THE EFFECT OF PRIMARY SOIL TILLAGE AND PRECIPITATION CONDITION ON SOIL BULK DENSITY

VPLYV ZÁKLADNÉHO OBRÁBANIA PÔDY A ZRÁŽKOVÝCH POMEROV NA OBJEMOVÚ HMOTNOSŤ PÔDY

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Abstract: *The field experiment was conducted on Luvi-Haplic Chernozem with loamy to clay-loamy texture and humus content of 1.8-2% in maize growing region in south-west of Slovakia. The aim of the research was the time and space evaluation of bulk density dynamics in conditions of the no-till system and the mouldboard ploughing. Soil samples for measuring the soil bulk density were always taken in the spring term (March-April), after the crops harvest in the summer term July-August except for the maize and mostly in September and October in the autumn term at the three soil layer 0.0-0.10; 0.10-0.20 and 0.20-0.30 m. A positive correlation between the soil bulk density and amount of rainfalls in the period from spring to summer was determined. In comparison with the mouldboard ploughing, soil in the no-till system was mellower in all layers. Relative differences at measured figures of the average SBDr between the tillage systems with regard to the depth of soil were the highest in the upper layer and were gradually reduced towards the depth. The biggest difference of the soil bulk density was recorded in summer. The differences were reduced from summer to autumn and they approached the figures measured in the spring season. The reduced soil bulk density was mostly influenced by weather, date and depth of sampling as well as the tillage system.*

Rezumat: *Poľný pokus bol robený na stredne ťažkej piesočnato hlinitej černozemi hnedozemného typu s obsahom humusu 1.8-2.0%, v kukuričnej výrobnej oblasti na juhozápade Slovenska. Cieľom práce bolo zistiť časovú a priestorovú dynamiku redukovanej objemovej hmotnosti pôdy pri bezorbovom a konvenčnom systéme s orbou pluhom. Pôdne vzorky boli odoberaní vždy po sejbe plodín na jar (marec-apríl), po zbere plodín v lete (júl-august), okrem kukurice, a v septembri-októbri z troch vrstiev 0.0-0.10; 0.10-0.20 and 0.20-0.30 m. Bola zistená pozitívna korelácia medzi množstvom zrážok v obdobý od jari do jesene a redukovanou objemovou hmotnosťou pôdy. Pôda v bezorbovom systéme bola kyprejšia vo všetkých sledovaných vrstvách pôdy. Rozdiely v priemernej objemovej hmotnosti medzi hodnotenými systémami základného obrábania pôdy vo vzťahu k vrstve pôdy boli najvyššie vo vrchnej vrstve a postupne sa zmenšovali smerom k hlbším vrstvám. Najväčší rozdiel objemovej hmotnosti bol v lete. Rozdiely sa od leta do jesene postupne zmenšovali až dosiahli hodnoty namerané na jar. Variabilita hmotnosti pôdy bola prevažne ovplyvnená počasím, dátumom odberu, hĺbkou odberu a systémom obrábania pôdy.*

Key words**:** *No-till system, low-input system, primary tillage, weather, soil bulk density*
Cuvinte cheie: *bezorbový systém, low-input systém s orbou, počasie, objemová hmotnosť pôdy*

INTRODUCTION

The target tillage in an interaction with crops rotation forms a hospitable soil habitat for sustainable soil fertility and stability of plant production (HUSNJAK ET AL. 2002; KAY AND VANDENBYGAART 2002). Crops leave soil in different physical condition (KOVÁČ AND ŠVANČÁRKOVÁ 2003; KOVÁČ ET AL. 2005). 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 are activated by the ploughing effect of winter frosts

(FRANZLUEBBERS 2002; JAVŮREK ET AL. 2004). The bulk density of soil is considered to be an integral coefficient of the soil habitat quality (BATTIKHI AND SULEIMAN 1999; LOGSDON AND KARLEN 2004). It mainly depends on the grain size, porosity and soil structure. In principle there prevails knowledge that a soil protecting tillage in the first years of its application raises soil bulk density (KOVÁČ AND ŠVANČÁRKOVÁ 2003). Higher soil bulk density is needed for winter crops in drier areas without irrigation. This can be provided for an earlier ploughing or the depth and tillage intensity reducing. Some no-till technologies can be successfully used at appropriate sites (HŮLA, PROCHÁZKOVÁ ET AL. 2002). The aimed tillage habitat management is crucial part of sustainable farming. Therefore we approached the research from which the presented results are.

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, 338mm per growing season. The soil is Luvi-Haplic Chernozem with loamy to clay-loamy texture with pH of 6.5 – 7.2 and 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 four-course crop rotation of peas-winter wheat-maize for corn-spring barley.

The integrated system (next IS) presents the no-till system of farming, without farm yard manure application. The integrated fertilization, plant protection and growing intercrops were realized. Crushed straw and applied compost remain on the soil surface after being scattered.

The low-input system (next LIS) presents the soil tillage with mouldboard ploughing to the depth 0.18 – 0.22 m. Application of pesticides and reduced doses of nitrogen nutrients from mineral fertilizers were applied. Straw was removed from the field. Soil samples were set by the Kopecky method with graduated cylinders with the cubic content 100 cm^3 in four replicates, at the three soil layer 0.0-0.10; 0.10-0.20 and 0.20-0.30 m. For reduced soil bulk density soil was dried to 105 °C. The data for bulk density as well as interaction were subjected to an analysis of variance using the stat graphics plus version 5.0. Soil samples for measuring the soil bulk density (T1) were always taken after sowing in the spring term (March-April), after the crops harvest in the summer term (T2 -July-August) except for the maize and mostly in September and October in the autumn term (T3). Data about soil freezing were used from the weather station Jaslovské Bohunice (Anonym 1998-2005).

The aim of the research was the time and space evaluation of bulk density dynamics in conditions of the no-till system and the mouldboard ploughing.

RESULTS AND DISCUSSION

The experimental years 1999-2005 were largely different from the aspect of weather conditions (table 1). Rainfalls in the period of sampling from the beginning of freezing in previous year to spring (To-T1) stand for 106.8 mm in average, rainfalls from the spring to the summer (T1-T2) varied from 46.5 to 263mm, from summer to autumn (T2-T3) varied from 102-207mm. Average dose of precipitation from spring to summer was 386. Rainfalls from the beginning of autumn frosts to the following autumn got to 493 mm.

Equations of the regression line y = 412.81x-467.18 revealed positive correlation ($r=0.5769^+$) between the amount of rainfalls during the period from sowing to the spring crops harvest and the reduced soil bulk density (next SBDr). By the authors Jambor (1987), Kováč and Žák (2002), the weather appears a key factor conditioning the SBDr.

Table 1

Sum of rainfall (mm) in time of soil sampling in the years 1999-2005

Rainfall mm	To – T1	T1 – T2	T2 – T3	T1 – T3	To – T3
1999	70.8	263.4	103.2	366.6	437.4
2000	172.4	72.2	159.0	231.2	403.6
2001	71.7	179.0	124.7	303.7	375.4
2002	71.2	177.8	172.9	350.7	421.9
2003	79.2	64.0	178.0	242.0	321.2
2004	110.6	46.5	102.3	149.0	259.4
2005	171.9	107.1	206.9	485.9	657.8
Average	106.8	130.0	149.6	386.4	493.2

The SBDr was highly significantly influenced (table 2) by weather condition of evaluated years, date of sampling, the soil layer, and tillage system. The relative effect of weather together with the other experiment inputs on the SBDr are documented by significant interaction of all evaluated factors.

Table 2

Multifactorial analysis of variance of soil bulk density (reduced) as affected by year conditions, time of evaluation, tillage system and soil layer in 2004-2006

Factor	Soil bulk density (reduced)			
	sum of square.	degree of freedom	F-statistics	significan ce
Year (Y)	2.372	6	61.617	++
Time of evaluation (T)	0.278	2	21.715	++
Tillage system (S)	0.261	1	40.670	++
Soil layer (L)	0.789	2	61.526	++
Year x term	0.778	12	10.101	++
Year x layer	0.303	12	3.940	++
Time of eval. x system	0.224	2	17.461	++
System x layer	0.108	2	8.463	++
Year x time of eval. x system	0.348	12	4.525	++
Year x time of eval. x layer	0.439	24	2.851	++
Year x system x layer	0.202	12	2.628	++
Residual	1.617	252		
Total	9.016	503		

The space and time variability of SBDr is documented in table 3. The average SBDr was 1.479 t m^{-3} in 1999-2005. The average SBDr in the IS was lower than in the LIS. In other words, soil characterized by the SBDr was significantly mellower in the IS (by no-till) in comparison with the LIS (by mouldboard ploughing). Differences of the SBDr in different years were small but mostly statistically significant (unpublished). Practically, the SBDr was identical in both systems in spring. An important difference of the SBDr was between the spring and summer season. The biggest difference of the SBDr in our trials was in summer, it presented 7.5%. Differences of the SBDr 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 SBDr phased down in both systems.

Table 3

Soil bulk density (reduced) in the years 1999 – 2005 (t m^{-3})

Year	Time of evaluation	System/layer							
		no-till system				ploughing system			
		0.0-0.1	0.1-0.2	0.2-0.3	0.0-0.3	0.0-0.1	0.1-0.2	0.2-0.3	0.0-0.3
1999 Peas	T_1	1.503	1.588	1.620	1.570	1.543	1.548	1.513	1.534
	T_2	1.483	1.545	1.468	1.499	1.575	1.560	1.580	1.572
	T_3	1.428	1.605	1.623	1.552	1.595	1.600	1.565	1.587
	average	1.471	1.579	1.570	1.540	1.571	1.569	1.553	1.564
2000 Winter wheat	T_1	1.543	1.565	1.580	1.565	1.493	1.548	1.623	1.554
	T_2	1.363	1.485	1.478	1.442	1.557	1.520	1.473	1.517
	T_3	1.428	1.598	1.673	1.566	1.585	1.590	1.548	1.574
	average	1.445	1.549	1.577	1.524	1.545	1.553	1.548	1.548
2001 Maize for corn	T_1	1.400	1.575	1.583	1.519	1.420	1.578	1.585	1.528
	T_2	1.580	1.523	1568	1.557	1.573	1.603	1.578	1.584
	T_3	1.580	1.557	1.553	1.563	1.660	1.678	1.553	1.630
	average	1.520	1.552	1.568	1.546	1.551	1.620	1.572	1.581
2002 Spring barley	T_1	1.410	1.443	1.455	1.436	1.408	1.620	1.558	1.528
	T_2	1.210	1.303	1.598	1.370	1.263	1.580	1.508	1.450
	T_3	1.438	1.585	1.610	1.544	1.495	1.643	1.635	1.591
	average	1.353	1.444	1.554	1.450	1.389	1.614	1.567	1.523
2003 Peas	T_1	1.340	1.565	1.555	1.487	1.350	1.560	1.468	1.459
	T_2	1.168	1.355	1.338	1.287	1.295	1.425	1.518	1.413
	T_3	1.315	1.523	1.500	1.446	1.543	1.435	1.448	1.475
	average	1.274	1.481	1.464	1.406	1.396	1.473	1.478	1.449
2004 Winter wheat	T_1	1.320	1.415	1.425	1.387	1.400	1.423	1.420	1.414
	T_2	1.200	1.295	1.303	1.266	1.368	1.423	1.383	1.391
	T_3	1.363	1.403	1.270	1.345	1.385	1.500	1.515	1.467
	average	1.294	1.371	1.333	1.333	1.384	1.449	1.439	1.424
2005 Maize for corn	T_1	1.290	1.490	1.573	1.451	1.425	1.438	1.470	1.444
	T_2	1.350	1.368	1.308	1.342	1.530	1.593	1.568	1.563
	T_3	1.343	1.300	1.535	1.393	1.260	1.250	1.275	1.262
	average	1.328	1.386	1.472	1.395	1.405	1.427	1.438	1.423
1999-2005	T_1	1.401	1.520	1.542	1.488	1.434	1.531	1.520	1.494
	T_2	1.336	1.411	1.437	1.395	1.452	1.529	1.515	1.499
	T_3	1.414	1.510	1.538	1.487	1.503	1.528	1.506	1.512
	average	1.384	1.480	1.505	1.456	1.463	1.529	1.514	1.502

This proves that ecological conditions in term of physical soil habitat for the grown crops were gradually improved. A change from the original state of the SBDr at the end of the monitored season presented in average 4.9%, it was more in the IS (5,8%) and less in the LIS (4.1%). Changes of the SBDr in the systems were the most modified (statistically significant) during the winter season, i.e. from autumn to spring. The SBDr in the no-till system was reduced during the years from 3% (2000/2001) to 21.26% (2003/2004) apart from the first and last winter seasons. In the system with tillage SBDr was reduced every year, the reduction varied from 2% (1999/2000) to 8.3% (2001/2002). The figures of the SBDr in both systems got at the same level during the spring season. Differences of the SBDr in the monitored systems were observed mainly in the summer season. Recorded results are only partly in accord with data published by Jambor (1987) who found out that the SBDr on medium no-till soil stayed in spring at the same figure as it had been monitored in late autumn. Conversely, the SBDr of soil ploughed in autumn was reduced in spring. Positively reduced figures of our experiment were acquired due to frost effects and soil preserved them up to summer (1.395 or 1.499 t m^{-3}), or it got back to the original figures measured in spring season. Hůla and Procházková (2002) introduce some information about worsening of the SBDr from sowing to harvest. Information about the progressive soil bulk density during a growing season was published by Kováč and Žák (2002). Our results recorded an identical tendency in the low-input system with mouldboard tillage.

From the point of view of monitored soil layers, the mellowest soil was in the upper soil layer. The biggest difference at the average SBDr was between the soil layers 0.10 – 0.20 m and 0.0 – 0.30 m (6.1%). The soil bulk density was also significantly influenced by the system interaction with the soil layer. Relative differences at measured figures of the average SBDr between the tillage systems with regard to the depth of soil were the highest in the upper layer; they were gradually reduced towards the depth. Dynamics of the SBDr differed in the monitored tillage systems, depths and harvest dates. Differences in tested farming systems (differ in primary tillage) were caused by correlate effects of different soil tillage and probably also by the management of post harvest residues of grown crops and the dates of soil sampling. On the same field (Borovce near Piešťany) Kováč and Švančárkova (2003) recorded the highest soil bulk density with the use of a soil protective technology during the third year of the experiment (1.53 t m^{-3}), the lowest soil bulk density was measured at the conventional soil tillage in the second year of the experiment (1.41 t m^{-3}). 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 SBDr in term of area according the systems were between the surface and under surface soil layers. In relative statement this difference presents 7% in the no-till system and nearly 9% (8.9%) at mouldboard ploughing. That proves that soil in this layer is gradually firmed by long-lasting tillage. This is in accordance with results published by Javůrek et al. (2004) who say that the differences of reduced soil bulk density phase down between layers in soil protective systems of tillage. Important differences of soil bulk density between layers are presented by Kováč and Žák (2002). It is very likely that this was also influenced by the different management of crop residues. 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 SBDr.

CONCLUSIONS

In the field experiments at dry arable land on Luvi Haplic Chernozem we determined the seasonal and space dynamic of soil bulk density as affected by no-till and conventional tillage with relations to rainfall conditions. The following knowledge was found in the given soil-ecological conditions:

A positive correlation between the soil bulk density and amount of rainfalls in the period from spring to summer was determined.

In comparison with the mouldboard ploughing, soil in the no-till system was mellower during the observation in all layers; it was the mellowest in its upper layer. Relative differences at measured figures of the average SBDr between the tillage systems with regard to the depth of soil were the highest in the upper layer and were gradually reduced towards the depth. The biggest difference of the soil bulk density was recorded in summer. The differences were reduced from summer to autumn and they approached the figures measured in the spring season.

The reduced soil bulk density was mostly influenced by weather, date and depth of sampling as well as the tillage system. The lower soil bulk density was measured in the no-till system in comparison with ploughed soil.

ACKOWLEDGEMENT

The paper was supported by the project "Solving the competitiveness and ecologization of crop production by farming systems on arable land and innovation of components of cultivating technologies" 2006 UO 27/091 05 01/091 05 10 and by VEGA Project 1/4441/07 "Ecologization of Agricultural Practices and the Environmental Function of Agriculture on the Intensive Farmland".

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