THE ENVIRONMENTALLY SOUND TILLAGE PRACTICES AS THE IMPORTANT FACTOR OF MAINTENANCE OF SOIL FERTILITY

Jozef SMATANA, Milan MACÁK, Eva DEMJANOVÁ

Faculty of Agrobiology and Food Resources, Slovak Agricultural University in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic, E-mail: jozef.smatana@uniag.sk

Abstract: *The field experiments was carried out over the period of 2007-2009 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 winter wheat – maize – spring barley crop sequence was evaluated. The soil tillage treatments as follows: T1 - conventional mould board ploughing with farm yard manure (FYM) application to maize (on autumn 2007) and incorporation of post harvested residues of spring barley, winter wheat and maize; T2 - conventional 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 variants of tillage, soil layer and crops growing in different years were ascertained. Evaluated tillage treatments have statistical influence on total porosity and soil bulk density in an average of three years. No till treatment (T3) influenced the less infiltration rate of soil profile with comparison only to mouldboard ploughing treatment+ incorporation of post harvest residues of spring barley, maize and winter wheat . The soil bulk density was highly significantly influenced by weather condition, growing crops, residue management, of used tillage systems and by soil layer. Total porosity range from 37.43 – 56.89% and Soil bulk density range from 1.095 - 1.583 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 (40.75%) with comparison to top layer 0.05 - 0.10 m (44.91%). Significantly less total porosity was created under canopy of maize (40.73%) and later on under spring barley (41.92%) with comparison to winter wheat (45.12%). Averaged three year results, the conventional mould board ploughing with farm yard manure plus incorporation of post harvest residues of spring barley, maize and winter wheat, 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

The soil management has a major effect on soil water, nutrition regimes and weed control with relationship to climate conditions. The aimed tillage habitat management is crucial part of sustainable farming (LACKO-BARTOŠOVÁ et al., 1995; LACKO-BARTOŠOVÁ, 2006; HUSNJAK et al., 2002, TÝR et al., 2009). 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). Deep Tillage cultivation resulted in the most stable soil structure, most favourable for the water and air regimes under the given conditions (CSORBA et al., 2011).

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

MATERIAL AND METHODS

During 2007-2009, the field trial was conducted at the experimental farm Kalná nad Hronom at south-west Slovakia. 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.

Gravimetric method of determination of selected soil physical properties was used. Soil samplings were set by the method of Kopecky 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 and for water regime were always taken in the layers from 0.05 up to 0.30 m.

Three tillage practices on selected physical soil characteristics were evaluated in winter wheat (2007) – maize (2008) – spring barley (2009) 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 maize and incorporation of post harvest residues of spring barley, maize 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.

RESULTS AND DISCUSSIONS

The experimental years 2007 - 2009 were largely different from the aspect of weather conditions. 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 2007 – 2009

Month	Normal 30 (1960 – 1990)		2007		2008		2009	
	°C	mm	°C	mm	°C	mm	°C	mm
IV.	9.6	46	12.6	0.1	10.8	33.2	15.2	4.5
V.	15.1	67	18.5	54.5	16.1	32.5	16.0	41.7
VI.	18.3	64	22.6	62.4	20.5	95.6	17.7	60.6
Spring average (IV. – VI.)	17.6	-	17.9	-	15.8	-	16.3	-
Sum of spring (IV. – VI.)	-	177.0	-	117	-	161.3	-	106.8
VII.	20.3	63	23.5	14.4	20.9	140.3	21.7	42.0
VIII.	19.6	56	21.8	74.6	20.6	19.7	21.5	48.8
IX.	15.8	54	13.8	63.7	15.3	38.3	18.1	22.4
Summer average (VII. – IX.)	18.6	-	19.7	-	18.9	-	20.4	-
Sum for summer (VII. - IX.)	-	173.0	-	152.7	-	198.3	-	113.2

The effect of tillage on total porosity, SBD and water content is documented in tables 2, 3 and 4 in different soil layers.

Table 2

Effect of tillage systems on soil physical properties in soil layer 0.05 – 0.10 m at Kalná nad Hronom, 2007 – 2009

Tillage	Total porosity (%)			Soil bulk density (1000 kg m^3)			Water content (%)		
	2007	2008	2009	2007	2008	2009	2007	2008	2009
T 1	41.93	41.26	41.33	1.475	1.492	1.491	30.0	28.4	26.3
T 2	54.84	41.42	45.95	1.147	1.488	1.373	21.1	29.4	22.0
T 3	56.89	39.84	40.75	1.095	1.528	1.505	21.3	29.7	23.3

Spring rate of precipitation influence the water balance in canopy of growing crops. The wet spring support the water balance of soil under maize, expressed by water content 28.4 - 33.5 % in 2008. No till treatment (T3) influenced the less infiltration rate of soil profile (21.8 - 27.3 - 20.7 %) 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 3

Effect of tillage systems on soil physical properties in soil layer 0.10 – 0.20 m at Kalná nad Hronom, 2007 - 2009

Tillage	Total porosity (%)			Soil bulk density (1000 kg m^3)			Water content (%)		
	2007	2008	2009	2007	2008	2009	2007	2008	2009
T 1	40.12	41.17	42.20	1.498	1.484	1.476	31.19	29.9	22.3
T 2	45.9	41.02	42.61	1.207	1.500	1.406	21.1	28.3	19.4
T 3	44.22	39.72	42.16	1.331	1.536	1.503	21.5	28.51	19.7

Deeper soil layer reflect also infiltration predisposition creates by different soil disturbation (Table 4). The significantly higher water content in deep layer was on soil under conventional tillage with FYM application. In real data an average content of water in T1 was 30.05 %, under T2 and T3 only 23.05%-23.06%.

Table 4

Effect of tillage systems on soil physical properties in soil layer 0.20 – 0.30 m at Kalná nad Hronom, 2007 - 2009

Tillage	Total porosity (%)			Soil bulk density (1000 kg m^3)			Water content (%)		
	2007	2008	2009	2007	2008	2009	2007	2008	2009
T 1	37.43	41.70	41.81	1.583	1.475	1.498	32.25	33.5	23.4
T 2	43.87	40.99	40.51	1.420	1.493	1.505	21.0	27.5	20.6
T 3	40.91	39.53	40.00	1.495	1.530	1.518	21.8	27.3	20.7

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. High values of total porosity in years after application FYM in soil layers 0.10 - 0.20 m and 0.20-0.30 m was also noted. The soil bulk density has inverse relationship to porosity in evaluated years. The effect of tillage, soil depth and growing crops on the total porosity in three - years sequence is documented in the tables 5a, 5b, 6a, 6b and 7a, 7b. Used tillage systems have significant influence on soil porosity, soil depth and growing crops have highly significant influence on variability of soil porosity.

Table 5a

Effect of tillage systems and growing crops on total porosity in evaluated soil layers at Kalná nad Hronom, 2007 – 2009

Source of variation	Sum of squares	Mean square	F ratio	Significant level
Tillage treatment	44.12	22.06	5.55	0.0307 *
Soil depth	80.95	40.47	10.19	0.0063 **
Years (crops)	92.58	46.30	11.65	0.0043 **
Residual	31.8	3.97		
Total	470.16			

*,** significant on P=0.05 and P =0.01 probability level

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).

Table 5b

Test of homogeneity - Difference of particular level of evaluated factors at Kalná nad Hronom, 2007 – 2009

Total porosity (%)					
Tillage	Average	Depth	Average	Crop in years 2007 – 2008 - 2009	Average
TI	40.99 a	0.05 - 0.10	44.91 b	Winter wheat	45.12 b
T2	44.12 b	0.10 - 0.20	42.12 a	Maize	40.73 a
T3	42.67 ab	0.20 - 0.30	40.75 a	Barley	41.92 a
LSD 0.05	2.1675		2.1675		2.1675
LSD 0.01	3.1538		3.1538		3.1538

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

We are noted low values of porosity on the conventional tillage variant with incorporation of post harvest residues (T1). We are observed significant difference between tillage variant T1 (conventional + residues) and T2 (conventional) in average evaluated three years in total porosity. We are noted high values of porosity on upper layers on the soil (0.00-0.05 m) with significantly difference opposite others evaluated soil layers (0.10-20 and 0.20-0.30 m). We are noted high values of porosity under winter wheat (in 2007) with significant difference opposite others evaluated crops (maize and spring barley).

The same tendency concerning tendency of total porosity noted also KOTOROVÁ et al. (2010b) on cultivated Eutric Fluvisol in long-term experiments: total porosity was significantly influenced of evaluated years and by farming system.

Table 6a

Effect of tillage systems and growing crops on soil bulk density in evaluated soil layers at Kalná nad Hronom, 2007 – 2009

Source of Variation	Sum of Squares	Mean square	F ratio	Significant level
Tillage treatment	0.0508	0.025	10.105	0.0065 **
Soil depth	0.0467	0.023	9.18	0.0085 **
Years (crops)	0.0975	0.049	19.39	0.0009 **
Residual	0.020	0.0025		
Total	0.3713			

Table 6b

Test of homogeneity - Difference of particular level of evaluated factors at Kalná nad Hronom, 2004 – 2007

Soil bulk density (1000 kg m^3)					
Tillage	Average	Depth	Average	Crop in years 2007 – 2008 – 2009	Average
TI	1.499 b	0.05 - 0.10	1.4018 a	Winter wheat	1.3638 a
T2	1.3932 a	0.10 - 0.20	1.4378 a	Maize	1.5028 b
T3	1.449 b	0.20 - 0.30	1.502 b	Barley	1.4750 b
LSD 0.05	0.05453		0.05453		0.05453
LSD 0.01	0.07934		0.07934		0.07934

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

Used tillage systems, soil depth and crops have highly significant influence on variability of soil bulk density. We are noted high values of soil bulk density on the

conventional tillage variant with incorporation of post harvest residues (T1). We are observed significant difference between tillage variant T1 (conventional + residues) and T2 (conventional) in average evaluated three years in total porosity. We are noted high values of SBD on bottom layers on the soil (0.20-0.30 m) with significantly difference opposite others evaluated soil layers (0.05-10 and 0.10-0.20 m). Significant difference and high values of SBD under maize (in 2008) opposite winter wheat (in 2007) have been noted.

The same tendency concerning tendency of values SBD noted KOTOROVÁ et al. (2010a) on heavy Gleyic Fluvisol (FM_G) in long-term experiments: high values of SBD ascertained on no – till variants opposite using of conventional tillage. The same tendency concerning of values of SBD noted also ALVAZER and STEINBACH (2009), that SBD was significantly high in no-till systems opposite with conventional tillage, in average was values of SBD on the no-till system highly by 4 % opposite conventional variant. In our experiments we have ascertained similar difference 3.85 %.

Table 7a

Effect of tillage systems and growing crops on water content in evaluated soil layers at Kalná nad Hronom, 2007 – 2009

Source of Variation	Sum of Squares	Mean square	F ratio	Significant level
Tillage treatment	151.54	75.77	50.27	0.0000 **
Soil depth	5.25	2.63	1.74	0.2353-
Years (crops)	239.17	119.59	79.34	0.0000 **
Residual	12.06	1.51		
Total	501.69			

Table 7b

Test of homogeneity - Difference of particular level of evaluated factors at Kalná nad Hronom, 2007 – 2009

Water content (%)					
Tillage	**Average**	Depth	Average	Crop in years 2007 – 2008 – 2009	Average
TI	28.58 b	0.05 - 0.10	25.72 a	Winter wheat	24.58 b
T2	23.37 a	0.10 - 0.20	24.65 a	Maize	29.17 c
T3	23.76 a	0.20 - 0.30	25.34 a	Barley	21.97 a
LSD 0.05	1.3350		1.3350		1.3350
LSD 0.01	1.9424		1.9424		1.9424

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

Used tillage systems and crops in years 2007-2009 were the most important factors in determining of water content and they have high significant influence on variability of water content. We are noted high values of water content on the conventional tillage variant with incorporation of post harvest residues (T1) opposite others two used tillage systems. Used soil depth has insignificant influence on variability of water content. Significant differences between selected of crops have been noted.

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 three years study the conventional mould board ploughing with farm yard manure and addition incorporation of post harvest residues of spring barley, maize and winter wheat, 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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