-TERM MONOCULTURE AND NORFOLK CROP ROTATION ON WEED INFESTATION OF SPRING BARLEY

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Abstract

The influence of crop rotation and soil tillage on weeds was observed on experimental field station in Žabčice, South Moravia region, Czech Republic. Spring barley was grown in long-term monoculture and in Norfolk crop rotation. In both cases there were used two variants of soil tillage: conventional with depth of tillage 0.22 m (CT) and minimum tillage (MT) where shallow loosening (discs) was used to the depth of 0.12 m. Results of the CCA showed that Cirsium arvense and Stellaria media were more often on variant with minimum tillage. Conventional tillage was connected with higher occurrence of Fallopia convolvulus, Silene noctiflora, Sinapis arvensis and Veronica polita. On variant where spring barley was grown in monoculture there were more common Cirsium arvense and Galium aparine. Amaranthus sp., Chenopodium album and Lamium purpurem were more frequent weeds in spring barley which was grown in Norfolk crop rotation.

Keywords: weeds, soil tillage, crop rotation

Introduction

Weed community is influenced by many factors which affect each weed species in a different way. Among factors, which can be influenced by man, belong tillage and crop rotation. Mostly in last years there are significant changes in crop rotation. Range of grown crop plants has been reducing and prevailing crop is very often winter wheat. Also tillage is developing mainly towards minimum soil tillage which is economically consumptive. Both these trends can affect weed spectrum in different crop stands.

Material and methods

The influence of crop rotation and soil tillage on weeds was observed on a field experimental station of Mendel university of agriculture and forestry Brno. The field experimental station is situated in Žabčice (South Moravia region, Czech Republic) in a very hot and dry climatic region of maize producing area. The long-term average of annual precipitation is 481 mm, the long-term average temperature is 9.2°C. Clayey loam gleyic fluvisol soil type is on the experimental field. Spring barley was grown in two variants of crop rotation. The first variant is long-term monoculture of spring barley established in 1970. In the second variant there is spring barley grown in Norfolk crop rotation (red clover, winter wheat, maize, spring barley). On both variants were used these variants of tillage: conventional with depth of tillage 0.22m and minimum tillage where shallow loosening (disking) was used to the depth of 0.12 m.
Weed infestation of spring barley was evaluating before application of herbicides for three years (13. 5. 2005, 22. 5. 2006, 29. 4. 2007). Numbers of weeds were counted on area of one square meter, in 25 replications on each variant.

Multidimensional analysis of ecological data was used to determination influence of crop rotation and tillage on each weed species. Optimal analysis was chosen in relation to Lengths of Gradient which was determined by Detrended Correspondence Analysis (DCA) and then Canonical Correspondence Analysis (CCA) was used as well. During testing of significant effect by Monte-Carlo test there were counted 499 permutations. Data were processed by computer program Canoco 4.4. (ter Braak, 1998).

Results and discussion

During three years there were found 33 weed species. The average number of species in the year 2005 is in Table 1. In Table 2 there are numbers stated in the year 2006 and in Table 3 there are numbers from the year 2007. The highest number of weeds was determined in the year 2006 (14.70 pc m^{-2}). In the other years differences were not significant, in the year 2005 – 9.56 pc m^{-2} and in the year 2007 – 8.59 pc m^{-2}.

The highest numbers of weeds of all species were determined on variant with monoculture and conventional tillage. On variant with Norfolk crop rotation there were relatively small differences in numbers of weeds on both variants tillage and they were changing during the observed years.

Results of CCA are in Figure 1. This Figure shows that on variant with minimum tillage were more often *Cirsium arvense*, *Sonchus oleraceus*, *Stachys palustris* and *Stellaria media*. On variant with conventional tillage rose mainly *Anagallis arvensis*, *Fallopia convolvulus*, *Persicaria lapathifolia*, *Silene noctiflora*, *Sinapis arvensis, Tripleurospermum inodorum*, *Veronica polita* and *Viola arvensis*.

On variant with monoculture of spring barley appeared mainly *Cirsium arvense* and *Galium aparine.* On variant where barley is grown in Norfolk crop rotation there were more common *Amaranthus sp.*, *Chenopodium album*, *Chenopodium hybridum*, *Lamium purpureum*, *Sonchus oleraceus*, *Trifolium pratense* and *Thlaspi arvense.*

Consolida orientalis, *Convolvulus arvensis*, *Lamium amplexicaule* and *Plantago major* appeared mainly on variant with minimum tillage and Norfolk crop rotation. On the other hand *Avena fatua*, *Echinochloa crus-galli*, *Hyoscyomus niger*, *Microrrhinum minus* and *Veronica persica* were more common on variant with conventional tillage and monoculture of spring barely. Species *Euphorbia helioscopia*, *Helianthus annuus*, *Lapsana communis* and *Polygonum aviculare* rose mainly on variant with conventional tillage and Norfolk crop rotation.

Table 1. Average number of weed species counted in the year 2005 on variants with crop rotation and soil tillage (pc m^{-2})

Weed species	Variants of crop rotation and tillage			
	Monoculture of spring barley		Norfolk crop rotation	
	Conventional tillage	Minimum tillage	Conventional tillage	Minimum tillage
Amaranthus sp.	0,04	0,08	0,00	0,00
Anagallis arvensis	0,12	0,00	0,00	0,00
Avena fatua	0,00	0,48	0,00	0,00
Cirsium arvense	0,16	0,64	0,40	0,96
Consolida orientalis	0,00	0,00	0,00	0,04
Convolvulus arvensis	0,00	0,12	0,04	0,16
Euphorbia helioscopia	0,00	0,04	0,04	0,00
Fallopia convolvulus	1,40	0,96	0,52	0,12
Galium aparine	3,04	2,72	0,36	1,08
Chenopodium album	0,00	0,04	0,12	0,00
Lamium amplexicaule	0,28	0,68	0,00	0,00
Lamium purpureum	0,00	0,00	0,16	0,08
Microrrhinum minus	1,68	0,04	0,00	0,00
Persicaria lapathifolia	1,04	0,12	0,08	0,04
Plantago major	0,00	0,00	0,00	0,16
Polygonum aviculare	0,04	0,00	0,00	0,00
Silene noctiflora	6,36	0,80	1,04	2,80
Sinapis arvensis	0,04	0,00	0,00	0,00
Sonchus oleraceus	0,12	0,00	0,16	0,04
Stachys palustris	0,00	0,36	0,00	0,00
Stellaria media	0,44	2,72	1,24	0,12
Thlaspi arvense	0,04	0,00	0,00	0,00
Trifolium pratense	0,00	0,00	0,12	0,04
Tripleurospermum inodorum	0,04	0,00	0,04	0,00
Veronica polita	1,96	0,76	0,20	0,64
Viola arvensis	0,08	0,00	0,00	0,00
Average on variant	**16,88**	**10,56**	**4,52**	**6,28**

On variants with minimum tillage and spring barley monoculture there were predominantly species which are not easy to control using herbicides (*Cirsium arvense*, *Galium aparine*, *Convolvulus arvensis*). On variant with conventional tillage there were more common species which can germinate from deeper soil layers (*Fallopia convolvulus*) or which have high number of seeds in the soil (*Silene noctiflora*, *Sinapis arvensis*). On variant with Norfolk crop rotation there were mainly species which appear mainly in root crops or in red clover (*Amaranthus sp.*, *Chenopodium album*, *Chenopodium hybridum*, *Trifolium pratense*, *Thlaspi arvense*).

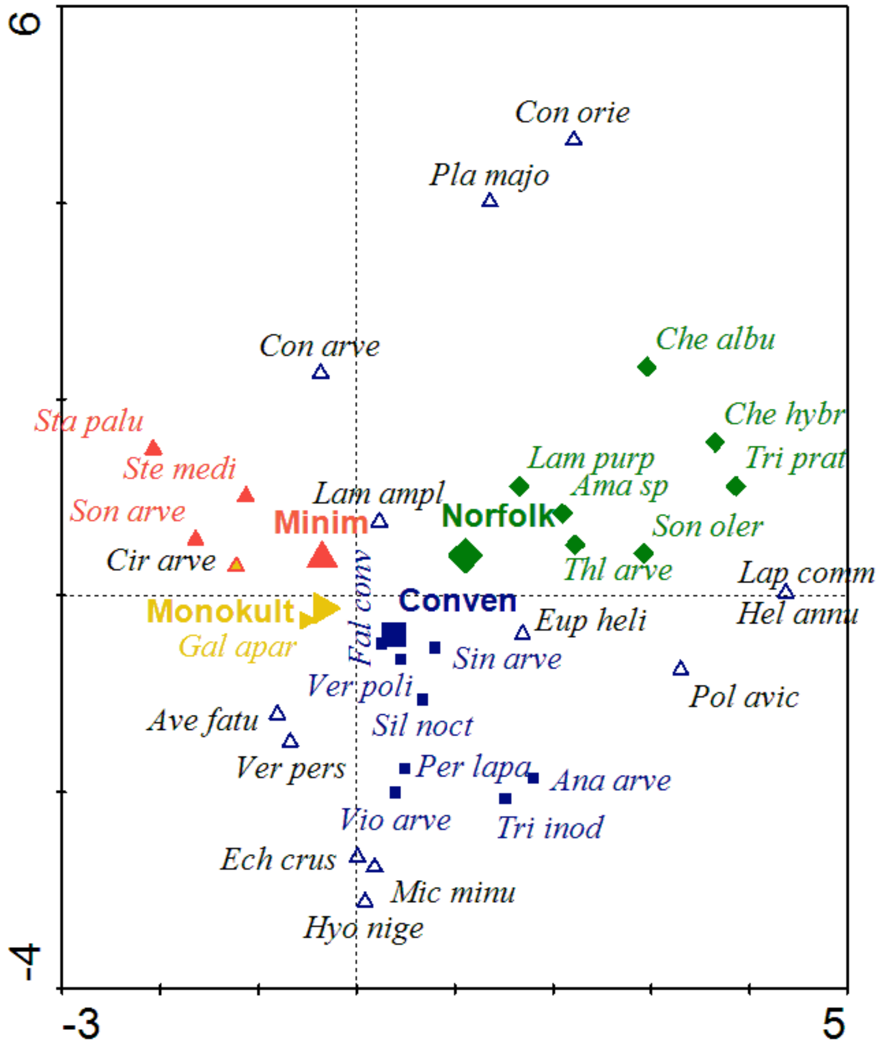
Table 2. Average number of weed species counted in the year 2006 on variants with crop rotation and soil tillage (pc m^{-2})

Weed species	Variants of crop rotation and tillage			
	Monoculture of spring barley		Norfolk crop rotation	
	Conventional tillage	Minimum tillage	Conventional tillage	Minimum tillage
Amaranthus sp.	1,92	0,00	1,72	2,32
Anagallis arvensis	0,00	0,00	0,08	0,00
Cirsium arvense	4,52	4,80	0,00	0,00
Convolvulus arvensis	0,00	0,12	0,04	0,12
Echinochloa crus-galli	3,12	0,00	0,00	0,08
Euphorbia helioscopia	0,00	0,00	0,04	0,00
Fallopia convolvulus	0,28	0,24	0,20	0,08
Galium aparine	2,24	2,28	0,52	0,24
Hyoscyomus niger	0,08	0,00	0,00	0,00
Chenopodium album	0,12	0,00	1,28	1,76
Chenopodium hybridum	0,00	0,00	0,08	0,00
Lamium purpureum	1,80	0,76	1,40	2,48
Lapsana communis	0,00	0,00	0,04	0,00
Microrrhinum minus	1,16	0,00	0,16	0,00
Persicaria lapathifolia	1,72	0,08	0,20	0,36
Plantago major	0,00	0,04	0,00	0,00
Polygonum aviculare	0,00	0,00	0,08	0,00
Silene noctiflora	2,72	0,16	0,08	0,12
Sinapis arvensis	0,04	0,00	0,00	0,04
Sonchus oleraceus	0,08	0,04	0,88	0,32
Stachys palustris	0,00	0,96	0,00	0,00
Stellaria media	0,84	6,20	0,60	0,44
Thlaspi arvense	0,00	0,00	0,08	0,08
Tripleurospermum inodorum	0,04	0,00	0,00	0,00
Veronica polita	3,88	1,16	0,92	0,52
Viola arvensis	0,04	0,00	0,00	0,00
Average on variant	24,60	16,84	8,40	8,96

Table 3. Average number of weed species counted in the year 2007 on variants with crop rotation and soil tillage (pc m^{-2})

Weed species	Variants of crop rotation and tillage			
	Monoculture of spring barley		Norfolk crop rotation	
	Conventional tillage	Minimum tillage	Conventional tillage	Minimum tillage
Amaranthus sp.	0,00	0,00	0,04	0,08
Avena fatua	0,68	0,00	0,00	0,00
Cirsium arvense	3,16	4,08	0,04	0,00
Convolvulus arvensis	0,00	0,08	0,04	0,16
Echinochloa crus-galli	0,00	0,20	0,00	0,00
Euphorbia helioscopia	0,04	0,00	0,00	0,00
Fallopia convolvulus	0,68	0,08	0,16	0,24
Galium aparine	3,12	1,28	0,08	0,28
Helianthus annuus	0,00	0,00	0,08	0,00
Chenopodium album	0,04	0,04	0,32	0,36
Chenopodium hybridum	0,00	0,00	0,00	0,04
Lamium amplexicaule	1,28	0,80	0,84	1,24
Microrrhinum minus	0,40	0,04	0,00	0,00
Persicaria lapathifolia	0,36	0,08	0,08	0,00
Polygonum aviculare	0,00	0,00	0,04	0,00
Silene noctiflora	3,48	0,16	0,76	0,48
Sonchus oleraceus	0,16	0,00	0,28	0,04
Sonchus arvensis	0,12	0,08	0,00	0,00
Stachys palustris	0,00	1,32	0,00	0,00
Stellaria media	0,56	2,80	0,04	0,00
Thlaspi arvense	0,04	0,04	0,08	0,00
Trifolium pratense	0,00	0,00	0,92	0,28
Veronica persica	0,44	0,24	0,00	0,00
Veronica polita	0,40	0,04	0,36	0,52
Viola arvensis	0,08	0,04	0,04	0,00
Average on variant	15,04	11,40	4,20	3,72

Figure 1. Ordination diagram show influence of different crop rotation and soil tillage on weeds



Explanatory notes: *Variants of crop rotation:* ◄**Monokult** – spring barley monoculture, ◆ **Norfolk** – Norfolk crop rotation; *Variants of soil tillage:* ■ **Conven** – conventional tillage, ▲**Minim** – minimum tillage.

Abbreviations of weed species: *Ama sp – Amaranthus sp., Ana arve – Anagallis arvensis, Ave fatu – Avena fatua, 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, Gal apar – Galium aparine, Hel annu – Helianthus annuus, Hyo nige – Hyoscyomus niger, Che albu – Chenopodium album, Che hybr – Chenopodium hybridum, Lam ampl – Lamium amplexicaule, Lam purp – Lamium purpureum, Lap comm – Lapsana communis, Mic minu – Microrrhinum minus, Per lapa – Persicaria lapathifolia, Pla majo – Plantago major, Pol avic – Polygonum aviculare, Sil noct – Silene noctiflora, Sin arve – Sinapis arvensis, Son oler – Sonchus oleraceus, Son arve – Sonchus arvensis, Sta palu – Stachys palustris, Ste medi – Stellaria media, Thl arve – Thlaspi arvense, Tri prat – Trifolium pratense, Tri inod – Tripleurospermum inodorum, Ver pers – Veronica persica, Ver poli – Veronica polita, Vio arve – Viola arvensis.*

Conclusion

The results show that if cereals (spring barley) markedly predominate in crop rotation and minimum soil tillage is used then there are created conditions for expansion of *Cirsium arvense* and *Galium aparine*. If the crop rotation is similar to Norfolk crop rotation then frequency of *Chenopodium album* as late spring weed is increased in spring barley. Long-term minimum soil tillage leads to lower weed infestation in conditions with high percentage of spring barley in crop rotation. But weed infestation of spring barley monoculture is even three times higher compared with barley in Norfolk crop rotation. In Norfolk crop rotation were not found any significant differences between variants of soil tillage.

Acknowledgement

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PROBLEM OF SOIL EROSION IN SPATIAL TRANSFORMATIONS OF RURAL AREAS IN POLAND

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Abstract

In this research, Polish and European activities focused on rural area development and environment modelling have been compared and analysed. It has been stated that in Poland, fundamental processes of land modelling remains as land consolidation, but in the EU - complex rural area development is based on the land consolidation.
So far, carried out in Poland, land consolidation has had a negative influence on the agricultural environment, increasing soil erosion. In order to eliminate this negative influence, additional activities should be introduced, including anti-erosion melioration, forestation, and land re-cultivation or creating biotopes.
This analysed research presented organisational (land management) methods of protection against soil erosion in Poland (arrangement of agricultural roads and land plots, transformations of land usage with an adaptation to natural conditions - land forestation and sodding, maintaining and protection of anti-erosion forestation, hydro meliorations with the reconstruction of water level, ecological area positioning).

Keywords: soil erosion, land management, environmental modelling, land consolidation

Introduction

Poland's entry to the European Union along with system changes in our country has initiated structural transformations in both cities and rural areas. Rural areas are increasingly finding themselves performing different functions that are non-agricultural, such as service industries, housing, ecological, or recreational. The differences in the outward appearance of urban and rural areas are becoming negligible, as rural areas are investing and equipping themselves with technical infrastructures.
Structural changes, from a legal and technical point of view are only possible after the fulfilment of each separate factor, but comprehensively, only in the wider scale of management process of rural areas, which was recognised in the "old member countries" of the EU in 70s of the last century. In this process, on the basis of the land consolidations, a comprehensive – reconstruction is being made - restructuring of a provided area, which its main objectives are decision making and leading into fulfilment of the objective, often changing the land usage (as forestation of arable land).
Management of rural areas - this is a set of planned technical and organisational processes, designed in adapting the spatial structure of an area for the needs of a practical organisation of agricultural spatial production.
The scale of work carried out in the management process can be different: from classical land consolidation, up to a comprehensive development of the area, based on the land consolidation process, which is also includes issues of the soil protection against erosion. Classical land consolidation on relief land surfaces has an adverse influence on the increasing erosion process (6); therefore, protection of the soil should be a consideration. It is possible in

the process of a wider comprehensive land consolidation or agricultural devices, taking together all parts into consideration.
Since in Poland the pace of structural transformations is increasing, it is possible as an element of this action to increase processes in order to reduce erosion.
The aim of this research was to present methods in order to protect soil from erosion and possible completion of the management process.

Material and methods
Recommended methods for the protection of soils against erosion used in the management process in rural areas were analysed. The results used in the research, were conducted in examinations carried out at IUNG Puławy, from this author and other authors. The range of management work and their ecological effects were presented and based on this author's examinations in the area of the administrative district of Wąwolnica in the Lubelskie region (5).

1. From reports of other authors, possible functional methods for the management process of soil protection were established (3, 4, 7, 14). The methods were verified by practical application and monitoring of the land consolidation projects on land with uneven slopes, together with an assessment on their influence for the environment.
2. The basis of analyse was a comparison of the work carried out in the management process of rural areas in Poland and in the "old member countries" of the European Union.
3. The classification of elements for comprehensive land consolidation was a result of consecutive stages of examinations in terms of their influence on the environment.
4. After analysis, parts of the results were suggested for general use without corrections, and other parts needed further correction before could be used.

Results
Analysis of different ranges of management work, included in table 1, states that the management process should be provide with a detailed analyse, predicted in the comprehensive land consolidation. They contain these elements, which as a whole, are shaping the rural area. Regarding this, action on reducing the erosion risk is understood as transformation of land use, and generally the exchange of the arable land for forestation or grassland use, hydro melioration, regarding construction of a water reservoir (colmatation) and hydro melioration protection from erosion.
Completion of these processes allows a comprehensive development of rural areas, and for considering issues of soil erosion protection to a wider extent.
Considering the above factors according to their influence on the environment, they can be divided in three groups (11):
I. They contain no beneficial influence, regarding the increasing surface area of plots or deforestation of the land,
II. They contain a beneficial influence for the environment by using forestation or sodding of ground, creating shelter belts, construction of water reservoirs or the location of ecological land,
III. They contain processes that have little influence on the environment, as the location of building areas or public footpaths.
In considering all the above information of this study, the following problems were considered in the management process, which have a significant influence on increasing the erosion process:
1. Arranging agricultural plots
2. Arranging agricultural roads
3. Transformation (conversion) of ground use

4. Location of shelter belts and soil protectors
5. Hydro meliorations

Arranging agricultural plots

A vital element in the management process in Poland is the size, shape, and arrangement of planned plots. It is well known that increasing the size of plots has an adverse effect on increasing the erosion process (6). Therefore, limitation of their size and an appropriate integrated system into the land relief are necessary. To this extent Józefaciuk and Kobyłka, 1975 (4), presented a proposal, when agricultural horse usage was still being practiced. In comparison to present conditions, agricultural tractor usage has made this criteria unusable, and to obey this previously mentioned criteria the plots would have to be divided into smaller proportions (present average 0.5-0.6 ha).

Table 1

A comparison of work carried out at different levels of accomplishment for the management of rural areas in Poland, and of the "old member countries" of the European Union

Specification of range of works	Land consolidation	Comprehensive land consolidation	Land management	Development village areas*
Land consolidation	++	++	++	++
Arrangement of farm roads	++	++	++	++
Village and farm roads hardening		+	++	++
Land use conversion suited – forestation		++	++	++
Hydro meliorations with reconstruction of water level		+	++	++
Erosion control and land reclamation	+	++	++	++
Arrangement of developed lands		++	++	++
Running water supply			++	++
Sewage system deployment and treatment			++	++
Utilisation of solid rubbish			++	++
Deployment of telephone system			++	++
Development of gas supply system			++	++
Local agricultural-food industry			++	++
Tourism and recreation			++	++
Environmental conservation		+	++	++
Renovation of monuments			+	++
Renovation of villages				++

++ - tasks fully executed in given process
\+ - tasks partially executed in given process
* - tasks fully executed in given process in European Union

Proposals on the size and the arrangement of plots - after correction made by the author is shown in table 2, their size is contained in picture 1, which taking into consideration should not increase the erosion process.

Appropriate integrating of the planned plots into the land relief surface is very important. Fundamental principles suggested by authors Ziemnicki (14) and Józefaciuk and Józefaciuk (3) for practical use is a crosswise-slope agreement of plots with the width depended on the slope of land and if the slope is steeper then the width should be smaller. Under Polish conditions the partial verification of research results for crosswise-slopes (“strip fields”), were made by practical application.

Table 2
Configuration and size of ground plots at consolidated, upland areas

Configuration of parcels	Size of parcels, depending on the degree of erosion*				
	small (up to 3°)	moderate (3-6°)	medium (6-10°)	strong (10-15°)	very strong (over 15°)
Crosswise-slope	length and width not limited	length and width not limited	length not limited, width not exceeding 80 m	length not limited, width not exceeding 60 m	length not limited, width not exceeding 30 m
Crosswise-slantwise-slope	as above	as above	length not limited, width not exceeding 80 m	length not limited, width not exceeding 50 m	not recommended
Slantwise-slope	as above	length not exceeding 200 m, width not limited	length not exceeding 120 m, width not exceeding 60 m	not recommended	not allowable
Langwise-slope	as above	length not exceeding 150 m, width not limited	not recommended	not allowable	not allowable

* - in the case of low soil variability, configuration and size of plots can be calculated due to the degree of terrain inclination.
Source: Own study based on the study of Józefaciuk i Kobyłecki (1975)

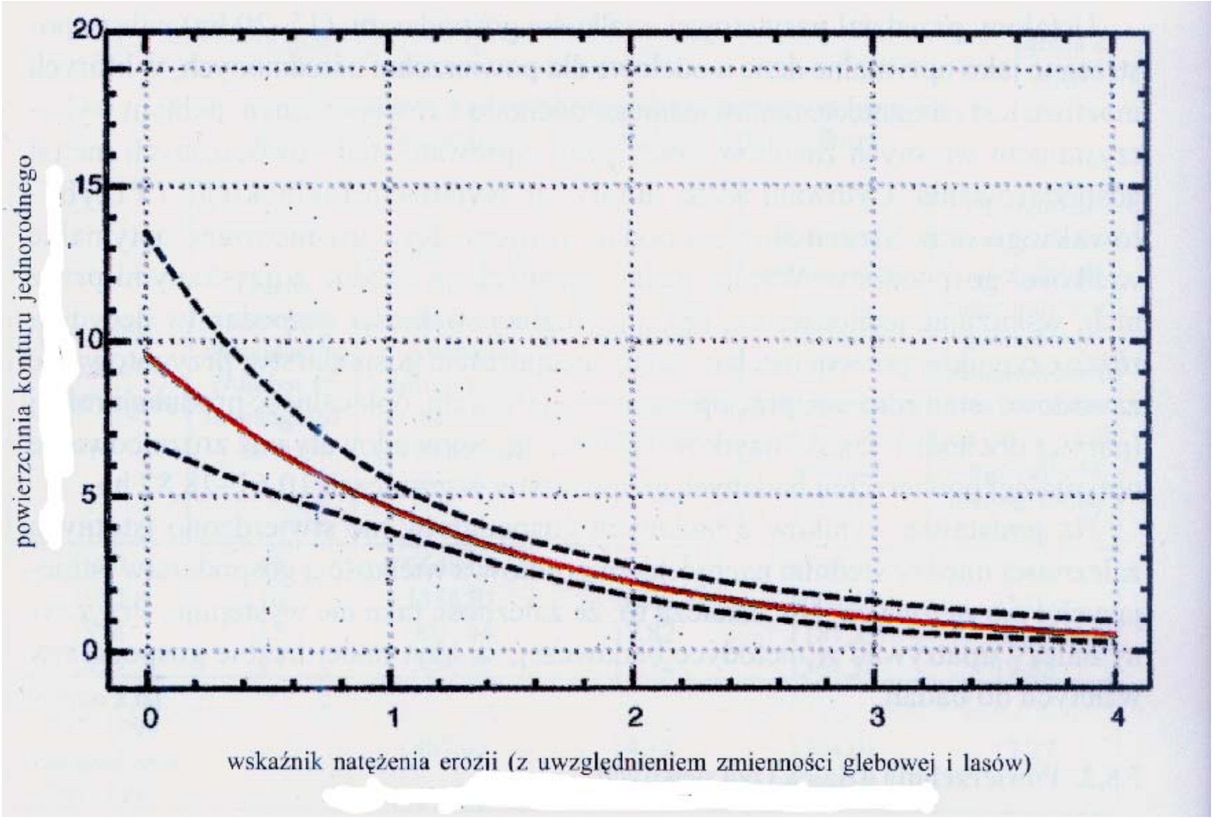

Fig. 1 Effect of erosion rate, soil variability and the occurrence of woodlands on the size of homogeneous land use complexes.
Source: Own study

Established in the 60s and 70s of the last century, trial strip fields did not fulfil expectations of neither authors nor farmers. At present, their part is considerable in the condition of set-aside (leaving fallow for at least a year) from the following causes:
- very long and narrow strip fields established in the period of general farm horse usage, are not adaptable for common present day tractor and combine harvester usage. The width of plots is not suitable for width of basic equipment used for the cultivation and harvesting, which is raising the cost of production.
- negative effects of positioning trees or shrubs flora on the field borders can have an influence on the surrounding crops causing negative effects on the economic production (13)
- there is no agreement from land owners. Condensed or linear systems of building developments along with the width on the majority of plots are too small (no more than 50 m). Crosswise-slope cultivation is not possible, and designing the parallel arrangement of plots behind buildings impairs the principles of the social justice, because one farmer will have land behind his and his neighbour's buildings, whereas the neighbour fields will be at a considerable distance from the buildings. A similar situation is appearing in forests, peculiarly localised on areas with steep slopes.

The shortening in the length of fields is an optimal solution possible in the conditioning of longwise-slope fields on areas with gradients up to 12^o (tab. 2) in addition to changing the usage of arable land to green or forest use with greater gradients.

Arranging agricultural roads

The economic development caused a rise in the automotive industry, along with increased work on the field. At present, farm horse usage in the field is disappearing and being replaced by modern tractor and combine harvesters. It creates a necessity for the localisation and construction of new public and agricultural roads, and the modernisation of existing roads. Especially, it concerns areas with a diversified relief surface, where the network of agricultural roads apart from fulfilling local communication needs should comprise of a visual landscape surrounding and constitute one of fundamentals of land anti-erosion reclamation (8).

The results obtained through research at IUNG (7, 8) assumes that on slopes up to a 6% gradient, the existing roads do not require any correction in their course, and also can be freely encompassed in the design of the management process – land consolidation. However, slopes above a 4% gradient, then the road surfaces should be hardened with specially strengthened devices for carrying away surface water, because the water erosion on the surface soil can transform the surface into narrow ravines.

At a slope of 6-14%, new proposed roads require correct positioning; the road should be located on the ridge part of the hillside or on localised watersheds with a lesser concentration of surface water, on the midslope valley, or slantwise to the slope with preserving the above-mentioned gradients (7, 8). No damage that was caused by erosion was found on roads that were positioned as described above.

Transformation of ground use

Change of farmland for woodland

Transformation of ground use is being instigated in the management process; mainly changing it from farmland into woodland, this also includes a defined agricultural-forest border. The designed borders for the planned ground change to forest should take into consideration the existing forest arrangement. In order to establish this process, we need to consider the soils valuation (determined in Polish pedological classification), natural borders and physiographic, the land gradient, as well as the erodibility.

The composition of a created forest complex should include: midfield forestation and different forestation areas, and farmlands of the Rz-VI class (selected for forestation) and R-VI (recognised as seventh complex of agricultural suitability of soil), as well as the R-V class (no possibilities of effective farming; recognised as sixth complex of agricultural suitability of soil), the pastureland with the class Ps-VIz and Ps-VI (located on areas with low-level of groundwater and directly adjoining to forest complexes) (13).

The results show that forestation is also appropriate for arable land with a slope over the 12^{o} (>20%) gradient, on poor quality soil / VIz - V /, above 20^{o} (>33%) on average soil and above 25^{o} (>40%) on good soil.

The above criteria should be taken into consideration when qualifying the land for conversion into forestation, both in the management process, as well as in spatial planning. However, in the current phase of land use, some projects should remain as they are, such as areas that come under local authority spatial plans that are intended for buildings, development of an infrastructure, industry, and general storage, development of tourism and different important social targets.

Change of arable land for grasslands

Suitable areas for grassy flora are compressed soils that are difficult for mechanical work, on slopes, areas with a high level of groundwater and by the water reservoirs.

The results suggest that for long-lasting sodding, the optimal areas are:
- located on slopes with gradients above 10-20^o (>17-33%) depending on the soil's quality, usually in the immediate neighbourhood of settlements,
- areas situated around water reservoirs (width belt 15-100 m);
- valleys that are without outflow

Location of shelter belts and soil-protection

An essential factor for limiting wind erosion is the managed reduction of occurring wind speeds. This can be established with the presence in the landscape of midfield forestation. After the wind has passed the shelter belt line there is a reduction of up to 60% of the initial speed (1). This strength of the wind diminishes over a distance of eight times the initial height of the trees (about 200 m). The midfield forestation reduces wind speed; therefore, they reduce erosion, and allow keeping more of the nutrients for plants in the soil.
The forestation is constructed in order to stop wind erosion and should be planted with multispecies at a width of 15-30 m allowing aeration, so air streams can pass through the forestation and above the crowns and converge at a certain distance behind the forest.
The forestation also constitutes a barrier limiting surface soil runoff, which counters the effect of water erosion. According to Węgorek (10) the most effective method in this case are forestation belts with undergrowth formed from a sod laid lengthwise with the contour and surface forestation in places mainly exposed to erosion. Forestation constructed in this way, positioned in the direction of the groundwater flow are a biogeochemical barrier.
Inserting shelter belts in Polish conditions is very difficult to fulfil because most of the ground is in the form of small plots and it constitutes as private property. The owners do not accept this because of a need of long lasting exclusion of these lands from agricultural production, which includes maintenance cost and has a negative influence on agricultural cultivations.

Hydro meliorations

Hydro meliorations constitutes as a basic component of the management process, which must be established first. The remaining processes are linked to hydro meliorations mainly to the network of drainage ditches, water reservoirs, and different constructions. They constitute as a set of permanent features, to which the management process should refer to these features. Moreover, hydro meliorations are changing the value of the farmlands; consequently, assessing the value of ground for purposes of land consolidation should not be done before, but only after finishing the hydro meliorations process.
The scale of hydro meliorations work is extensive, because apart from classical hydro meliorations, the water reservoirs are built most often in a multifunctional form, where its main function is anti-erosion. River valleys are often a location for water reservoirs and its main functions are different from anti-erosion, i.e. recreational, microclimatic, economical, whereas in bottom of ravines anti-erosion is the main function, in the form of retention reservoirs, colmatation reservoirs (fig. 2) or retention-colmatation.

A proposed mechanism for the protection of soil in the management process

The results from this author's research allow a process of methodology. Reconstruction of the spatial ground structure on the relevant object (village) (which is only possible in the land consolidation process), should start from forming assumptions for the comprehensive land consolidation project, according to the Polish legal rules (9). In this project, all necessary action should be taken into consideration, in the scale of soil protection against erosion. At this stage, special attention should be paid to the conformity of the project and to the decisions of the local spatial management plan. If the planned tasks are outside the range of

this plan, then these changes should be inserted into the local plan. They constitute as a basis for the comprehensive project that after approval by landowners, is accepted for fulfilment in consideration of the procedure predicted in the act of land consolidation (9).
The achievement of a comprehensive implemented procedure in the management process should cause a reduction in the threat of erosion by a factor of 1-2 degrees in a five-degree scale (12).

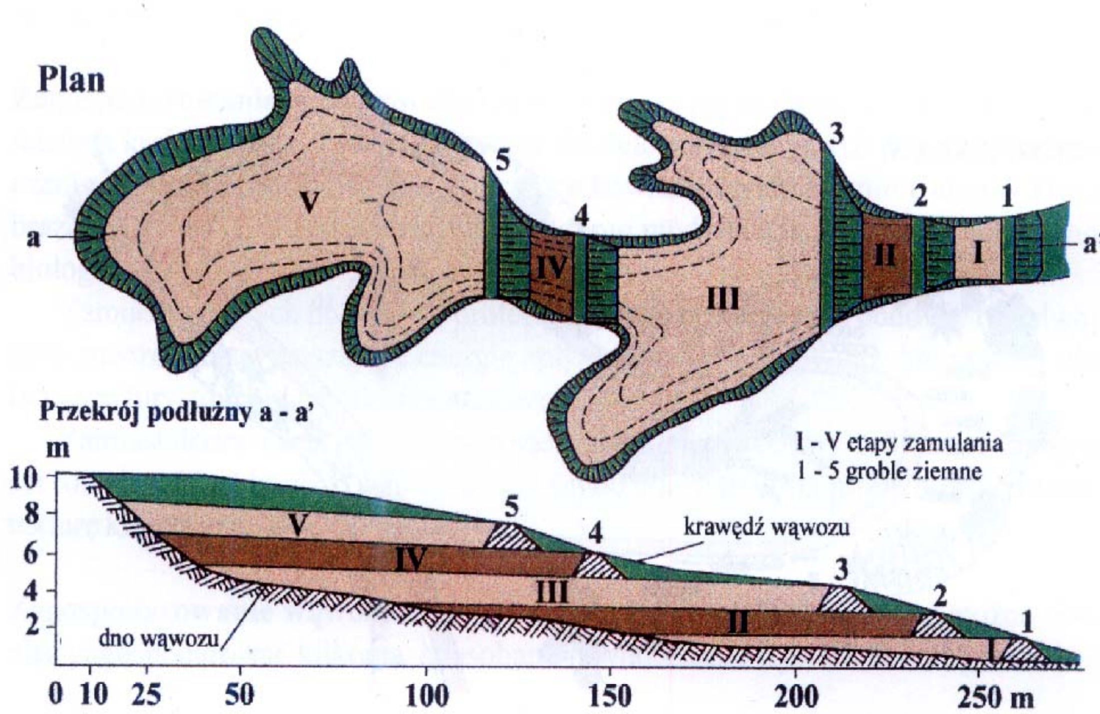

Fig. 2 A valley gully transformation for reservoir to silt scheme
Sources: (2)

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PAPERS OF THE SECTION IV

ISTRO

CLIMATE CHANGE – URGENT NEED FOR INTRODUCING NEW TILLAGE TECHNIQUES IN CENTRAL EUROPE

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Abstract

In the last two decades long-term tillage trials were conducted in number in both countries in similar and different arable sites where numerous factors were compared. In spite of the different research conditions the certain conclusions were often agreeing that is soil deterioration effect of the conventional tillage; coherence between soil quality deterioration and climate sensitivity of soils; beneficial effect of the soil conservation and climate harm mitigation. Importance of this study can be reviewed by the consequences of the drought ensued in 2007, in the Central European region. In the first topic factors of climate damage increasing conventional tillage regarding this region are summarised. In the second topic soil physical defects increasing climate damages are listed. In the third topic theoretical and practical standpoints of the climate damage mitigating soil tillage are summarised.

Keywords: climate change, conventional tillage, climate sensitivity, adaptable tillage

Introduction

Various consequences of climate change – warming, declining annual precipitation, other weather extremes – have been observed in the Central European region as well (Figure 1). Cropping is adversely affected by extreme weather events, such as long dry periods alternating with short rainy periods, torrential rains, extreme heat days in the summer, mild winters and early or late frost damaging crops, waterlogging, drought even within a single growing season (Láng et al., 2007; Mokhov, 2002; Pokorny et al., 2002, 2007; Jolánkai and Birkás, 2007; Várallyay, 2007b). One of the fundamental causes of climate damage is extreme shortage or abundance of precipitation, i.e. too dry or too wet soil. From the aspect of cropping the damage caused by the underlying factor is also affected by the site parameters, the actual soil fertility, its nutrient supply and water regime (Pokorny and Denesová, 2003; Javurek and Vach, 2004; Kvaternjak et al., 2008). Our studies have shown that the state of soils hit by climate damage is another important factor (has there been a compact layer in it preventing movement of moisture up from deeper layers to the root zone or its movement down to be stored in deeper layers). Unreasonable insistence on applying conventional tillage practices having a negative impact on soil water transports may be an important factor in this region (Várallyay, 2007c). These may relate to both site and soil. Climate sensitiveness have been found to be influenced not only by the original characteristics but also by circumstances modified – usually negatively – by farming, such as quality deterioration. As authors (Javurek and Vach, 2004; Birkás and Kalmár et al., 2007) stressed, to maintain good soil quality may reduce the effects of climatic extremes at reasonable cost. Although the climate situation is rather grave today, there is a wide variety of means for protection. The question is, whether those concerned recognise factors aggravating the damage and whether they apply the available methods of preventing or mitigating damage (adaptation).

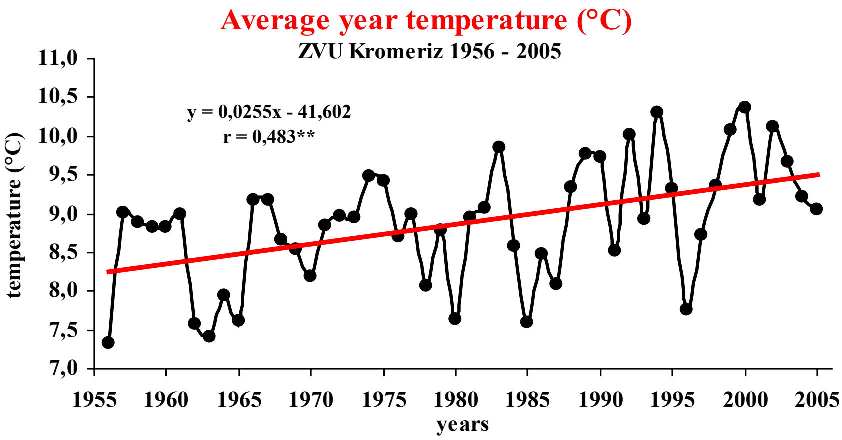

Figure 1 Average year temperature (^{o}C) in Kromeriz (NE from Brno, CZ)

Material and methods

This paper based on soil condition monitoring and measuring that started 20 years ago in Hungary by Department of Soil Management at Szent István University Gödöllő (Birkás et al., 2004), and in Croatia by Department of General Agronomy at University Zagreb (Kisic et al, 2006), and by Department of Crop Production at Strossmayer University in Osijek (Jug et al., 2006). Similar field experiments have been running in frame of long term project at three different experimental sites of Crop Research Institute Praha-Ruzyne for 12 years, in which production, pedological and economic aspects of several variants of tillage technology are studied. Conventional (CT), soil condition improving (CI), reduced (RT) or shallow (ST), and direct drilling (DD) tillage variants are equally included in each of the three sites and in every experiment. The trials involved the production of crops that are adaptable to the site, such as winter wheat, maize and soybeans in Croatia, winter wheat and spring-sown barley in the Czech Republic and winter wheat and maize in Hungary. Catch crops (phacelia, mustard, rye) are growing in the experiments running in Czech and in Hungarian experimental sites. In recent years the studies were supplemented by assessing the interactions between soil quality and climate impacts. The experiments were set, the tillage versions were arranged and the measurement of the soil condition parameters and the crop responses at each of the three sites in accordance with the relevant standards and regulations (Tóth et al., 2005; Javurek and Vach, 2006, 2007; Jug et al, 2007, Birkás, 2008). The amount of evaporated water during the period (E) was measured in accordance with the formula worked out by Szász (1997): $E = W_0 - W + P$; where W = the soil moisture content at the end of the period concerned; W_0 = the soil moisture content at the beginning of the period concerned and; P = precipitation during the period. The following subjects are discussed below: 1) Conventional tillage in view of climate damage. 2) Relationship between soil state and climate impact. 3) Features and likely results of climate-adaptable tillage

Results

Conventional tillage in view of climate damage

In the relevant long term tillage trials the conventional system is applied as the basis of comparison (control), where primary tillage is applied in the form of ploughing of various depths, with secondary tillage carried out in a separate pass. A large number of experiment findings show that conventional tillage has a very positive impact on yields in years of average precipitation, with varying impacts in dry or wet years (Figure 2), for any major water loss reduces the output of cropping. Conventional tillage has favourable impacts in controlling weds, pests and pathogens as well. The short term impact on soil varies (between neutral and unfavourable), however, the long term impact is definitely adverse. The consequences of conventional ploughing are also similar to what has been experienced, i.e. we find plough pan formation, degrading structure and loss of carbon.

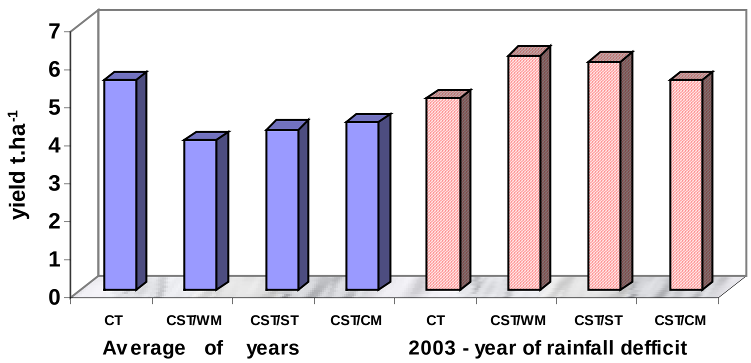

Figure 2. Influence of tillage technology on grain yield of spring barley under different year conditions in medium-heavy Greyzem at Caslav (CZ).

Legend: CT: conventional tillage, CST/WM: direct drilling, CST/ST: shallow tillage, CST/CM: direct drilling into mulch.

1. As has been discussed in our earlier studies, the disadvantages of conventional tillage may be encountered particularly in growing seasons characterised by extreme weather conditions primarily as a consequence of high number of tillage (6-8) passes, aeration (loss of carbon) and moisture loss. The time requirement of the large number of tillage passes entails risks in the case of extreme weather conditions, for it results in quality decline and soil defects. The high energy input demand referred to in technical literature is real and what with the current energy prices this is an input price that cannot be recovered. Deeper ploughing results in higher yields only if deeper inverting eliminates some soil defect that used to limit cropping yields. Deeper ploughing may, however, be applied only in soils of deeper fertile layers. The advantage of ploughing may be enhanced if it is carried out according to high standards, but producing deteriorates the soil state and has no positive impacts at all. The larger surface resulting from ploughing through which water can be lost is a major disadvantage in comparison to other modes of tillage not only in the summer but also in the autumn, during mild winters and in early spring. Since ploughing is conventionally followed by a separate secondary tillage pass, it results in a substantial aggregate water loss. Inverting field residues has a definite advantage in the conventional practices of crop protection. It should be considered though, what is more useful for the soil – leaving crop residues on the surface to protect the soil or to turn it over. Studies have shown that the conventional – so-called crop-oriented – tillage approach overrated the importance of inverting and underrated the disadvantages entailed by them. In the wake of research finding we have summarised the real and assumed benefits of ploughing, that is: (1) inverting soil surface, covering field residues, weeds and weed seeds. (2) controlling pests, pathogens and weeds. (3) reliable or higher yields. Advantages should be expected only if tillage is adapted to the depth of the fertile layer and to soil moisture conditions. Actual risks of the conventional ploughing-based tillage systems are: (1) large surface through which water is lost, if dry or too wet soil is ploughed. (2) small surface can be expected only if the soil moisture content is near optimum

at the time of ploughing. (3) a large surface is created through which carbon is lost, and inverting results in excessive soil aeration anyway. (4) depth limit in the case of soils of unfavourable chemical parameters or high stone contents below 20 cm. (5) high energy requirement of ploughing or the high number of tillage passes required for surface forming. (6) structural degradation in the case of frequent ploughing (clod and dust forming). (7) structural degradation in wet soil (puddling, smearing). (8) plough pan forming (creating a layer impermeable to water), in the regular ploughing depth, increasing the soil climate sensitiveness, Table 1). (9) degrading earthworm habitats by ploughing in dry or wet soil. The loss of water and carbon, and direct and indirect damage to the soil structure contribute to deteriorating soil conditions and increasing climate sensitiveness.

Table 1. Soil condition and likely climate damage (between 1976 and 2007, based on 910 data recorded in Hungary)

In the given profile	Soil moisture transport	Likelihood of negative climate impact
no layer hindering water transport	good	weak
no insulating layer, the soil is settled, water transport is limited	medium	medium
one or more layers in the soil restrict water transport	weak	strong

Relationships between soil state and climate impact

The authors studied the interactions between soil and plants. One typical question is what tillage-determined soil conditions can alleviate the adverse climate effects. Circumstances that have been found to aggravate climate damage: (1) reduced permeability to water, (2) hindered movement of soil moisture from deeper layers towards the root zone, (3) large surface through which water and carbon is lost, (4) too cloddy or dusty structure that easily goes silting or capping, (5) massive mineralising of organic materials and its loss through CO_2 perspiration, (6) uncovered, exposed surface.

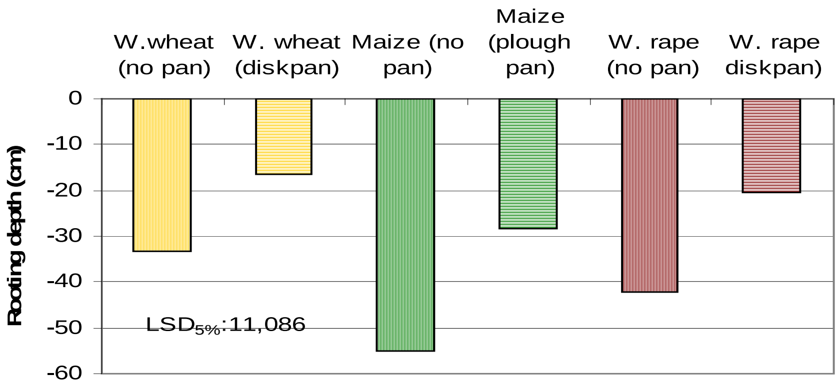

Figure 3. Rooting depth of three plants at two soil condition variants (Hatvan, 2007)

The following details have been collected on the basis of a monitoring project at Szent István University's Soil Management Department since 1976 (assisted by information supplied by scientists working in Croatia and in the Czech Republic) with regard to the subject of this study: 1) The role of the looseness of the soil in the root zone. The state of the top 50 cm layer of the soil shows whether there is any compact layer in the soil down to the depth of the root zone impeding water transport (Figure 3). In 922 out of 1011 studied cases detrimental compaction occurred in soils of 26-66 % clay contents, accompanied by medium and drought damage in 2000, 2003 and 2007 and by damage caused by waterlogging in 1998 and 1999. 2)

The location of the compact layer impeding water transports. In 45 %, 50 % and 5 % of a total of 922 cases compaction had been caused by disking or ploughing, respectively. 3) The extent of the compacted layer impeding water transport. The thickness of the compact layer reflects the gravity of damage and the likely risks. In 886 out of 922 cases the compacted layer was thicker than 4 cm and could not be broken by bare hands. 4) The coverage of the soil surface (by chopped field residues) shows whether there is a protective layer on the top of the soil. 68 % and 32 % of the 510 cases involved in the study were sites in fields with coverage and without coverage, respectively. Greater (about 25%) coverage provides more effective protection. On hot spring days the temperature of soil without coverage may be 5-8 ºC higher than that of soil covered by residues. 5) The soil aggregation provides (apart from soils of naturally poor structures) information over a long period about processes characterising the structure of the soil. In this case we took samples from originally favourably structured chernozem, meadow and forest soils (116+53+77, a total of 246 cases). In the above dry years the level of adverse climate impacts was lower in soils containing more than 75 % aggregates and less than 10 % dust (38% of the cases). By contrast, in soils containing less than 50 % aggregates and more than 25 % dust (16 % of cases) heavy climate damage was observed. In sites where medium levels of climate damage were observed (46 % of the cases) the crumb fraction equalled 50-60 %, a very unfavourable proportion in the case of such soils. 6) The relationship between land use and water transports in the soil. Longer land use (resulting in loss of water or conserving moisture) reflects the level of risks in the given area (high, medium or low; a total of 412 cases were studied). More serious damage is observed in dry years in sites where water was being continuously lost, regardless of the amount of precipitation. Water wasting land use practices are characterised by the following: deep stubble tillage without surface pressing, ploughing in the summer without subsequent pressing (Figure 4), ploughing in the autumn leaving furrows on the soil surface, loss of water before sowing in the spring, heavy weed infestation (with heavy losses of water) after harvest.

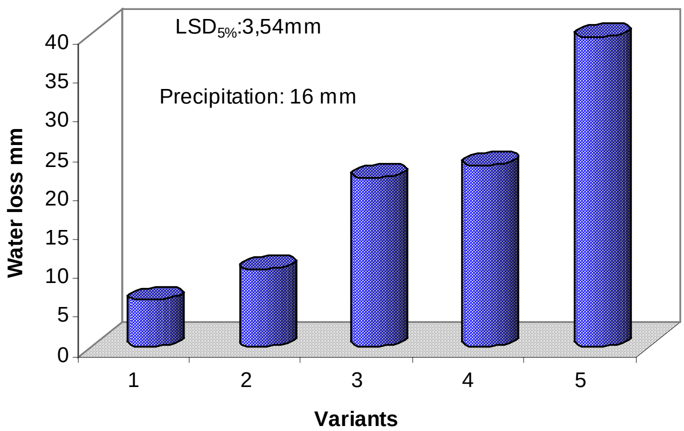

Figure 4. Rata of water loss after summer tillage (45 days, Hatvan, 2007)
Legend: 1. mulch tillage (6-8 cm); 2: disk tillage (14-16 cm) + rolling; 3: disk tillage (14-16 cm) without rolling; 4: ploughing (25-28 cm) + pressing; 5: ploughing (25-28 cm) without pressing

7) Relationship between tillage and climate effects (a total of 1045 cases were studied). A close link was found between tillage degrading soil condition and losses caused by extreme climate conditions (466 cases, 44.5 %) and between conserving tillage and effective climate damage mitigation (579 cases, 55.5%). Accordingly, protection of the quality of the soil may be a means for effectively alleviating climate damage.

New terms were also created during our trials, such as 'climate stress', which may occur in soils under long periods of extreme heat and/or torrential rains, or 'climate risk', indicating likely consequences of soil state defects and of interventions altering the soil structure.

The features and likely results of climate-adaptable tillage

In our trials the relevant tillage treatments and crop sequences were focused on improving the quality of the soil, conserving its C contents and mitigating climate damage. Despite differences between sites the authors found that the lowest climate stress levels are encountered in places where the soil is loosened to a greater (40-45 cm). Shallow tillage resulted in favourable effects over 1-3 year periods, thereafter compaction reduced the rooting depth and led to lower yields in growing seasons characterised by extreme weather conditions. The experiments prove the favourable impacts of soil coverage in each of the three sites. In the growing season shading by the crops, outside the growing season coverage by field residues and/or catch crops provided protection. In years of extreme weather conditions 30-35 % surface coverage in the case of wide-row crops (maize, soybeans) or 12.5-15 % soil surface coverage provided in a statistically proven favourable impact providing protection against heavy rains and capping resulting from drying out. The degree of protection by mulch crops sown in field covered by stubble residues after wheat or barley depended on the degree of their growth. The loosened layer – without tillage pan – was also utilised by crops sown on fields covered by crop residues as well, providing up to 85-95 % rates of coverage. Though the soil surface is protected by both catch crops and volunteer crops, these do not have the same favourable effects – by force of their water uptake – than do stubble residues that do not take up water. The continuity of soil structure and surface protection is proven by the increase of the proportions of the 0.25 - 10 mm aggregate fractions. E.g. in chernozem soil in the Hatvan region the original aggregate fraction ratio (55%) increased up to 81%. In view of the given processes of climate change C-flux is considered to be a new soil condition and tillage quality factor. Soil disturbed to greater depths releases more carbon. In our case the C loss of soil equals some 50-60 kg ha^{-1} measured over a period of three days (Figure 5), lower than data in technical literature (Tóth and Koós, 2006), since in our experiments primary tillage was always followed by secondary tillage. In dry years we found higher rates of carbon loss after tillage, though on fields covered by stubble residues C loss rates were definitely lower.

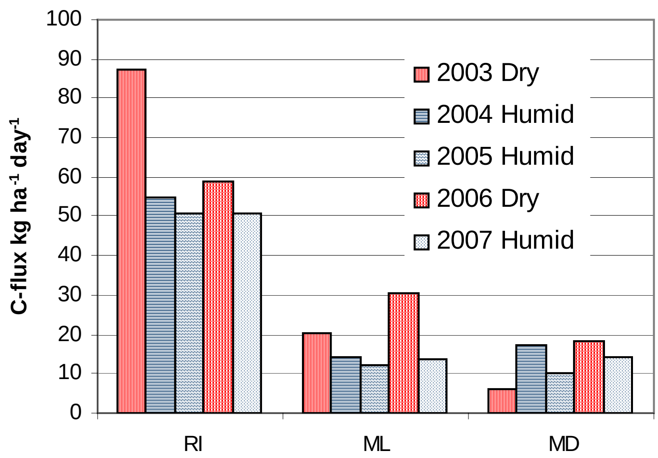

Figure 5. CO_2-C flux of soil after primary tillage (Hatvan, 2002-2007)
Legend: Tillage: RI: root zone improving; ML: mulch-till; MD: direct drilling

In relation to adaptation to the changes in the climate the aggregated results and findings of our experiments are also highly interesting. We found that quick alternation of wet and dry

periods and higher precipitation rates do not reduce the importance of soil moisture conservation. More emphasis should be laid on leaving mulch cover on the fields after harvest and on covering the surface even after sowing. In the system of producing a given crop efforts aiming to mitigate climate damage should be started by stubble treatment practices, since this is the period during which the soil can rest and recover. Any major heat stress on the soil during the stubble period has been found to reduce workability and impedes earthworm activity. Since the area of land under winter oil-seed rape (*Brassica napus* L. ssp. *oleifera*) has been increasing, primary tillage is being carried out in the summer on ever increasing areas. Where ploughing is followed by surface forming in the same tillage pass a variety of processes considered by farmers to be caused by unfavourable weather patterns.
Our experiments have also shown that mitigating damage caused by changes in the climate calls for urgent changes in summer tillage practices primarily. At the same time the soil moisture loss observed between October 2006 and April 2007 (up to 81-180 mm depending on clay content and surface preparation) shed new light on the requirements considered earlier to have to be met by tillage, for leaving large open surfaces (after ploughing) during autumn and winter months of milder weather conditions results in water loss that is unfavourable for crops during their growing season. The features of climate-adaptable tillage are summarised as follows: (1) Knowledge of the risks relating to soil condition – the depth of the loosened layer is indicative of the likely level of damage. (2) Eliminating any compact layers that could hinder water transports. (3) Loosening of a soil layer of an adequate depth (without creating large surface). (4) Reducing the surface through which water could be lost in any period (except for sites exposed to erosion). (5) Protection of the soil structure in all seasons, whatever tillage intervention is applied. (6) Application of tillage techniques leaving a mulch cover. (7) Surface cover after harvest, as long as possible: conserving soil structure and moisture outside the growing season, mitigating heat stress during the growing season. (8) Organic material (carbon) conserving, in all seasons, whatever tillage intervention is applied. (9) Adaptable primary tillage preventing and mitigating damage. (10) More rational seedbed preparation to reduce soil moisture loss: a single tillage pass in the case of crops 12-48 cm row widths, reducing the period between tillage passes in the case of wide-row crops.
In our view the future of the methods of primary tillage – the most favourable variants in this region – will be determined by the extent to which it can be adapted to climate protection adaptations.

Conclusions

Findings from tillage trials and experiments in three Central European countries and data from the monitoring of soil states have been assessed from the aspect of the ongoing global warming process. The authors found that particular attention should be paid to soil states caused by tillage in a short run and in a longer run as well. Close interactions have been found between soil state and water transports (intake and loss balance), and between soil quality and degree of climate damage. Conventional tillage has been found to contribute to the deterioration of the condition of the soils – despite some positive effects – and to growing climate sensitiveness. As a consequence of the climate change there is no more room or time for delaying active adaptation and making efforts to mitigate damage, one of the most fundamental elements of which may be soil conserving tillage.

Acknowledgements

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CURRENT PROBLEMS OF ARABLE FARMING PRACTICES IN THE CZECH REPUBLIC

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Abstract
The paper deals with the main problems relevant to the effect of farming on soil fertility in the Czech Republic over the last years: aggravation of physical state of soil; decline in amount and quality of organic matter in the soil; compacted subsoil layer; acidification of soil; changed mineralization regime; slowed soil warming up; within-field soil heterogeneity; high interannual heterogeneity of yields. The major causes of these problems are: a) long-term (large size of farms and high percentage of hired land); b) external – bad economic situation and resulting features (staff decrease, limited technology innovation, low inputs, decrease in livestock population, omitting fixed crop rotation and change in crop structure); c) internal – management abilities. Arable farming in CR is now far beyond a good state and it will be difficult to eliminate negative impacts of previous period.

Introduction
Agriculture in the Czech Republic is about 15 years after crucial change in 1990. Some features still persist from the previous period but they have to exist in new conditions of market economy. The attempt of farms to survive in market conditions led to changes in crop structure and farming practices with extensive effect on soil fertility and whole agricultural system.

The main problems relevant to the effect of farming on soil fertility in the Czech Republic over the last years are as follows:

- aggravation of physical state (above all compaction and texture) of soil accompanied by a number of implications (untimely maturation of plants, water-logged sites at snow thawing or downpours, erosion due to slow infiltration of precipitation water, alluvial areas of the field become secondary tracks of water run-off, cultivation measures are carried out at higher soil moisture, increased occurrence of slugs and moles due to soil compaction),
- decline in the amount and particularly quality of organic matter supplied in the soil,
- compacted subsoil, decreased activity of rootlet formation,
- acidification of soil surface layers (CaO leaching into lower layers), further acidification by acid residues of mineral fertilizers at their increased application (under minimum soil tillage systems),
- accumulation of post-harvest residues in topsoil surface layers, changed mineralization regime (N release in later periods of the growing season),
- increased incidence of diseases, pests and weeds, earlier less significant or almost of no economic importance (it is also associated with climatic changes and extremes),
- slowed soil warming up that is encouraged by spring destroy of intercrops, which results in sowing in immature soil and delayed stand establishment,
- within-field heterogeneity of soil fertility and soil compaction in headlands increase, plant emergence takes place in time waves,
- low level of agronomic practices, infestation by perennial weeds, increased incidence of diseases and pests,
- high interannual variation of crop yields.

Major causes of mentioned problems are:

a) long-term – large size of farms and hired land
b) external – economic situation
c) internal – management ability of agricultural enterprise administration

Results and discussion

Basic information about the Czech agriculture shows Table 1.

From the past persists large acreage of farms. Nearly 30 % of the land is managed by farms larger than 2000 ha and other 27.7 % by farms with acreage of 1000 – 2000 ha. The structure of Czech farms from the point of view of acreage shows Table 2. In many cases the agricultural enterprises are transformed former co-operative farms, whose land was restituted to the original owners and agricultural enterprises hire it. About 87 % of agricultural land is hired and it often leads to worse soil care. An advantage of the great acreage is a possibility of using high-performance machines and advanced technologies, above all in crop growing.

Table 1. Basic information about the Czech agriculture (31.12.2006) (source: CSO, VUZE 2006, MOA, 2006a, adapted)

Area of the Czech Republic (thousand ha)	7 887
Area of farm land in the Czech Republic (thousand ha)	4 254
Number of inhabitants	10 287 189
Area of farm land per capita (ha)	0.41
Arable land (thousand ha)	3 040
Grassland (thousand ha)	976
Proportion of arable land (%)	71.5
Proportion of less favoured areas (LFA) (%)	50
Vulnerable areas according to Nitrate Directive (% of farm land)	44
Livestock units per ha (cattle)	0.32
Proportion of land under organic management (% of farm land)	6.6
of which:	
- arable land (%)	8.1
- grassland (%)	82.4
Area under minimum soil tillage (% of arable land)	ca 30
Area under precision farming (% of arable land)	ca 10

Table 2. Size structure of agricultural enterprises. (state at the end of 2006) (Vanek, 2007)

Size categories of enterprises (ha)	Agricultural enterprises			
	number		acreage	
	abs.	%	abs.	%
0 - 5	23 948	54,0	36 543	1,0
5 - 10	5 117	11,6	36 495	1,0
10 - 50	9 000	20,3	201 402	5,7
50 - 100	2 043	4,6	143 315	4,1
100 - 500	2 342	5,3	517 784	14,6
500 - 1 000	788	1,8	575 083	16,3
1 000 - 2 000	691	1,6	978 137	27,7
2 000 <	360	0,8	1 047 781	29,6
Total	44 309	100,0	3 536 541	100,0

Intensification of agricultural production required creation of large fields and significant increase of proportion of arable land in the past. Former collectivisation in agriculture and field consolidation led to establishment of large agricultural cooperatives with large parcels and fields. Consolidation of fields and placing crops on these fields were often done without taking landscape structure into account and didn't respect fundamentals of soil protection from erosion. Intensive large area utilisation of soil for agricultural production has set up the possibility for incidence of erosive forces on its surface and processes based on destructive effect of water and wind developed. Erosion is not only ecological but also economic problem. Lack of quality arable land leads to need for higher inputs to reach good yields. There is about 50 % of arable land under threat of water erosion in the CR (Table 3) (Anonym, 2008) which is by estimation about 1.4 million ha of agricultural land (MOA CR, 2006b).

Table 3. Threat of water erosion in the Czech Republic (Anonym, 2008)

Water erosion threat	Very slight	Slight	Medium	Strong	Very strong	Extreme
Soil loss [$t.ha^{-1}. year^{-1}$]	> 1,5	1,6 - 3,0	3,1 - 4,5	4,6 - 6,0	6,1 - 7,5	7,5 <
Percent of agricultural land	3	26	25	17	11	18

Nowadays main external factor is economic situation, when every farm has to compete in market economy. It depends on management of each farm, how they solve their situation, which is the main internal factor and also basis of great difference of production level and quality of products and also farming system and farming practices quality among Czech farms.

Bad economic situation of farms in period of 1990 - 2006, led to:
- decrease in number of workers in agricultural primary production,
- limited technology innovation,
- low inputs in soil and crop management for a long time,
- decrease in livestock population, particularly in cattle,
- omitting fixed crop rotations, decrease in areas under good preceding crops (sugar beet, potatoes, legumes and perennial forage crops), considerable enlargement of areas planted with oil crops (rapeseed, poppy)
- minimization in soil tillage
- alternative farming and preferring measures supported by subsidies.

All these changes and factors influence, directly and indirectly, the agricultural system itself, its homeostasis, productivity and quality of products.

Decrease in workers in agricultural primary production (Figure 1) took place after social changes in the early 1990s. The agriculture of a strategic importance during the socialist period has been converted to market economy with 5 to 6fold lower state subsidies as compared with those in the late 1980s. In the period of three years (1991-1993), 270 300 workers left the agricultural primary production, which accounts for 48.9 % of the original status in 1990 (553 300). The decrease in agricultural workers has been continuing even though at a slighter rate. Also, the unfavourable conditions in agriculture settled for accession to the EU played a certain role. In 2005, the percentage of people employed in agriculture sunk to 27.2 % of that of 1990 (Figure 1). At present, less than 150 000 people are employed in the Czech agricultural primary production, which is the decrease by 3/4 in comparison with the state at the end of the socialist period.

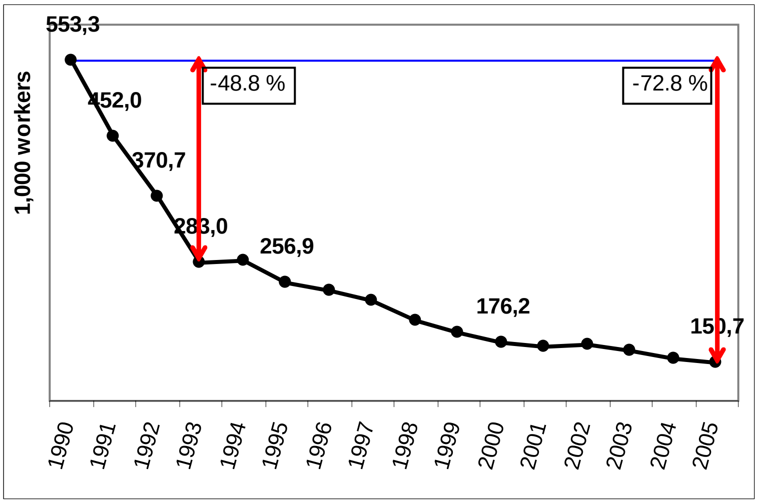

Figure 1. Number of workers in the Czech agriculture (in 1,000; source: CSO, adapted)

The average wage in the agricultural primary production was in 2007 73 % of the national average. It is one of the lowest in the CR but also the fastest increasing wage (CSO). Due to quitting the agricultural primary production by numerous academically educated personnel, the specialist level of agronomical practices has decreased in many agricultural enterprises and requirements for advisory services have been increasing.

In close connection to bad economic situation of agricultural enterprises **the technology innovation was limited** from the point of view of innovation of machinery but also introduction of new technologies which need capital investments**.** On the other hand, money saving measures, like minimisation in soil tillage and establishment of crop stands, were introduced into the praxis. About 30 % of arable land is managed in this way. However, this farming system leads to complex change of system and new difficulties occur. We deal especially with changed organic residues and soil moisture management and mineralization regime. Also pests and plant diseases treatment has to be changed when using minimisation.

Very important for soil fertility and also very significant is **decrease in agrochemical inputs in crop growing.** The graph in Figure 2 illustrates the historical evolution of consumption of main nutrients (NPK) in mineral fertilizers applied to 1 ha of farm land (1948-2004) and cereal yields (1920-2007). The relationship between the yields and supplied nutrients is confirmed by statistically significant correlations ($r = 0.48$ for NPK and 0.82 for N). Nutrient rates decreased from 272.6 kg NPK ha^{-1} in 1985 and have been stable on the level of ca. 90 - 100 kg NPK ha^{-1} since the early 1990s. In 2006, 77.4 kg N, 11.7 kg P_2O_5 and 9.4 kg K_2O in mineral fertilizers were applied to 1 ha of farm land (ME CR). The graph also indicates stagnation of cereal yields in the 1990s and their considerable variation over the last years. Interesting information is presented in Figure 3 demonstrating changes in emissions of acidifying gases since 1990. A considerable decrease in emissions is apparent particularly in SO_2 during the 1990s resulting from sulphur removal in coal power stations (owing to changes in coal combustion procedures). Because of an extensive increase in the rapeseed area (requiring more sulphur), some locations are in need of sulphur fertilization.

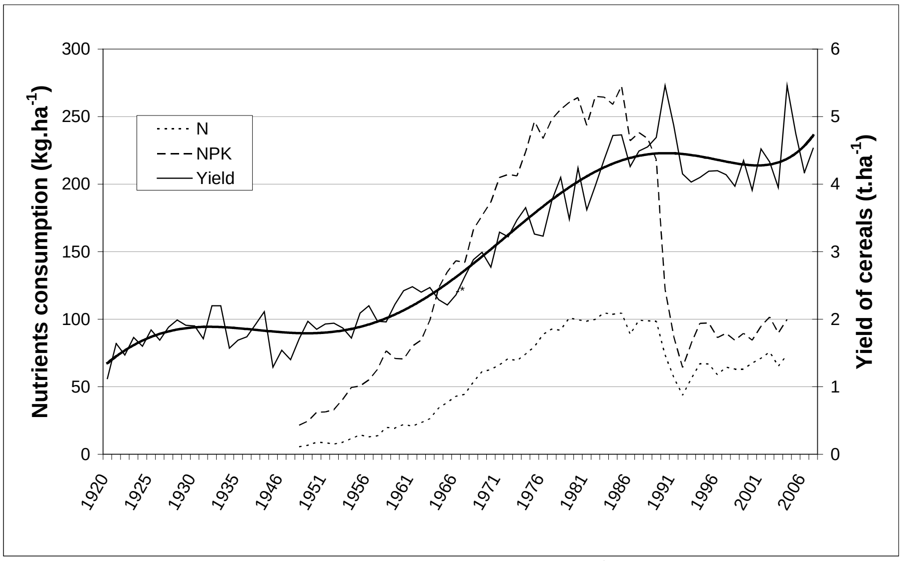

Figure 2. Applied amount of fertilizers (kg.ha^{-1}) and yield of cereals (t.ha^{-1}) (source: CSO)

The consumption of pesticides and their active ingredients for individual crop categories is given in Table 4. The decrease in the consumption of pesticides, above all herbicides and desiccants, was also recorded in the early 1990s (Figure 4). Similarly to trends in agrarian advanced countries, proportions of individual groups of pesticides have been changing during the recent years tending to a slight increase in fungicides consumption, including seed protectants and growth regulators. However, their consumption is still lower than that in West Europe.

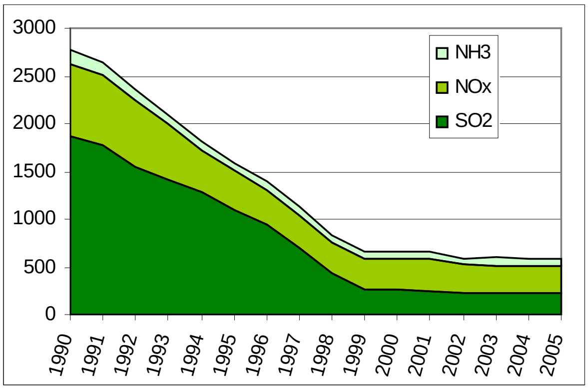

Figure 3. Emissions of acidifying gases (1,000 t; ME CR)

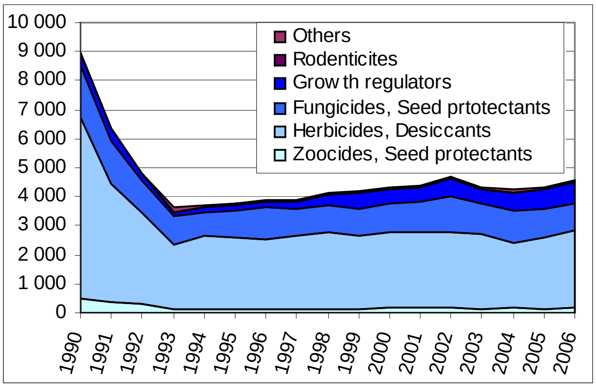

Figure 4. Applied amount of pesticides (t of active ingredient; ME CR)

After 1990 occurred also significant **decrease in the livestock population** (Figure 5). The highest decrease has been recorded in cattle. The number of livestock units per ha reduced from 0.66 in 1990 to ca. 0.32 at present. Likewise, pig and poultry stocks have fallen down. Particularly, the decrease in cattle and, in relation with it, the area under perennial forage crops, production of farmyard manure and consumption of bedding strew, has been negatively reflected in quality of organic matter incorporated into the soil and soil organic matter balance. Changed structure of organic matter influences the maintenance of soil fertility, particularly in lighter soils at higher altitudes.

Table 4. Consumption of plant protection products (in standard font) and active ingredient (in *italics*) in 2007 (kg, l .ha^{-1}) (SPA, 2008)

Categories	Total	Cereals	Maize	Sugar beet	Potatoes	Rapeseed
Herbicides and	**1,4995**	1,3546	2,9917	6,4943	1,5333	3,4884
desiccants	***0,6821***	*0,6185*	*1,8401*	*2,1011*	*0,5474*	*1,4341*
Fungicides and	**0,5881**	0,8573	0,0091	0,4856	3,3992	0,7834
seed protectants	***0,2306***	*0,2799*	*0,0004*	*0,1796*	*2,3368*	*0,1475*
Zoocides and	**0,2320**	0,1116	0,2453	0,3385	0,5333	1,4128
seed protectants	***0,0860***	*0,0362*	*0,0507*	*0,1162*	*0,1720*	*0,5908*
Growth regulators	**0,2013**	0,4415	0,0000	0,0212	0,0101	0,4659
	0,1650	*0,3725*	*0,0000*	*0,0037*	*0,0035*	*0,3441*
Rodenticides	**0,0624**	0,0846	0,0000	0,0000	0,0000	0,1880
	0,0011	*0,0008*	*0,0000*	*0,0000*	*0,0000*	*0,0049*
Others	**0,1237**	0,0397	0,1505	0,0978	0,0563	0,1236
	0,0281	*0,0243*	*0,1229*	*0,0816*	*0,0465*	*0,0747*
Total	**2,7069**	**2,8893**	**3,3967**	**7,4373**	**5,5322**	**6,4620**
	1,1929	***1,3322***	***2,0141***	***2,4821***	***3,1062***	***2,5960***

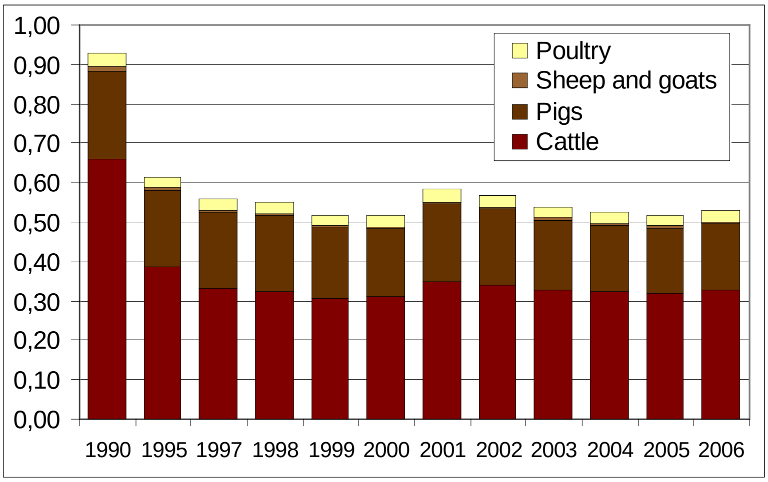

Figure 5. Livestock farming intensity and livestock population structure (livestock units; source: CSO, adapted)

Change in the grown crop structure was caused by unfavourable economic situation of agricultural enterprises in the 1990s and possibilities to market the production. Figure 6 illustrates the reduction in the area under annual and perennial forage crops due to the decrease in cattle stock, and the area planted to root crops (sugar beet and potatoes) and legumes. This decline was compensated for by larger areas of oil crops, particularly rapeseed and poppy as well as maize for grain. At present, the main profitable crops in the CR are particularly malting barley, bread wheat, rapeseed and poppy, and in the case of sale contracts, also potatoes and sugar beet. In general, changed structure of crops in interaction with market economy conditions led toward omitting fixed crop rotations and also to a lower proportion of good preceding crops in crop rotations and decrease in agrosystem homeostasis.

Destabilization of agrosystems increase rather than compensate for the impact of climatic and extreme weather changes, whose frequency has been increasing during the last years, on production of field crops. An example can be:

- winter destruction of winter crops (rapeseed, winter barley and winter wheat) in 2003 due to severe frosts without a snow cover,

- heat and drought in July and August in 2006,
- irregular local torrential rains (thunderstorms with hails) that considerably damage crop stands.

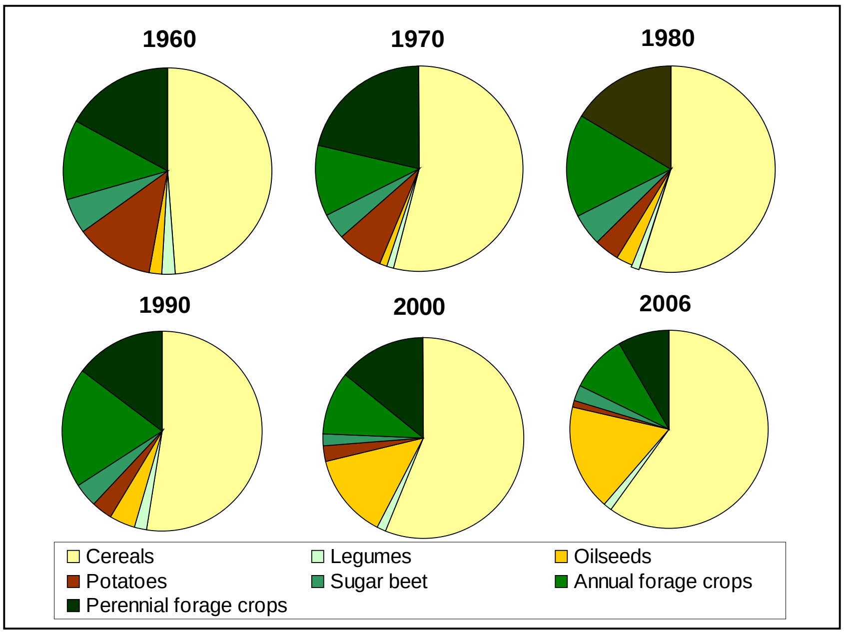

Figure 6. Structure of crops (% of total sowing area; source: CSO, adapted)

Conclusions

The main driving force for Czech farmers is economy. It is only the one of three columns of sustainable agriculture (ecologic, economic, social) but nowadays the most actual one. In past 15 years the economic problems were prioritized to the detriment of agronomical and social aspects. The structure of crops is determined by trade and also other activities (agronomical practices, soil tillage system, choose of fertilisers and pesticides etc.) are dependent on economics. Arable farming in the Czech Republic is now far beyond a good state at the end of about 15-year period of exhausting of internal sources and it will be difficult to eliminate its negative impacts in a short time. An increase of prices of agricultural commodities in recent years can improve the situation of agricultural enterprises but it has to be taken into account that economic problems will be solved as the first and the social and agronomic or environmental sustainability will come to the interest after then. In spite of supposed higher inputs of agrochemicals and innovation of machinery, sustainability of the current agrosystems can be problematic in the future due to inappropriate structure of grown crops in relation to expanding minimum soil tillage practices and breaking the rules of crop rotation. The applied farming practices increase rather than compensate for the impacts of climatic changes on production of field crops.

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THE INFLUENCE OF SOME FACTORS ON THE INCIDENCE OF SOME PATHOGENS AND PESTS ON WINTER WHEAT GROWN IN THE SYSTEM OF ORGANIC FARMING

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Abstract

The incidence of pathogen *Mycosphaerella graminicola* and thrips, aphids, cereal leaf beetles, midges, tortricid moths and sawflies was determined on winter wheat grown in organic farming system in years 2006 and 2007. The intensity of pathogen infection and abundance of pest were evaluated in relationship to some factors: straw management, fore-crop, variety and row width. The influence of some of these factors on pathogen and pests incidence was found out. The fore-crop and variety had significant influence on incidence of pathogen *Mycosphaerella graminicola.* Wheat grown after spring barley was infected less, than wheat grown after mustard and soya.

Key words: Winter wheat, pathogens and pests, organic farming

Introduction

The food quality and safety is very important nowadays. Conventional farming system uses the pesticide for sufficient production, but there are some risks for environment. Ecological farming system does not use the pesticides, or use only limited spectrum of pesticides. The occurrence of the pests or pathogens can cause a problem for ecological farmers, especially the keeping the pests occurrence down may be problematic.

The aim of this work was to find, which factors and how much influenced the occurrence of pathogens and pests in ecological farming system and recommend suitable farming technologies.

Material and methods

The influence of some factors on the occurrence and density of these species of pests of wheat was observed in years 2006 and 2007: thrips (*Limothrips denticornis, Haplothrips aculeatus*), aphids (*Sitobion avenae*, *Metopolophium dirhodum* and *Rhopalosiphum padi*), cereal leaf beetles (*Oulema melanopa, O. lichenis*), lemon wheat blossom midge (*Contarinia tritici*) and orange wheat blossom midge (*Sitodiplosis mosellana*), cereal leaf roller (*Cnephasia pumicana*) and tenthredinids (*Dolerus gonager*).

The evaluation was done on base of number of specimens on 10 stalks in several terms in each year (2006: 19.6., 28.6., 10.7., 18.7.; 2007: 22.4., 5.5., 13.5., 22.5., 31.5., 6.6., 20.6., 3.7.).

The intensity of infection by *Mycosphaerella graminicola* on wheat was evaluated at the same years. The seven point scale was used for evaluation (1.-without infection, 7.- leaf area totally covered with spots caused by fungus *Mycosphaerella graminicola*). The 20 leaves of each repetition were evaluated and disease index was calculated.

The four repetitions in each variant were evaluated. The multi-factorial analysis of variance by programme UNISTAT was used for identification of single factor influence.

The factors were

A. Foregoing crops
   a) barley + pea – years 2006, 2007
   b) mustard +pea – year 2006, safflower – year 2007
   c) soya – year 2006, 2007

B. Straw management
   a) straw removed
   b) straw crushed down and ploughed

C. Cultivars – only the code are given, authors provide the name of varieties
   a) winter food – A – year 2006
   b) winter forage – B – year 2006
   c) spring – C – year 2007
   d) spring – D – year 2007

D. Rows width
   a) 12,5 cm
   b) 25 cm

Results and discussion

The multi-factorial analysis showed that the occurrence of the thrips was affected by foregoing crops, the significant higher occurrence after barley and mustard was found in the year 2006. The straw ploughed influenced their occurrence 28.6. and 10.7., when the occurrence in varieties with straw ploughed was higher. The influence of the cultivar was found in 10.7. and 18.7., when the significant higher occurrence was in forage wheat A, but it may be caused by differences in maturing. The rows width had no influence on thrips occurrence. In the year 2007 there was significantly higher occurrence of the thrips only 22.4. and 5.5. in the straw ploughed variant. There were no significant differences between variants with straw removed and ploughed on the next terms of evaluation. The influence of foregoing crops, cultivar and rows width was not determined in this year.

The influence of foregoing crop on the aphid infestation was detected in 28.6.2006, when the highest infestation was determined on wheat after barley, the lowest infestation was on the wheat after soya. This factor had no influence in other terms of observation. The influence of other factors (cultivar, straw management, rows width) on the aphid infestation was not determined. The occurrence of aphids was not influenced by factors cultivar and row width in the year 2007, the factor straw management was determined in 5.5., 13.5. and 22.5., when the aphids occurrence in variant with straw removed was higher. The influence of foregoing crop was observed 5.5. and 3.7., when the infestation of wheat after barley was higher.

The influence of foregoing crop on infestation of cereal leaf beetles was observed in the year 2006 only in 14.6., when the lowest infestation was after soya, the highest after barley and mustard. This factor had no influence in other terms. The factors cultivar, rows width and straw management had not influence on cereal leaf beetle infestation in this year. The rows width had not influence on cereal leaf beetles infestation in the year 2007, but lower occurrence of these pests was found in straw removed variant, whereas higher occurrence was found in variant with straw ploughed. The foregoing crop and cultivar had no influence on the occurrence and density of cereal leaf beetles.

The lemon wheat blossom midge and orange blossom wheat midge were determined only in 10. 7. and 18. 7. in the year 2006. The foregoing crop, cultivar and straw management had no influence on the occurrence of these pests. The rows width had no influence only in 10.7. 2006. The higher occurrence of wheat blossom midges was 18. 7. in the narrow rows. In the year 2007 the occurrence of wheat blossom midges was not influenced by cultivar and by width of the rows. The foregoing crop had influence in 13. 5. and 20. 6., the occurrence of these pests was higher after barley. At 8. 6. higher occurrence was in variant with removed straw

The occurrence of the cereal leaf roller was higher in variant with straw removed in 14.6. and 18.7. 2006. The other factors had no influence on occurrence of this pest this year. The occurrence of the cereal leaf roller was higher in variant with straw removed in the period of 22. 4 - 8. 6. 2007, there was no difference between both of the variant in the next period. There is possible to exclude the influence of the straw management because of the biology of *C. pumicana*. The plots straw removed variant bordered with cart road bordered with trees and bushes, which are good for egg laying and overwintering of cereal leaf roller larvae. The plots with ploughed straw were farther for migration of caterpillars, and possibility of anemochoric spread is here lower. The occurrence of cereal leaf roller was not influenced by foregoing crop, cultivar and rows width.

The sawfly (*Dolerus gonager*) occurred in each variant in the year 2006 but it was no serious pest. No one factors influenced the infestation intensity of wheat. The occurrence of sawfly in the year 2007 was not influenced by rows width, the straw management had influence only in 5.5., when the higher density of larvae was found in variant with straw removed. The foregoing crop influenced the occurrence of this pest only in 5. 5. in the variant after soya. The factors cultivar and rows width had not influence on occurrence of sawfly larvae.

The most important pests on the trial plot were thrips, aphids, cereal leaf beetles and wheat blossom midge. The larvae of the sawfly did not cause important injuries. The occurrence of cereal leaf roller was bound on occurrence of trees and bushes on the plot margins, where are good conditions for eggs laying and overwintering of their caterpillars. The other species occurred on the plot: click beetle (*Agriotes* sp.), bugs larvae and adults especially *Lygus rugulipennis*, *Calocoris norvegicus, L. pratensis*, the adults of *Euragaster maura* and *Aelia acuminata*. These species were not serious pests in this trial. The adults of the *Cephus pygmaeus* were observed, the influence of the particulars factors was not determined in this case because of great mobility of this species.

The number of parasitoids and predators especially from orders Hymenoptera and Coleoptera occurred in all of variants. It is possible to suppose they reduced some species of pests, especially aphids.

The cultivar influenced the occurrence of pathogen *Mycosphaerella graminicola* in both years. The influence of foregoing crop was determined in the year 2006, too (the lowest infection after barley). The rows width influenced infection in the 2007; the infection was lower in broad rows. The straw management influenced the infection in this year, the infection was lower in variant with removed straw.

It is evident, there is no possibilities to eliminate infection by pathogens and infestation by pests in organic farming. The efficient agriculture measurements and suitable cultivar may reduce the occurrence of pathogens and pests and ensure good yield and quality of wheat. It is possible to recommend removing of the straw (post-harvest residue) from stand, because it can be a growth medium for survival and propagation of pathogen *Mycosphaerella graminicola*. The suitable foregoing crops are necessary, it was barley in our experiment.

The preventive measurements would be focused on most important pests, which occur in region. For instance, the good effect against the thrips was examined in variant of removed straw, but the occurrence of the aphids were higher in this variant.

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THE ANTHROPIC DEGRADATION OF THE SOILS FROM GORJ DISTRICT – ROMANIA

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Abstract

Within the Gorj District, Romania, the main pollution sources are: the mining industry, building material industry and energetical industry; they affect as much as 78,909.4 ha which means 27% of the District surface.

The main polluting sources are physical and chemical. By physical pollution there are degraded 13,034 ha where the former soils were totally replaced due to the surface mining activity.

The chemical pollution affects 65,874 ha by the following forms: salty water, powerplant ash, heavy metals and dust from the cement factories.

Keywords: pollution, anthropic degradation, surface mining

Introduction

The Gorj District is located in the Southwestern part of Romania and is more affected that other districts by anthropic pollution of soils.

The main polluting sources that affect the Gorj District are:

1. The mining industry = 13,504 ha of which:
    - surface quarries = 13,034 ha
    - oil extraction = 474 ha.
2. The energetic industry – lignite powerplant ash – 50,000 ha.
3. The building material industry by cement dust – 15,000 ha

The total surface that is affected by anthropic pollution is 78,909 ha.

Material and Metod

There have been studied the degradation phenomena of the soils as a result of these pollution forms by chemical and physical analyses; the analyses have been made before and after the pollution.

Results and discussions

The way these forms of pollution and degradation of the soils from the Gorj District affect different soil types is presented in the table 1.

Table 1

The polluted soils from Gorj District

The soil class	The soil	Factors and polluting types									Total	%
		Physical pollution				Chemical pollution						
		Excavations	Deposit	Underground activities	Total	Mixed	Salty water	Ash	Cement ash	Total		
Cambisoils	C.E.	2017.38	2295.10	69.20	4381.68	68.10	125.30	8295.00	8501.00	16989.40	21371.08	27.08
Luvisoils	El	52.50	-	-	52.50	-	-	-	-	-	52.50	0.06
	LV	1318.32	423.50	631.6	2373.42	244.80	163.70	18650.0	2111.0	21169.5	23542.92	29.83
	LV	1024.04	329.00	-	1353.04	47.00	-	6021.00	1083.00	7151.00	8504.04	10.77
	VS	68.01	-	-	68.01	-	195.40	78.00	-	273.40	341.41	0.43
Protisoils	SA	124.10	119.30	-	243.40	-	-	6535.00	2783.00	9318.00	9561.40	12.11
	SA	10.65	-	-	10.65	29.50	1.00	545.00	235.00	810.50	821.15	1.04
	SR	-	-	-	-	-	-	760.00	83.00	843.00	843.00	1.06
	TE	-	-	-	-	-	-	4585.00	-	4585.00	4585.00	5.86
Complexes and associations of soils	Cx	2006.50	514.60	2030.8	4551.9	-	-	4531.0	204.0	4735.0	9286.9	1176
Total		6621.5	3681.5	2731.6	13034.6	389.4	85.4	50000	15000	65874.8	78909.4	100

Of the total anthropic polluted surface of 78,909 ha the most polluted soils belong to the cambisoils and eutricambisoils class, respectively, luvosoils.
The eutricambisoils are affected on a total surface of 21,371 ha of which physical pollution 4,381 and chemical pollution of 16,989 ha.
The luvosoils are affected on a total surface of 23,542 ha of which physical pollution of 2.373 ha and chemical pollution of 21,169 ha.
The table 2 shows the physico-chemical features of the stagnic luvosoil before pollution.

Table 2

The main physico-chemical features of the stagnic luvosoil before pollution

The horizon	Depth cm	The main physico-chemical features												
		Chemical							Physical					
		pH	H %	$CaCO_3$ %	N.I.	P ppm	K ppm	V %	Sand I %	Sand II %	Loam %	Clay I %	Clay II %	Texture
Ao	18	6.5	3.6	-	2.94	1.9	116	80.1	14.2	36.6	37.7	36.3	15.5	SL
El	15	5.5	0.8	-	0.52	2	48	62	10.2	30.7	38.5	30.8	20.6	LP
EB	7	7	-	-	-	-	-	-	-	-	-	-	-	-
Bt(w)	30	5.5	0.6	-	0.41	2	68	65	14.9	17.1	27.7	56.7	38.3	LA
Bt(w)	30	5.6	0.5	-	0.37	2	92	67.4	23.8	15.2	15.1	55.9	45.9	LAP

A. The physical pollution

The physical pollution has unfold after coal and oil extraction. Such way, the place of natural soil has been taken by geological materials of a high physical and chemical diversification.

The table 3 shows the size of the geological deposits. It can be appreciated that the geological have the following size structure: 20% sandy texture, 60% loamy texture and 10% clay texture and 10% pebbles.

The table 4 shows the main chemical features of the geological deposits. No matter their size, their chemical composition is at least satisfactory (pH=4.9-8.9, lime till 18.5%, soluble phosphorus 2.3-94 ppm, soluble potash 14-172 ppm, the bases saturation degree > 73%).

B. The chemical pollution

The most frequent chemical pollution forms are:

1. The oil and salty water pollution

This kind of soil pollution is encountered when damages are produced to the extraction devices and transport and consist of leakage of the oil and the salty water to the soil surface and accumulation in low zones. Due to this process the soil is polluted on a depth of 5-20 cm by oil with the following consequences:

- all life forms die;
- the exchanges with the exterior are interrupted;

Under the depth of polluted zone of 5-20 cm the soil features remain unchanged (table 5).

2. The salty water pollution

The salty water pollution is produced during the oil and natural gases extraction. Due to the pressure the water bursts affecting the nearby soils. In function of the drilling point, soil texture and the quantity of salty water this infiltrates into the soil till 150 cm. In these conditions it modify the soil chemical properties by increasing the sodium and chlorine contents over the admissible limits.

Table 3

The physical characterization of the geological deposits brought to the surface after the physical pollution

Texture	%	Types of materials	Physical features					
			size					Texture
			Sand I	Sand II	Silt	Clay I	Clay II	
Sandy	20	Sands	1.9-51.0 (3.6-43)	34.7-88.4 (36.1-65)	3.7-17.7 (4.1-15.8)	5.1-18.7 (15.5-16.5)	2.2-11.8 (2.8-10.5)	N-NL
Loam	60	Silty sands	2.2-47.0 (3.1-41.0)	24.3-63.6 (26-52)	8.7-25.6 (9.5-22.5)	18.2-37.2 (19.5-35)	11.4-22.9 (12-20)	LN
		Silt	1.6-24.9 (2.5-21.2)	28.3-56.6 (30-53.0)	15.6-26.4 (16.5-25.0)	32.2-44.3 (33.0-43.0)	19.1-32.0 (20-31)	L
		Clayey silt	0.2-25.1 (0.5-19.5)	20.8-39.3 (21.5-36)	9.1-33.4 (10-32.0)	17.7-58.3 (18-56)	24.5-43.5 (25-42)	LA
Clay	10	Clay	0.4-10.7 (0.6-9.5)	6.3-25.3 (6.5-23.6)	14.6-51.6 (15.2-47.5)	62.3-88.6 (63.6-69.5)	40.7-72.8 (41.5-61.6)	AL-A
-	10	Pebbles	-	-	-	-	-	-

Table 4

The chemical characterization of the geological deposits brought to the surface, after the physical pollution

Text.	%	Types Of materials	Chemical features									
			pH	$CaCO_3$ %	Org. matter %	C %	NI	P_2O_5 ppm	K_2O ppm	B.S. me/100g soil	T me/100g soil	V %
Sandy	20	sands	6.2-8.7 (6.8-7.2)	0.3-13.2 (0.5-6.0)	0.03-1.5 (0.05-1.28)	0.02-0.87 (0.04-0.53)	0.03-1.5 (0.05-1.28)	3.2-14 (3.5-6.4)	14-16 (14-15)	7.2-9.2 (7.5-8.4)	8.7-11.1 (8.9-10.5)	80-100 (83-95)
Loam	60	Sandy silts	6.2-8.5 (6.6-7.5)	0.1-14.7 (0.3-9.5)	0.16-3.0 (0.25-2.5)	0.09-1.74 (0.1-1.36)	0.16-2.76 (0.25-2.20)	3.4-94.0 (3.6-32.1)	32-166 40-87	8.9-24.5 9.3-21.4	10.1-25.2 10.5-22.3	88.1-100 90-96
		Silts	5.4-8.8 (5.7-7.7)	0.1-15.6 (0.9-13.0)	0.12-5.92 (0.25-4.70)	0.06-3.43 (0.1-3.2)	0.12-5.27 (0.2-4.6)	3.0-45.6 (4.0-36.1)	22-132 25-115	21.3-39.5 24.0-32.5	24.1-44.3 26.0-39.0	89.1-100 (91-97)
		Clayey silts	6.8-8.9 (7.0-7.7)	0.1-9.8 (1.0-9.5)	0.40-6.04 (0.45-5.90)	0.23-3.50 (0.25-3.2)	0.40-5.64 (0.5-5.2)	2.30-53.2 (2.5-38.0)	24-116 26-110	11.9-28.0 12.5-26	12.3-29.4 13.1-28.2	93.0-100 (94-96)
Clay	10	Clay	4.9-8.5 (5.5-7.2)	0.71-26.0 (1.50-18.5)	0.32-4.52 (0.40-4.40)	0.41-2.62 0.50-2.50	0.32-4.16 (0.4-3.95)	6.6-4.9 7.5-35	96-172 97-165	24.6-39.1 25.1-36.5	33.1-42.3 14.5-40.3	74.3-100 (75-96)
-	10	pebbles	-	-	-	-	-	-	-	-	-	-

Table 5

The main physico-chemical features after salty water pollution

The hori zon	Depth cm	The main physico-chemical features												
		Chemical							Physical					
		pH	H %	$CaCO_3$ %	N.I.	P ppm	K ppm	V %	Sand I %	Sand II %	Loam %	Clay I %	Clay II %	Text ure
Ao	21	5.7	1.99	-	1.26	2.18	10.2	63.7	15.0	36.2	30.2	-	18.6	SL
El	19	5.4	1.07	-	0.59	2.18	59.7	56.0	13.0	33.4	31.0	-	22.6	LN
EB	10	5.3	0.73	-	0.45	0.87	107.9	61.5	10.0	26.0	25.3	-	38.7	LA
Bt(w)	50	5.5	-	-	-	-	-	62.4	8.5	22.6	19.8	-	59.1	AL

In the table 6 there is presented a typical polluted eutricambosoil by salty water where the sodium content has increased till 22.53 me/100 g soil and the chlorine till 802.7 mg/100 g soil.

Table 6

The main features of the sodic eutricambosoil after the salty water pollution

The hori zon	Depth cm	The main physico-chemical features												
		Chemical							Physical					
		pH	H %	$CaCO_3$ %	N.I.	P ppm	K ppm	V %	Sand I %	Sand II %	Loam %	Clay I %	Clay II %	Text ure
Ao	29	7.6	2.7	13.08	2.7	91.1	22.53	802.7	5.7	34.1	17.6	52.3	42.6	LA
Bv1	20	6.1	0.96	13.0	64	86.8	21.90	152.3	10.1	34.6	13.5	48.2	41.8	LA
Bv2	28	6.3	0.66	8.7	50	75.2	7.30	155.3	2.8	27.1	33.2	56.2	36.9	PAL
Bv3	17	6.5	-	-	-	83.9	1.03	79.0	1.0	24.6	31.0	63.2	43.4	LA

Also, in an proxicalcaric aluviosoil (table 6) by salty water pollution the sodium content has increased till 9.29 me/100 g soil and the chlorine till 724.2 mg/100 g soil.

3. The powerplant ash pollution

There have been researched the soils from nearby powerplants Rovinari and Turceni. The analyzed soil profiles have been placed 1,000 m SW of the pollution source. The SW is the direction of the dominant wind.

After 30 years of powerplant ash pollution the main physico-chemical features of the nerby soil have less changed (table 7).

Table 7

The main features of the stagnic luvosoil after the powerplant ash pollution

The horizon	Depth cm	The main physico-chemical features												
		Chemical							Physical					
		pH	H %	$CaCO_3$ %	N.I.	P ppm	K ppm	V %	Sand I %	Sand II %	Loam %	Clay I %	Clay II %	Texture
Ao	21	5.6	1.31	-	0.99	7	84	76.2	9.3	40.1	21.2	42.8	29.4	L
El	12	5.3	1.14	-	0.79	3	88	69.3	9.7	36.6	21.8	46.9	31.9	LA
Bt(w)1	23	5.8	0.45	-	0.35	4	122	78.5	6.0	32.6	18.8	55.5	42.6	LA
Bt(w)2	39	6.5	-	-	-	7.2	132	85.9	5.6	19.7	31.7	57.4	43.0	LA
Cca	5	8.7	-	8.6	-	2.2	108	100	6.2	33.4	16.5	55.0	43.9	LA

4. The heavy metals pollution

The determinations have unfolded at the Rovinari powerplant zone on a diameter of 15 km on NE and EW directions as well as on intermediary directions. The soil samples have been taken from the first 20 cm from soils that belongs to the following clases: eutricambosoils, preluvosoils, luvosoils. Within the table 8 there are presented the concentration intervals for each element in ppm.

Table 8

The loading degree by heavy metals of the soils from the Turceni and Rovinari zone

Soils	Specification	Heavy metals, ppm							
		Copper	zinc	Lead	cobalt	Nickel	Manganese	Chrome	Cadmium
CE, El, LV, AS	Conc. intervals	14.5-52.0	35.5-506.5	14.0-52.0	6.0-19	10.0-59.5	70.0-832.5	36.5-91.0	0.65-1.20
	Normal content	<21	<101	<21	<21	<21	<31	<31	<1.1
	Maximal admissible limits	100	300	100	50	50	1500	100	3

There can be observed that only the cobalt and manganese are in the normal limits. The other elements overpass in some points the normal limits and the zinc and nickel overpass the maximal limits.

5. The cement dust pollution

There was researched a zone that was affected by cement dust from the Barsesti cement factory. The distribution of the cement dust within the nearby zone is made especially on the wind dominant direction (SW).

There have been made researches both horizontally and vertically, pH determinations, lime, in comparison with the situation before the cement factory was built. On horizontally the cement dust was transported till 15 km SW yet the pH and $CaCO_3$ changing are observed only at 8 km. Vertically there is observed the pH and $CaCO_3$ modification. The depth of $CaCO_3$ leaching depends on the soil texture, the rainfall, the pebbles content and the quantity of deposited dust.

Table 9

The physico-chemical modifications of the soils after cement dust pollution

The BMti soil	The main physical features							Modif. 1960-2000				
								pH		CaCO3		Leaching depth
	Sand I	Sand II	Silt	Clay	Pebbles	T.P.	H.C.	1960	2000	1960	2000	
Ao 25 cm	14.5	37.4	34.9	13.2	-	50	427	5.8	7.6	-	0.73	100 cm
Bv1 30 cm	8.5	39.0	36.8	15.7	-	40	59	5.42	5.52	-	-	
Bv2 45 cm	65.2	8.4	12.5	13.0	-	39	41	5.2	5.2	-	-	

In the table 9 there are presented the pH modifications and the $CaCO_3$ content after 40 years of cement dust pollution. On two soils from the zone (500 m SW of the pollution source) there was observed that the soil with high pebbles content (40-90%) the lime is leached till 110 cm. The lime content at the surface is 3.7% and it decreases to 0.17% in the depth and the pH, over 40 years of polluting increases from 5-5.8 to 7.3-8.2. In the soil without pebbles the depth of lime leaching is 40 cm, and it reached 0.28%-0.73% and the pH has increased from 5.4-5.8 to 7.4-7.6.
The depth of leaching is higher for the soils that have pebbles due to the larger pores.

Conclusions

1. The main polluting sources from Gorj District are:
- the mining industry
- the energetic industry
- the building materials industry.
2. The polluted surface by main polluting sources is of 78,909.4 ha (2000 year) of which:
- physical pollution = 13,034.40 ha
- chemical pollution – 65,874.80 ha.
3. The physical pollution has determined the radical modification of the existing soils: 60% of the geological material brought to the surface has good suitability for cropping. The chemical composition is satisfactory yet not sustainable.
4. The chemical pollution has determined changes as follows:
- the oil and salty water pollution has determined the impregnation of the soil on 5-20 cm depth with direct negative effects on soil life and indirect on soil exchanges with the atmosphere.
- the salty water pollution modify the chemical composition of the soils by increasing their sodium and chlorine content over the maximal limits.
- the powerplant ash pollution has not produced quantifiable changes yet.
- the heavy metals pollution has determined the punctual increasing of the excepting the cobalt and manganese that are kept in normal limits. The zinc and nickel overpass in some points the maximal limits.
- the pollution by cement dust has determined increasing of the pH from 5-5.8 to 7.3-8.2 at 500m away from the factory and the lime content has increased till 3.7%.

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REMEDIATION OF PETROLEUM-CONTAMINATED SOILS USING COMPOST AND NON-TRADITIONAL CROPS

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Abstract
In a model small-plot trial established and carried out in the years 2005 – 2007 a two-phase technology of remediation of soil contaminated with diesel oil was tested "*in situ*" using the action of organic matter with high microbial activity (compost) incorporated in the soil and the rhizosphere of subsequently sown non-traditional crops. At the same time yields of these crops grown with different levels of diesel oil contamination of soil were assessed. The assumption that the process of biological decontamination of petroleum-polluted soil "*in situ*" is positively affected by the action of organic matter with high microbial activity (forced compost) incorporated into the soil and the rhizosphere of test plants was verified. During trial establishment and after crop harvest the content of non-polar extractable substances (NES) was analyzed in all treatments and throughout all experimental years.

Keywords: revitalization, diesel oil, compost, non-traditional crops

Introduction
Macek *et al*. (2007) denoted phytoremediation as a process of using green plants for degradation, retention or accumulation of various harmful environmental contaminants. The plants can remove organic, aliphatic and aromatic substances and also heavy metals from the environment. Organic substances can be degraded or transformed by enzyme systems. The interaction of plants with rhizospheric microorganisms consists in providing support to these organisms with plant root exudates. The exudate substances may serve not only as a source of nutrients but some substances may directly induce degradation enzymes of microorganisms. The aspects of phytoremediaton and rhizoremediation were also discussed in the book prepared by the team of Macková *et al.* (2006), which predominantly characterized ecological aspects, application techniques and methods, analytical procedures, etc.
Microbial degradation of petroleum hydrocarbons in soil is an efficient and economically advantageous biological method with no adverse effects on the environment. Bioremediation technology can be successfully used for solving ecological stresses when the contaminated environment is not toxic to the basic component of the sanitation process, i.e. microorganisms.
Taking a decision about the appropriateness of applied biotechnologies and the choice of suitable technological procedures becomes responsible only when the toxicity and biodegradability of contaminants is verified by tests (Siglová, Čejková *et al*., 2006). Bioremediation of petroleum hydrocarbons contained in the contaminated soil by adding biological sludge and other additives was studied by Katsivela, Moore *et al.* (2005). The problems of remediation of petroleum contaminated soils were also discussed in a number of institutes abroad (Welander, 2005, Banks, Schultz, 2005, Molinabarahona *et al.,* 2005). Interesting is the information about the possibility of using genetically modified microorganisms of the strain *Pseudomonas* sp. for remediation of the environment, predominantly for biodegradation of organic pollutants. These patented genetically modified bacteria are, for example, capable of degrading petroleum substances into hydrocarbons

which can be then metabolized by the sea plankton (Pavlíková, Macek, Macková, Balík, 2005).
Medveď (2007) studied the problems of biodegradation of petroleum products in contaminated soils by composting. In the course of two years he conducted an experiment in six plastic composters filled with heavily contaminated soil and 50 kg of fresh immature farmyard manure. The soil was contaminated with a mixture of diesel oil and motor oil at a weight ratio of 1:2. He found out that after 120 days it was possible to degrade petroleum substances in the soil heavily contaminated with petroleum products with 79 – 86 % efficacy.

Material and methods
In a model small-plot trial established and carried out in the years 2005 – 2007 a technology of two-phase remediation of soil contaminated with diesel soil was tested *in situ* by using the action of organic matter with high microbial activity (compost) incorporated into soil and the rhizosphere of subsequently sown non-traditional crops. Herbage and dry matter yields of these crops were assessed, always after treatment with different levels of soil contamination with diesel oil.

In the small-plot trial the following evaluations were carried out:
- NES (non-polar extractable substances) content in the soil (controls) - in $mg.kg^{-1}$DM
- Total NES content in soil contaminated with diesel oil – in $mg.kg^{-1}$ DM, crop yields (herbage and DM).

In the experimental years 2006 - 2007 these experimental crops were tested:
safflower *(Carthamus tinctorius L.),* cluster mallow *(Malva verticillata L.,)* rye *(Secale cereale,var.multicaule METZ .ex ALEF***.,** and common fenugreek (*Trigonella foenum – graecum*),

They were grown with different levels of soil contamination with diesel oil:
- control, without diesel oil application, seeding of test crops only
- soil (without diesel oil application) + compost + seeding of test crops
- soil + compost + diesel oil at a rate of 0.5 l per m^2,
- soil + compost + diesel oil at a rate of 1.0 l per m^2,
- soil + compost + diesel oil at a rate of 1.5 l per m^2 ,

Determination of NES content
The prepared extract was measured by an IR-spectrometer at predetermined wave numbers and the calibration of the method was made using an external standard. Measurements were made in accordance with the standards ČSN 75 7505 and TNV 75 8052. Analyses of NES content in the soil were performed by the GEO-test Brno, a.s. laboratory as before.
In control treatments after trial establishment, NES content was analyzed as a background value for the assessment of the dynamics of remediation of soil contaminated with diesel oil.
The results of NES analyses were statistically treated using analysis of variance.

Results and discussion
In the autumn of 2005 a small-plot trial was established with the following treatments (test crops, applied rates of diesel oil) with the aim of verifying phytoremedial effects of the above mentioned non-traditional crops on soils contaminated with diesel oil in particular conditions (Troubsko site).
In that year NES initial values were analytically determined in each experimental treatment.
In the years 2006 and 2007 the test crops were sown using a small-lot seeder. The harvest of the test crops was carried out gradually depending on stand maturity in individual years.

Soil decontamination

With the increased initial contamination of soil with diesel oil (see trial methodology) the content of NES in the soil in the autumn of 2005 markedly increased. In Treatment 3 it was 550 mg/kg of DM and in Treatment 4 it was 3 400 mg/kg of DM. The highest values of NES content in the soil were recorded in Treatment 5, being 11700 mg/kg of DM (Table 1, figures 1 – 4).

In the year 2006 the best performing crop in the process of soil decontamination (like in pot trials established in Troubsko) was common fenugreek. After this crop there was the highest decrease in NES content in the soil (e.g. in Treatment 5 the decrease in NES content after this crop within one growing season was 93.7 %). The lowest decrease in NES content in the soil was recorded in the same treatment after growing safflower, the decrease was 76.8 %.

In the following experimental year (2007) NES values decreased almost to the level of NES values in control treatments, i.e. treatments without compost and diesel oil applications.

NES content in the soil between the experimental years and the treatments was statistically significant.

Yields of test crops per m^2 in relation to treatments in the years 2006 and 2007 are given in Table 2.

Growth and development of stands seeded in the year 2006 were markedly affected by adverse ambient conditions, e.g. soil moisture on 28 July of that year reached the critical level, being 7.8 to 10.9 % in relation to particular treatments. These adverse conditions in interaction with the contaminated soil had a negative effect on the growth of all test crops in the year 2006. The stands were very varied, plants dried up especially in the initial growth stages, the course of blooming was also very inconsistent, and the stands had to be prematurely harvested because of drying up. In spite of these adverse conditions, the trend recorded in pot trials was confirmed. Herbage and DM yields decreased with the increasing rates of diesel oil in the soil.

In the subsequent year (2007) stand emergence was negatively affected predominantly by a shortage of rainfall, especially common fenugreek was very sensitive to poor rainfall. Crops were harvested in stages, the first to harvest was common fenugreek (26 July) and the last was cluster mallow (30 August). From this viewpoint, yields per unit area were very inconsistent especially as a result of uneven emergence and at later stages as a result of drying (common fenugreek).

Conclusion

In model small-plot trials a hypothesis was tested out that in the course of biological decontamination of soil polluted with petroleum substances „*in situ*“ this process was positively affected by the action of organic matter with high microbial activity (forced compost) incorporated into the soil and the rhizosphere of subsequently seeded crops. The small-plot trial continues in the year 2008, following the proposed methodology.

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Acknowledgement

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Tab. 1: Decontamination of soil polluted by diesel oil (Troubsko)
(average value NES in mg/kg of dry matter)

Crop	Years	Variant	Initial state Spring 2006	After decontamination Autumn 2006	After decontamination Autumn 2007
Fodder mallow *(Malva verticillata)*	2006/2007	1	20	20	20
		2	23	80	52
		3	550	257	43
		4	3400	460	44
		5	11700	1457	42
Safflower *(Carthamus tinctorius)*	2006/2007	1	20	20	22
		2	23	32	51
		3	550	187	41
		4	3400	583	35
		5	11700	2720	39
Rye *(Secale cereale)*	2006/2007	1	20	56	20
		2	23	48	20
		3	550	227	31
		4	3400	993	66
		5	11700	1123	29
Fenugreek *(Trigonella foenum-graecum)*	2006/2007	1	20	20	20
		2	23	55	84
		3	550	207	32
		4	3400	433	32
		5	11700	738	70
Without plants	2006/2007	1	20	20	20
		2	23	34	27
		3	550	93	43
		4	3400	477	63
		5	11700	1017	171

Fig. 1

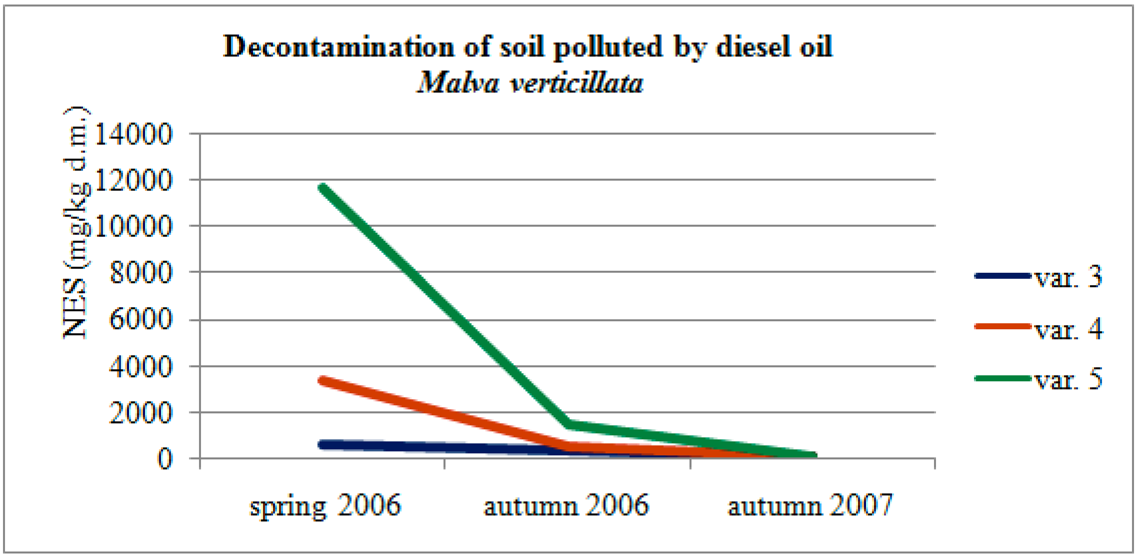

Decontamination of soil polluted by diesel oil
Malva verticillata
NES (mg/kg d.m.)
14000
12000
10000
8000
6000
4000
2000
0
spring 2006
autumn 2006
autumn 2007
var. 3
var. 4
var. 5

Fig. 2

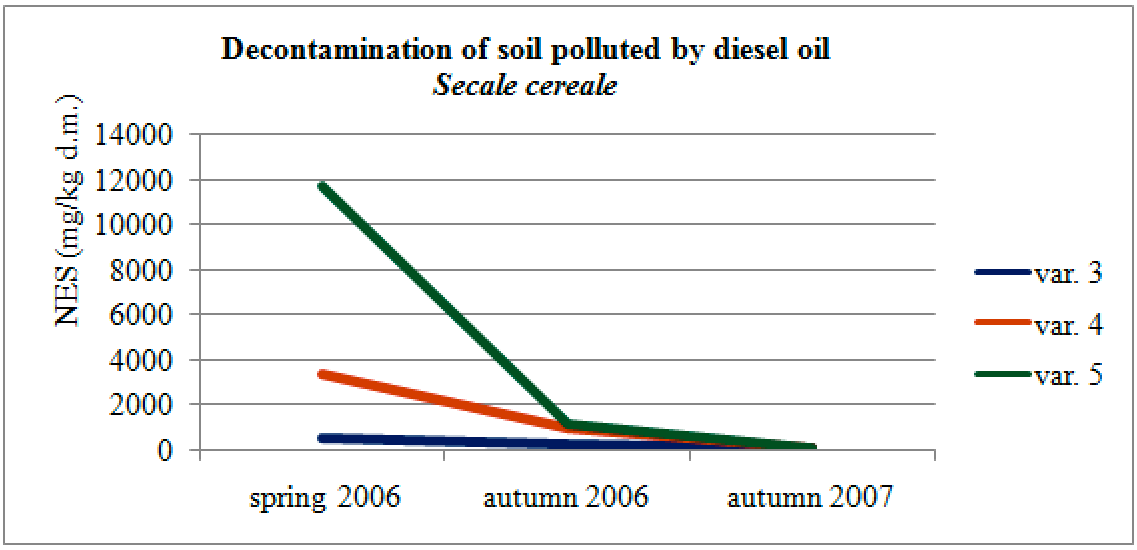

Decontamination of soil polluted by diesel oil
Secale cereale
NES (mg/kg d.m.)
14000
12000
10000
8000
6000
4000
2000
0
spring 2006
autumn 2006
autumn 2007
var. 3
var. 4
var. 5

Fig. 3

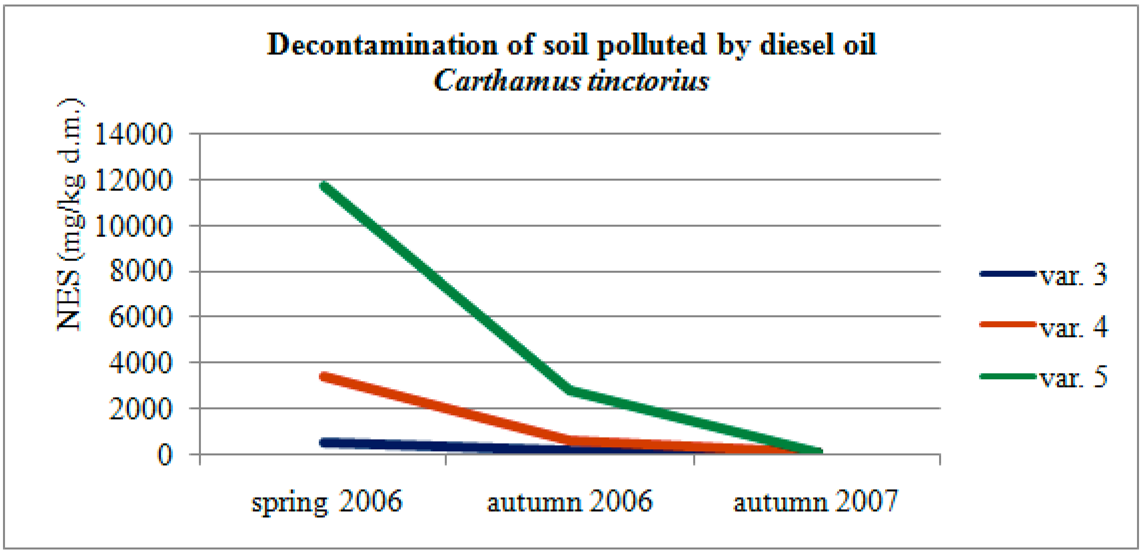
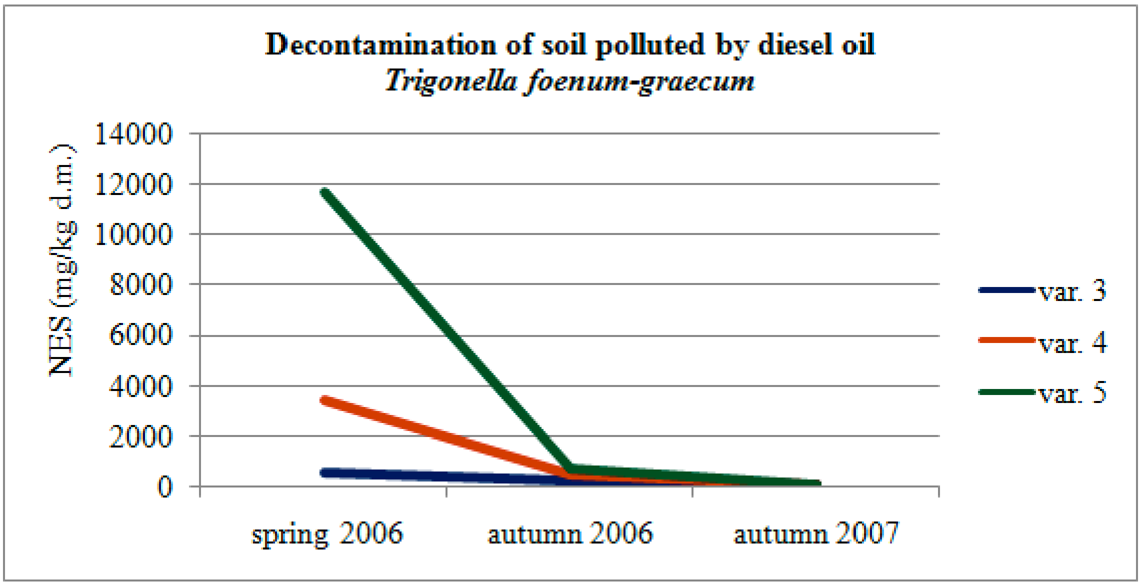

Decontamination of soil polluted by diesel oil
Carthamus tinctorius
NES (mg/kg d.m.)
14000
12000
10000
8000
6000
4000
2000
0
spring 2006
autumn 2006
autumn 2007
var. 3
var. 4
var. 5

Fig. 4


Decontamination of soil polluted by diesel oil
Trigonella foenum-graecum
NES (mg/kg d.m.)
14000
12000
10000
8000
6000
4000
2000
0
spring 2006
autumn 2006
autumn 2007
var. 3
var. 4
var. 5

Tab. 2: Plant weight (g/m2) according to experimental variants

Crop	Variant	2006		2007		Average	
		Green matter	Dry matter	Green matter	Dry matter	Green matter	Dry matter
Rye ***(Secale cereale)***	1	1200	550	750	650	975	600
	2	2900	1000	1000	850	1950	925
	3	2800	900	1150	950	1975	925
	4	1850	700	700	650	1275	675
	5	1000	650	650	550	825	600
Fenugreek ***(Trigonella foenum-graecum)***	1	735	258	2700	1649	1718	954
	2	546	328	383	236	465	282
	3	291	150	441	247	366	199
	4	346	169	1200	655	773	412
	5	412	188	1800	550	1106	369
Safflower ***(Carthamus tinctorius)***	1	4400	2350	5250	2950	4825	2650
	2	3950	2050	3600	2450	3775	2250
	3	4650	2250	3600	2600	4125	2425
	4	5150	2450	4100	2700	4625	2575
	5	6200	2700	5000	3150	5600	2925
Fodder mallow ***(Malva verticillata)***	1	12250	4900	6600	2150	9425	3525
	2	8200	3600	3650	1450	5925	2525
	3	8000	2600	4300	1950	6150	2275
	4	6600	2000	6200	2350	6400	2175
	5	7000	2200	7450	2800	7225	2500

THE CHARACTERIZATION OF THE GANGUE DUMPS FROM HUSNICIOARA, MEHEDINTI COUNTY, ROMANIA AND ECOLOGICAL BUILD UP MEASURES

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Abstract
After coal extraction and depositation of the gangue there are formed dumps that replace the initial soils within the Husnicioara quarry perimeter. The initial soils were: reddish preluvosoil, typical preluvosoil, vertic luvosoil, albic luvosoil; they were replaced by the psamic entiantrosoil that has not favoraable features for plant growth. Its texture is sandy-loamy or sandy in comparison with the initial one that was clayey, the reaction is weak or moderate alkaline, in comparison with formerly weak acid, the humus content has decreased to 0.5% from 1.5-2.2% and the phosphorus and potash contents have severelly decreased.
This soil belongs to the Vth class of fertility, in comparison with the former ones which belonged to the IInd or IIIrd class.
Their ecological recovery can be made using suitable crops as annual and perenial pulses and by using large quantities of organic and chemical fertilizers. The goal ist o enrich the new soil in organic matter.

Keywords: gangue dumps, compost, fertilizers, corn, sunflower, chick pea, alpha alpha

Introduction
The lignite extraction from surface quarries determines the most aggressive form of soil degradation. They produce total or partial transformations of the soil on a period of 10-15 years. There take place the inversion and the blending of the geological strata, the natural migration of the nutritive elements from the soil, the intensification of the erosion process, the landscape degradation the place of the former soil being taken by gangue deposits. The former soil has disappeared or was excavated along with the gangue material and deposited separately the result being a heterogeneous mixture of geological strata.

Material and Metod

In order to research the fertility degree and the main agrochemical features of this degraded soil and to establish the needed measures for their recovery there was set up an experiment in Husnicioara Mehedinti quarry. There have been made several soil profiles. For the ecological buildup there have been made several trials in 2001-2004 period with different crops and fertilizer doses in order to determine how these plants behave in these conditions.

Results and discussions

In the case of surface quarries the impact on the soil was harsh. By exploitation and depositation the former soils have disappeared either by inseparable blending or by separately depositation. The place of the former soils like: typical preluvosoil, reddish preluvosoil, albic luvosoil, entiantrosoil have been taken by diverse lithological materials that are heterogeneously mixed and form the psamic entiantrosoil.
The main physico-chemical features of the psamic entiantrosoil are given in the table 1

Table 1

The main physico-chemical features of the psamic entiantrosoil from Husnicioara

Layer	Depth	Size composition						Chemical features					
		Sand I	Sand II	Silt	Clay I	Clay II	Tex ture	pH	$CaCO_3$	H %	T N %	P ppm	K Ppm
S_1	0-23	21.5	75.3	0.3	3.0	2.9	S	8.7	4.8	0.4	0.16	6.96	44.86
S_2	24-37	39.3	51.9	3.2	7.6	5.6	SL	8.9	4.8	0.5	0.16	4.52	39.95
S_3	38-72	45.5	47.3	4.0	7.1	3.2	S	9.0	3.2	0.4	0.2	5.09	33.24
S_4	63-128	30.9	62.1	3.7	5.4	3.3	S	8.0	2.4	0.4	0.08	11.09	33.21

The texture is silty – sandy, silty or sandy with high content of thick sand (21.5-45.5%) and fine sand (47.3-75.3), lower of loam (0.3-4.0%) and physical and colloidal clay (2.9-7.6%). The reaction is low to moderate alkaline (pH 8.0-9.0) and low to moderate content of $CaCO_3$ (3.2-4.8).
The humus total nitrogen content is extremely reduced (0.4-0.5%) and 0.08-0.20% being low supplied by nitrogen.
The available phosphorus is low (5.09-11.09 ppm) that indicates a low supplying degree with this element.
The potash content of 33.21 – 44.86 ppm also indicates a low supplying degree.
Calculating the evaluation mark of these soils there results a 10.20 mark, these terrains being included in the Vth category of soils, the lowest. Initially, the former soil had the evaluation mark of 70 and was included in the second category of fertility.
All these aspects show that the gangue deposits have a low fertility degree and they need special measures of increasing their fertility.

Ecological buildup measures
On the basis of several experiments carried out within the 2001-2004 period on the gangue deposits by different fertilizer doses there have resulted the means that must be taken in order to recover these gangue deposits.
The main objective of the biological recultivation is the increasing of the organic matter and nutrients content. In this respect the using of chemical and organic fertilizer has a special importance. Without them the wheat and corn crops do not succeed on this kind of soils.
Because the wheat crop gives low yield even with fertilization of $N_{64}N_{120}$ between 448-1208 kg/ha in comparison with 2500 kg/ha on the nearby soils, it is not recommendable.
The corn crop is advisable on the gangue deposits only when fertilized. The recommended dose is $N_{136}P_{80}K_{80}$ when yields of over 2200 kg/ha can obtained and when using 20-30 t/ha manure along with $N_{136}P_{80}$ there can be obtained 3500 kg/ha.
The sunflower is the crop that succeed on these soil more than wheat and corn even without chemical fertilizers yet its yields are still low.
The pulse crops are of perspective on the gangue deposits. In fact with these crops the ecological buildup of these terrains must begin. The alpha-alpha is the crop that gives the best results on the fresh gangue deposits. Without any fertilizer it gives 861 kg/ha hay. The fertilization only by chemical fertilizers of N_{96} or $N_{96}P_{64}$ increases the yield to 2883 kg/ha hay and when an organic mineral fertilization is applied (25 t/ha manure + $N_{96}P_{64}$) there are obtained 4717 kg hay per hectare.
Along with the alpha-alpha crop, the peanuts can be introduced on the gangue deposits from Husnicioara. They give yields of 510-800 kg pods/ha. When chemically fertilized by N_{96} or $N_{96}P_{64}$ or orcanic mineral fertilization, the peanut yield can reach 900 – 1200 kg/ha.

Conclusions

Taking account of the obtained results by using to the chick pea, sunflower and corn of an organic fertilizer of compost type that has 3.1 times more nitrogen and 2.5 times more phosphorus than the usual manure we advise its applying due to the following advantages:

- the increasing of the yield from 708 to 791 and 926 kg/ha with chick pea after applying 10, 20 and respectively 30 t/ha in comparison with 596 kg/ha when it is not applied;
- A higher yield when applied to the sunflower crop, from 619 kg/ha when no applied to 708, 1058 and 1167 kg/ha when 10, 20 and 30 t/ha are applied;
- When applied to the corn crop there are obtained 2600, 3225 and 3793 kg/ha in comparison with 914 kg/ha when no compost is applied.

Our recommendation is to apply 20-30 t/ha compost to all crops that are cropped on the gangue deposits, alone or along with N64, P64 or N96P64K80.

The compost has a positively effect on the increasing the organic matter content of the gangue deposits.

The gangue deposits can be cropped by woody species like acacia and poplar. The acacia can be planted in order to fasten the versants in crossed form (X).

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CHANGE IN MECHANICAL RESISTANCE OF SOIL AS TO MANAGEMENT SYSTEM

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Abstract
The impact of fertilisation on the mechanical resistance of soil, some other soil properties and correlation between mechanical resistance and yields was investigated in a long-term experiment with three year field crop rotation of maize – wheat – barley at Jable near Ljubljana. The experiment was conducted as a two factorial trial (management system with organic matter: B – 30 t/ha farmyard manure ploughing in before maize, straw removed, C – straw remains on the field, catch crop ploughed in before maize, A – no organic fertilisation and mineral nitrogen rate). Management system has an important impact on the mechanical resistance of soil and soil structure, while there is a lower impact of mineral nitrogen fertilisation, as it was detected in all soil depths (20 cm, 30 cm, and 40 cm). As expected, mechanical resistance of soil is increasing with soil depth; in the average of all three crops it was 67.4 N/cm^2, 101.6 N/cm^2 and 151.8 N/cm^2 in the depths of 20 cm, 30 cm and 40 cm, respectively. Penetrometric measurements show a high variability of the experimental field according to mechanical soil resistance. There is also an important impact of weather conditions in certain season and a strong correlation between soil mechanical resistance and the power of tractor needed for ploughing. For ploughing 20 cm of soil after maize, 60-80% higher tractor power is needed compared to the power needed after wheat or barley.

Key words: cone index / ploughing / nitrogen / crop rotation / mechanical soil resistance

Introduction

Soil compaction is one of the most important physical parameters of soil which impact the yield and economy of production. More authors indicate that soil compaction is the result of heavy mechanization use (Gill, 1961; Raney et al., 1955; Hummel et al., 2004). Thomson et al. (1987) found out a strong correlation between soil mechanical resistance (cone index - CI) and length and density of the root system. Specific soil resistance impacts regeneration of the root system, too. Investigations show that growth and development of the root system is strongly aggravated at CI between 15 and 30 bars, while at CI higher than 30 bars root growth is practically impossible (Boone and Veen, 1994; Koolen and Kupiers, 1983).

Apparent soil density is increasing by soil depth because organic matter content is usually decreasing and because of the mass of upper layers. And these lower layers are rarely loosened by cultivation (Soil Density and Porosity, 2005). Similar findings are reported by Packer et al. (1998) who found out that beside soil depth apparent soil density is impacted by

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soil type and there is an important impact of the year, too. Mühlbachova and Ružek (2002) reported that beside soil depth there is an important impact of soil tillage on the apparent soil density. After two years apparent soil density is lower at conventional tillage compared to conserving tillage and direct sowing. At conventional tillage apparent soil density is increasing by soil depth, at conserving tillage and direct sowing there is a difference in soil density only between sowing layer (10 cm) and deeper soil layers (20 cm, 30 cm), so it is not increasing by soil depth.

Different management systems and mineral N rates reflect in changes in soil humus content and consecutive also in changes of physical characteristics of soil; the consequence is a change in apparent soil density. All of that changes impact soil water capacity which is in our conditions often a limit factor in field crop production.

The aim of the study is to investigate the impact of different field crops in the field crop rotation and management system with organic matter on the mechanical resistance of soil at different soil depths.

Material and methods

Location and climate

The field experiment was conducted at Jable near Ljubljana (46°8'N, 14°34'E) in 1999-2001 within the long-term field experiment IOSDV, which was conducted in a way that factors of soil fertility can be studied in dependence of management system, mineral N fertilization and field crop rotation in subalpine climate.

Soil is deep, heavy and hydromorphic, silt loam, moderately gleyic on calcic ground (FAO classification *Planosols*). Rock base are alluviums of rivers from regions Karavanke and Alps. Root system extend till the depth of 120 to 130 cm (Tajnšek, 2003). Drought periods appear only rarely. In the period of 1951 to 1990 there was average annual temperature 8.3^{o}C, average temperatures ranged from 7.3°C to 9.8°C, the warmest month was July (18.5°C), the coldest January (-2.4°C) (Agromet, 1999, 2000, 2001). In the investigated period average annual temperature was higher for more than 1^{o}C compared to the long term average. In 1999 average annual temperature was 9.0°C, in 2000 10.2°C, in 2001 9.3°C.

Precipitation quantity in the period 1961-90 was between 987 mm.a and 1.777 mm.a, while average annual precipitation was 1384 mm.a.

At IOSDV Jable each year maize – winter wheat – winter barley are sown in the field crop rotation in three management systems (A, B, C).

A system: no organic fertilization, main and side yields (straw) are taken from the field.

B system: farmyard manure 10 t/ha.a (ploughed in before maize in a quantity of 30 t/ha), main and side yields (straw) are taken from the field.

C system: no organic fertilizers, all aboveground rests stay on the field after harvest, after spring barley catch crop oil redish is sown.

In A two mineral N rates are included (N0: 0 kg/ha.a mineral N, N3: 220 kg/ha.a mineral N), in B and C four (N0; N1: 73 kg/ha.a mineral N; N2: 143 kg/ha.a mineral N; N3). Treatments are combination of organic fertilization and mineral N rate. So, there are red fertilization treatments: AN0, AN3, BN0, BN1, BN2, BN3, CN0, CN1, CN2, CN3. All plots are treated the same way from the conduction of the field experiment (1992) in three replications. The size of one plot is 30 m^2 (5 x 6 m).

Measurements of mechanical resistance of soil

Horizontal penetrometer, attached to tractor and computer with appropriate programme, was used for measurements. They were performed each year after harvest of all three crops at 14-15% soil moisture content at 20 cm soil depth. Mechanical resistance of soil was measured in depths 20 cm, 30 cm and 40 cm all along the plots. Formula for calculations of cone index (CI) which was used to measure specific soil resistance was:

$$CI = \frac{F}{S} (\text{bar}, \text{N/cm}^2)$$

where F is strength per cone and S is projection surface of the cone. CI can be expressed in bars [B], N/cm^2 or Pascal [Pa]. We used N/cm^2. Values (strength and depth) were captured directly by sensors; computer processing was done immediately (Godeša, 2000). For statistical analyses computer package Statgraphics Plus 4.0 was applied. Differences among treatments were detected by Duncan multiple range test $p \leq 0.05$.

Results

Impact of year and depth on the mechanical resistance of soil

Impact of year and depth on the mechanical resistance of soil at certain crops is shown in Table 1. There was an impact of soil depth and certain year – plot site and crop, respectively. Mechanical resistance of soil was increasing by soil depth. Differences among soil depths were significant at all crops (Table 1). At all crops the lowest mechanical resistance was on 20 cm depth, the highest at the depth of 40 cm (Figure 1). In the average of years and depths mechanical resistance of soil was the highest after wheat harvest (125.8 N/cm^3), followed by mechanical resistance after barley harvest (114.5 N/cm^3). The lowest mechanical resistance of soil was after maize harvest (80.3 N/cm^3). In the average of all years the increase in mechanical resistance of soil from the depth of 20 cm to the depth of 30 cm was by 47% at barley, by 49.8% at wheat and by 57.9% at maize.

Table 1. Mechanical resistance of soil [N/cm^3] with regard to soil depth and year at certain field crops (Duncan multiple test, $p \leq 0.05$).

Year	Depth [cm]	Mechanical resistance of soil [N/cm^3]						
		Wheat	Increase in resistance (%)	Barley	Increase in resistance (%)	Maize	Increase in resistance (%)	Together
Average of years	20	82.1 a	100	74.4 a	100	45.8 a	100	67.4 a
	30	123.0 b	149.8	109.4 b	147.0	72.3 b	157.9	101.6 b
	40	172.2 c	209.7	159.8 c	214.8	122.7 c	267.9	151.8 c
Average of depths	1999	105.3 b		114.8 b		89.9 a		103.3 a
	2000	143.1 c		97.9 a		86.7 a		109.2 a
	2001	128.8 a		130.9 c		64.3 b		108.0 a
Interaction between depth and years		yes (p=0.0002)		yes (p=0.0000)		yes (p=0.0000)		
Average of years and depths		125.8		114.5		80.3		106.9

In the average of all years the increase in mechanical resistance of soil from the depth of 30 cm to the depth of 40 cm is by 59.8% at wheat, by 67.8% at barley and by 110.0% at maize. The soil is the most compacted after wheat harvest and the least after maize harvest. At the same time compaction is increasing by depth the most of all at maize.
Comparing average mechanical resistance of soil at all depths among investigated years, let us find out that significant differences appear among years at all investigated crops (Table 1), with exception at maize between 1999 and 2000. But also in that case the average mechanical resistance of soil was higher in 1999 compared to 2000. In spite of increasing of mechanical resistance of soil by soil depth, at certain crops interaction year x depth was detected, which was a consequence of different rates of increase of mechanical resistance in certain depths and certain years.

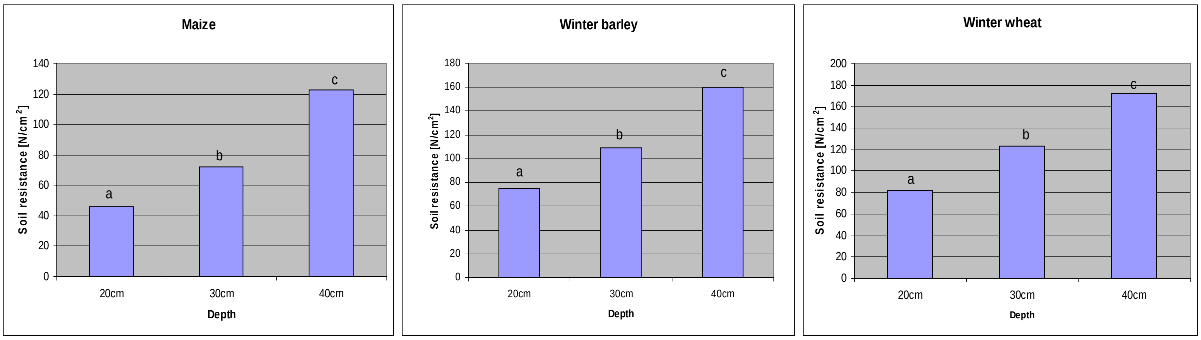

Figure 1. The effect of soil depth on the CI (maize, barley, wheat)

The impact of management system and mineral nitrogen fertilization on the mechanical resistance of soil

In the average of four mineral N rates mechanical resistance of soil in the average of depths 20 cm, 30 cm and 40 cm did not significantly differ between system B, where 10 t/ha a. farmyard manure was ploughed in in the average of the rotation, and system C, where each year aboveground residues are ploughed in (Table 2). Comparison of average mechanical resistance of soil among systems A, B and C shows no significant differences, if mineral N rates N0 and N3 are included in the calculations. But in the system A, where no organic fertilization is included, mechanical resistance of soil was significantly higher at N3 compared to N0 (Table 2).

Table 2. Mechanical resistance of soil [N/cm^2] in the average of all soil depths (20 cm, 30 cm and 40 cm) with regard to management system and mineral N rate and significance of difference (Duncan multiple test, p≤0.05).

Management system	A		B				C			
Mineral N fertilization	N0	N3	N0	N1	N2	N3	N0	N1	N2	N3
Average of mineral N rates	106.6 a	114.0 b	102.0 a	103.7 a	106.8 a	107.4 a	107.2 a	103.4 a	105.6 a	108.4 a
Average of organic fertilization in N0 and N3 rate	110.3 a		104.7 a				107.8 a			
Average of systems B in C			105.5 a				106.2 a			

Discussion

Measurements of mechanical resistance of soil in dependence of organic fertilization (A system: no organic fertilization, main and side yields (straw) are taken from the field; B system: farmyard manure 10 t/ha.a, main and side yields (straw) are taken from the field; C system: no organic fertilizers, all aboveground rests stay on the field after harvest, after spring barley catch crop oil redish is sown) in combination with mineral N rate 8 to 10 years after conduction of the long-term experiment at Jable showed no significant differences in this parameter. Table 2 shows that no significant trend of increasing in mechanical resistance of soil in system B (farmyard manure) by mineral N increasing is indicated. In the system with no organic fertilization (system A) the highest mineral N rate (N3) significantly increased mechanical resistance of soil compared to the variant with no fertilization by mineral N (N0). The reason can be found in aggravating of the soil structure because of soil pH lowering at higher mineral N rates (Rowell, 1997). Although it is known that humus content in soil improves their porosity and structure (Truman and Franzmeier, 2002), in the period investigated it was not diversificated that much (non published data) to result in diversification of mechanical resistance of soil.

The impact of crops on the mechanical resistance of soil is also interested (Table 2). As it was predicted, in the average of years and depths mechanical resistance of soil was the lowest after maize harvest, which is a row plant where seedbed is prepared in spring, close by maize sowing, so harvest, after which measurements were preformed, was only six months later. More surprising was the fact that lower mechanical resistance of soil after maize harvest compared to mechanical resistance of soil after barley and wheat harvest, was lower not only in the depth of 20 cm, but also on the depths of 30 cm and 40 cm. Mechanical resistance of soil was comparable after barley and wheat harvest at all depths. Mechanical resistance was increased by depth at the most at maize. Mechanical resistance of soil was importantly impacted by year, too (Table 1).

Measurements were performed at the same soil moisture content in the depth of 20 cm, but at deeper layers soil moisture was different according to different time of penetrometric measurements. This fact and the fact that soil characteristics are not completely the same with regard to the field are probably reasons for strongly expressed impact of the year on the mechanical resistance of soil. Consequently significant interactions appeared between the depth and year. Comparing CI at maize with CI at barley and wheat shows that for ploughing 79% lower drawing power is needed after maize compared to stubble after wheat, and 62% lower after maize compared to stubble after baley.

Conclusions

Results of measurements of mechanical resistance of soil by horizontal penetrometer in the long-term field experiment IOSDV at Jable can be condensed:

- After 8-10 years of different organic and mineral N fertilization in field crop rotation of maize – wheat – barley changes in humus content and other parameters of soil did not reach such differences that would reflect in significant differences in mechanical resistance of soil in the average of measurements in 20 cm, 30 cm and 40 cm soil depths.

The only significant change was the increase in mechanical resistance of soil at the highest mineral N rate (220 kg/ha.a) in the system with no organic fertilization.
- Mechanical resistance is increasing by soil depth; it was higher by two times in the depth of 40 cm compared to the depth of 20 cm.
- There was interaction 'year x depth' what was a consequence of different soil moisture at deeper soil layers.
- For ploughing the upper layer of 20 cm of soil after maize harvest the needed tractor power is lower by 60-80% compared to the tractor power, needed for ploughing stubble after wheat or barley.

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