TILLAGE PRACTICES AND THEIR INFLUENCE ON SOIL PHYSICAL CHARACTERISTICS IN SOUTH-WEST OF SLOVAKIA

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Abstract: *The field experiments was carried out over the period of 2004 - 2007 at the experimental farm Kalná nad Hronom in south-western Slovakia. The aim of the research was to evaluate the influence of conventional and reduced tillage and management of organic matter on the soil physical characteristics. The sugar beet - spring barley – sunflower - winter wheat crop sequence was evaluated. The soil tillage treatments as follows: T1 - conventional mould board ploughing with farm yard manure application to sugar beet and incorporation of post harvested residues of spring barley and sunflower; T2 - convnentional mould board ploughing; T3 - no-till Horsch CONCORD CO 9. During June soil samples were taken from 0.05 - 0.10 m, 0.10 - 0.20 m, 0.20 - 0.30 m. Total porosity, soil bulk density and soil moisture was evaluated. The differences between soil layer and crops growing in different years were ascertained. Evaluated tillage treatments have no statistical influence on total porosity and soil bulk density in an average of four years. No till treatment (T3) influenced the less infiltration rate of soil profile with comparison to mouldboard ploughing treatments. The soil bulk density was highly significantly influenced by weather condition, growing crops and residue management and significantly influenced by soil layer. The positive effect of FYM on total porosity was evaluated in 2004 during sugar beet phase of rotation in first and second soil layers 0.05 - 0.10 m (T1 47.47 %) and 0.10 - 0.20 m (46.93 %) which is in relationship with soil bulk density 1.266 t.m^3 and 1.279 t.m^3 in topsoil layers 0.5 - 0.20 m. Soil bulk density range from 1.361 - 1.52 t.m^3, in an average. Average data of total porosity revealed the significant less total porosity in deeper soil layer 0.2 - 0.3 m (41.65 %) with comparison to top layer 0.05 - 0.10 m (44.5 %). Significantly less total porosity was created under canopy of sunflower (39.9 %) with comparison to sugar beet (43.3 %), spring barley (43.8 %) and winter wheat (45.1 %). In four year average results, the conventional mould board ploughing with farm yard manure form the most suitable soil environment (soil bulk density, total porosity and soil humidity retention), but we also recommended no-till for this specific area of Slovak region.*

Key words**:** *conventional tillage, no-till, soil bulk density, total porosity, soil moisture, crop rotation*

INTRODUCTION

On the soil management changes have a major effect soil water, heat, nutrition regimes, tillage management and climate conditions.

The aimed tillage habitat management is crucial part of sustainable farming (HUSNJAK et al., 2002). 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). The SBD and total porosity is considered to be an integral indicator of the soil habitat quality (LOGSDON and KARLEN, 2004). The importance and influence of tillage systems on physical characteristics is broadly recognized (BIRKÁS et al., 2008; BOJA et al., 2008).

The aim of this study was to evaluate the influence of tillage practices (conventional and reduced) and organic matter management on the soil physical characteristics.

MATERIAL AND METHODS

The field trial was conducted at the experimental farm KALNÁ nad HRONOM (south-west Slovakia) in 2004 - 2007. Experimental farm is situated in warm and moderate arid climatic region. The average annual rainfall is 539.0 mm. The average annual rainfall during the growing season is 320.3 mm. The mean annual temperature is 10.2 ˚C. The mean temperature during growing season is 16.3 ˚C. The soil is Ortic Luvisol with loamy texture.

Method of determination selected soil physical properties: gravimetric method for soil humidity and calculations. Soil samplings were set by the Kopecky method with cylinders with the cubic content 0.001 m^3 in four replicates. Soil samples for measuring the soil bulk density (SBD) and total porosity were always taken and for water regime in the layers from 0.05 up to 0.30 m. The spring and summer weather conditions are documented in the table 1.

Table 1

Spring and summer weather conditions at the farm Kalná nad Hronom during the experimental years 2004 – 2007

Month	Normal 30 (1960 – 1990)		2004		2005		2006		2007	
	°C	mm	°C	mm	°C	mm	°C	mm	°C	mm
IV.	9.6	46	11.8	39.6	11.7	71.7	12.7	43.2	12.6	0.1
V.	15.1	67	14.2	50.2	16.5	45.2	15.1	84.9	18.5	54.5
VI.	18.3	64	18.1	88.7	18.8	46.1	19.7	90.3	22.6	62.4
Spring average (IV. – VI.)	17.6	-	14.7	-	15.7	-	15.8	-	17.9	-
Sum of spring (IV. – VI.)	-	177.0	-	178.5	-	163.0	-	218.4	-	117
VII.	20.3	63	20.2	25.8	20.9	75.4	24.0	14.3	23.5	14.4
VIII.	19.6	56	20.5	13.8	18.7	114.9	18.6	114.1	21.8	74.6
IX.	15.8	54	15.3	46.5	16.9	40.1	17.7	30.8	13.8	63.7
Summer average (VII. – IX.)	18.6	-	18.7	-	18.8	-	20.1	-	19.7	-
Sum for summer (VII. - IX.)	-	173.0	-	86.1	-	230.4	-	159.2	-	152.7

Three tillage practices on selected physical soil characteristics were evaluated in sugar beet (2004) - spring barley (2005) - sunflower (2006) - winter wheat (2007) crop sequence. The main plot with four replicates was 10 m by 550 m. The soil tillage treatments as follows: T1 conventional mould board ploughing with 40 $t.ha^{-1}$ farm yard manure (FYM) application to sugar beet and incorporation of post harvest residues of spring barley, sunflower and winter wheat; T2 conventional mould board ploughing; T3 no-till Horsch CONCORD CO 9. During June the soil samples were taken from 0.05 - 0.10 m, 0.1 - 0.20 m, 0.2 - 0.3 m. The total porosity, soil bulk density and actual soil moisture was determined by core samples of 0.001 m^3.

RESULTS AND DISCUSSIONS

The experimental years 2004 - 2007 were largely different from the aspect of weather conditions. The effect of tillage on total porosity, SBD and water content is documented in tables 2, 3 and 4 in different soil layers. The positive effect of FYM on total porosity was evaluated in 2004 during sugar beet phase of rotation in first and second soil layers 0.05 - 0.10 m (T1 47.47 %) and 0.10 - 0.20 m (46.93 %) which is in relationship with SBD 1.266 $t.m^3$ and 1.279 $t.m^3$ in topsoil layers 0.5 - 0.20 m. In subsequent evaluated years 2005 - 2006 the topsoil layers 0.5 - 0.20 m were more compacted with comparison to 2004 after first year of FYM application.

Spring rate of precipitation influence the water balance in canopy of growing crops. The wet spring support the water balance of soil under sunflower, expressed by water content 27.7 - 29.3 % in 2006. No till treatment (T3) influenced the less infiltration rate of soil profile (21.69 - 10.61 - 19.36 - 21.80 %) with comparison to mouldboard ploughing treatments.

The same tendency concerning infiltration rate noted also KOVÁČ et al. (2005) on Luvi-Haplic Chernozem with loamy to clay-loamy texture with a medium humus content of 1.8 – 2 %.

Table 2

Effect of tillage systems on soil physical properties in soil layer 0.05 – 0.10 m at KALNÁ nad HRONOM, 2004 - 2007

Tillage	Total porosity (%)				Soil bulk density(t.m^3)				Water content (%)			
	2004	2005	2006	2007	2004	2005	2006	2007	2004	2005	2006	2007
T1	47.47	43.39	41.54	41.93	1.266	1.438	1.485	1.475	21.49	14.6	28.5	30.0
T2	40.20	42.52	41.61	54.84	1.513	1.460	1.483	1.147	22.14	15.07	26.5	21.1
T3	44.65	46.92	34.17	56.89	1.406	1.400	1.672	1.095	21.97	13.58	24.25	21.3

Table 3

Effect of tillage systems on soil physical properties in soil layer 0.10 – 0.20 m at KALNÁ nad HRONOM, 2004 - 2007

Tillage	Total porosity (%)				Soil bulk density(t.m^3)				Water content (%)			
	2004	2005	2006	2007	2004	2005	2006	2007	2004	2005	2006	2007
T1	46.93	44.4	42.82	40.12	1.279	1.340	1.427	1.498	23.53	13.06	27.7	31.19
T2	40.32	41.38	42.93	45.9	1.510	1.485	1.448	1.207	22.72	14.20	25.4	21.1
T3	47.17	41.3	37.66	44.22	1.342	1.400	1.579	1.331	21.31	10.22	21.64	21.5

Table 4

Effect of tillage systems on soil physical properties in soil layer 0.20 – 0.30 m at KALNÁ nad HRONOM, 2004 - 2007

Tillage	Total porosity (%)				Soil bulk density(t.m^3)				Water content (%)			
	2004	2005	2006	2007	2004	2005	2006	2007	2004	2005	2006	2007
T1	39.42	46.92	40.00	37.43	1.460	1.343	1.518	1.583	22.74	9.83	29.34	32.25
T2	39.61	41.91	40.00	43.87	1.528	1.485	1.518	1.420	21.60	13.81	26.5	21.0
T3	44.10	47.83	38.50	40.91	1.420	1.320	1.556	1.495	21.69	10.61	19.36	21.8

The knowledge of the soil porosity is of the highest importance because the whole dynamics of soil depends on it (BOJA et al., 2008). We evaluated temporal and spatial dynamics of porosity. The incorporation of FYM and aboveground residues significantly influence the increasing of total porosity with comparison to lack of organic matter incorporation. No differences between soil layers were noted. Due to wet conditions we noted insufficient porosity in 2006 under canopy of sunflower. The soil bulk density has inverse relationship to porosity in evaluated years. MANEA et al. (2009) observed in your experiments that unconventional soil tillage considerable increased of bulk density values and of air porosity. Their results are in opposite with results in our experiments.

Table 5a

Effect of tillage systems and growing crops on total porosity in evaluated soil layers at KALNÁ nad HRONOM, 2004 – 2007

Source of Variation	Sum of Squares	Mean square	F ratio	Significant level
Tillage treatment	5.16	2.58	0.39	0.6841 -
Soil depth	48.8	24.4	3.71	0.0558 -
Years (crops)	133.4	44.4	6.75	0.0064 **
Residual	79.0	6.5	-	-
Total	684.7	-	-	-

Table 5b

Test of homogeneity - Difference of particular level of evaluated factors at KALNÁ nad HRONOM, 2004 – 2007

Total porosity (%)					
Tillage	**Average**	**Depth**	**Average**	**Crop in years 2004 – 2005 - 2006 - 2007**	**Average**
TI	42.69 a	0.05 - 0.10	44.51 b	Sugar beet	43.32 b
T2	42.87 a	0.10 - 0.20	42.98 ab	Barley	43.84 b
T3	43.57 a	0.20 - 0.30	41.65 a	Sunflower	39.91 a
				Winter wheat	45.12 b
LSD 0.05	2.28349		2.28349		2.63674
LSD 0.01	3.20112		3.20112		3.69634

Mean within columns followed by the same letter are not significantly different at the probability level $P < 0.05$ and $P < 0.01$ using the LSD-multiple range test.

Weather conditions with tillage treatments create specific physical conditions. This is in accord with the information about differences of soil physical properties caused by different tillage, published by SKUKLA et al. (2003) and KOVÁČ et al. (2010).

The effect of tillage, soil depth and growing crops on the total porosity are documented in the tables 5a, 5b, 6a, 6b and 7a, 7b. Used tillage systems and soil depth have insignificant influence on variability of porosity. Crops were the most important factor in determining porosity and have high significant influence on variability of porosity.

Table 6a

Effect of tillage systems and growing crops on soil bulk density in evaluated soil layers at KALNÁ and HRONOM, 2004 – 2007

Source of Variation	Sum of Squares	Mean square	F ratio	Significant level
Tillage treatment	0.0014	0.0007	0.18	0.8365
Soil depth	0.358	0.0179	4.41	0.0367
Years (crops)	0.1227	0.0409	10.06	0.0013
Residual	0.0148	0.0041	-	-
Total	0.522	-	-	-

Table 6b

Test of homogeneity - Difference of particular level of evaluated factors at KALNÁ and HRONOM, 2004 – 2007

Soil bulk density ($t.m^3$)					
Tillage	**Average**	**Depth**	**Average**	**Crop in years 2004 – 2005 – 2006 - 2007**	**Average**
TI	1.426 a	0.05 - 0.10	1.4033 a	Sugar beet	1.413 a
T2	1.433 a	0.10 - 0.20	1.4038 a	Barley	1.407 a
T3	1.418 a	0.20 - 0.30	1.4705 b	Sunflower	1.521 b
				Winter wheat	1.361 a
LSD 0.05	0.05672		0.05672		0.06550
LSD 0.01	0.07952		0.07952		0.09182

Mean within columns followed by the same letter are not significantly different at the probability level $P < 0.05$ and $P < 0.01$ using the LSD-multiple range test

Used tillage systems have insignificant influence on variability of SBD. Crops (years) were the most important factor in determining of SBD and they have high significant influence on variability of SBD. Soil depth has significant influence on variability of SBD. Significantly less water balance was noted in no till system with driest soil water content during June in 2006. Significant differences between layers have been noted.

Table 7a

Effect of tillage systems and growing crops on water content in evaluated soil layers at KALNÁ and HRONOM, 2004 – 2007

Source of Variation	Sum of Squares	Mean square	F ratio	Significant level
Tillage treatment	127.77	63.88	52.65	0.0000 **
Soil depth	4.35	2.18	1.79	0.2083 -
Years (crops)	913.22	304.41	250.85	0.0000 **
Residual	14.56	1.21	-	-
Total	1231.45	-	-	-

Table 7b

Test of homogeneity - Difference of particular level of evaluated factors at KALNÁ and HRONOM, 2004 – 2007

Water content (%)					
Tillage	**Average**	**Depth**	**Average**	**Crop in years 2004 – 2005 – 2006 - 2007**	**Average**
TI	23.6858 c	0.05 - 0.10	21.708 a	Sugar beet	22.1322 b
T2	20.928 b	0.10 - 0.20	21.131 a	Barley	12.7755 a
T3	19.102 a	0.20 - 0.30	20.877 a	Sunflower	25.4655 c
				Winter wheat	24.5822 c
LSD 0.05	0.98012		0.98012		1.13174
LSD 0.01	1.37398		1.37398		1.58654

Mean within columns followed by the same letter are not significantly different at the probability level $P < 0.05$ and $P < 0.01$ using the LSD-multiple range test

Used tillage systems and crops (years) were the most important factors in determining water content and they have high significant influence on variability of water content. Significant differences between selected levels of tillage have been noted. Significant differences between crops have been noted (except sunflower and wheat).

CONCLUSIONS

The results present characteristics which are binding with soil genetic type and climate conditions. The pressure of the reform of CAP EU on soil environment protection will lead to more intensive implementation of ecological and conservation soil management which can be qualified as having sustainable effect on environment quality. According four years study the conventional mould board ploughing with farm yard manure, form the most suitable soil environment (SBD, total porosity and soil humidity retention) but we also recommended the no-till for this specific area of Slovak region.

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