Acta fytotechn. zootechn., 16, 2013(2): 39–44

Original Paper

The development of selected properties of heavy soil at different tillage conditions

Dana Kotorová*

Plant Production Research Centre Piešťany – Agroecology Research Institute, Michalovce, Slovakia

Between 2006 and 2010 at the Experimental place of Slovak Agricultural Research Centre – Agroecology Research Institute Michalovce (West Slovakia) a field experiment took place on heavy Gleyic Fluvisol. The effect of various tillage of soil on soil physical properties was evaluated. Three soil tillage technologies were studied as follows: conventional tillage – traditional tillage with ploughing; minimal tillage – soil before sowing is prepared by using skive plough-harrow; no-tillage – direct sowing without ploughing. Field treatment was carried out in natural conditions without irrigation. Physical properties of Gleyic Fluvisol were determined from undisturbed soil samples taken once a year in spring (14-day after sowing of spring crops). Topsoil was sampled in cylinders of 100 cm^3 in depth 0.0–0.3 m with four replications. Soil bulk density total porosity and maximum capillary capacity were determined. For modelling of the development of soil parameters the trend analysis was used. The development of the trend component was expressed by equation $y = a + bx$. The trend lines can be assumed as the major trend of the development of selected soil parameters. On Gleyic Fluvisol at direct sowing without ploughing (no-tillage) we ascertained higher bulk density and lower total porosity in comparison with conventional tillage and minimum tillage, too. Maximum capillary capacity was relatively equal and ascertained values were typical for given soil type. From evaluation of 5-years time series influenced significant increasing of bulk density under conventional tillage and direct sowing without ploughing and its decreasing under minimum tillage. The total porosity was lower under conventional tillage and no-tillage variants and higher under minimum tillage variant. Maximum capillary capacity was slightly increasing under conventional and minimum tillage systems, but it was no-significant decreasing under no-till system. The soil protective technologies, minimum tillage and also direct sowing without ploughing, are one method for keeping and conservation of the soil fertility. For their successful is needful application as whole the farming system and the continuity of this system is very important. Using of the protective technologies may also contribute to keeping of stability of ecologically sensitive the heavy soils.

Keywords: soil tillage, time-series, trend analysis

1. Introduction

Soil has natural signs and properties which are changed by using its production and non-production functions, too. The various technological methods and systems are applied at land use. These systems and methods usually have effect on soil properties changes and so different tillage has significant portion on changes of soil physical and hydrophysical properties. Overall, the soils with less quality, as are heavy soils with higher content of clay particles, have high possibility also negative changes of its properties.

For Slovakia, from historical point of view, of conventional tillage system with the ploughing is typical. In last decades, in agricultural practice the technological systems and agrotechnical methods oriented on decreasing of the inputs to production process and on the keeping of soil properties and soil fertility, are used. Soil protective technologies, at their accurate use, may have significant effect not only for quality of soil environment, but also for economic evaluation of the production process.

The systems without plough are alternative and at present in the world it use on more than 100 million hectares of soil (Lal et al., 2007). Advantage of protective tillage of soil is the connection of ecological and economical aspects (Nail et al., 2007). The using of soil protective technologies in this case are limited mainly conditions of the concrete locality.

The bulk density and total porosity is base soil properties. The soil tillage technologies have significant effect on values of these soil parameters. Some aspects of the different tillage in relation to soil properties were published by Demo, Bielek et al. (2000), Gomez et al. (2001), Husnjak et al. (2002), Kováč and Švančárková (2003), Kotorová (2007), Macák et al. (2008), Horák et al. (2009). These authors indicate mainly advantages of using of minimal protective systems in compare to conventional soil tillage systems. For soil protective technologies are very important as follows: selection of forecrop, fertilization, soil and field surface state and post-sowing treatment of soil.

Alvarez and Steinbach (2009) studied the effect of soil tillage systems on soil physical properties. Studied systems were divided into three categories by its intensity – conventional system, reduce tillage, no-till system. By authors the bulk density was significantly higher for no-till

***Correspodence:** Dana Kotorová, Plant Production Research Center – Agroecology Research Institute Michalovce, Špitálska 1273, 071 01 Michalovce, Slovakia, e-mail: kotorova@minet.sk

system compared to conventional tillage. The differences of this soil parameter between conventional and reduce tillage wasn't determined. In average, but the bulk density for no-till variant was higher by only 4 % in compare conventional variant.

Ledvina et al. (2004) and Dam et al. (2006) determined higher values of bulk density and lower values of total porosity for no-tillage system in compare conventional tillage. Similarly also Kotorová (2007) in nine-year experiment on heavy clay-loamy soil determined increasing of bulk density and decreasing of total porosity for no-till system opposite conventional system. Soil tillage system statistically significant influenced maximum capillary capacity and available water capacity of clay-loamy soil.

For the East Slovak Lowland is typical presence of heavy soils with content of clay particles higher than 45 %. The heavy Gleyic Fluvisol, Gleyic Cambisol, Planosol and Gleysol are localized on till 65 % of agricultural lands of the East Slovak Lowland (Vilček, 2005). Soil types and soil textures are alternating on short distances. The effect of soil tillage on changes of properties of soils on the East Slovak Lowland is long-term studied. Results obtained from experiments in conditions of heavy Gleyic Fluvisols published some authors, for example Kotorová (2007), Mati and Kotorová (2007), Kotorová et al. (2010), Mati et al. (2011).

Selected technological tillage system in relation to the physical soil properties is usually seen after a long time of their application in a concrete locality. Long-time series, by Šútor et al. (2007), are very fine for evaluation of tillage effect on soil properties. Five-years and more year time-series may to give more objective aspect on valuation of development of specific soil factor and then may be the base for various analyses and predictions (Chajdiak, 2005). Trend component is used for modeling of time-series and prediction of some parameter, and it indicates the development of the evaluated parameter over time. The prediction of the future development of selected indicator is main part of time-series and it is modelled on function contain also model of trend.

The aim of this work was determined the trend of development of selected physical properties of Gleyic Fluvisol topsoil during five years of different tillage regimes application.

2. Material and methods

Between 2006 and 2010 at the Experimental place of Slovak Agricultural Research Centre – Institute of Agroecology Michalovce (North part of West Slovakia) a field experiment took place on heavy Gleyic Fluvisol. The effect of various tillage of soil on soil physical properties was researched. The experimental site is located at Milhostov, on the East Slovak Lowland near of the city Trebišov with latitude 48° 40‘ N, longitude 21° 44‘ E, altitude 101 m, grain maize production area (Kotorová et al., 2010). Experimental locality belongs to warm and very dry lowland continental climatic region T03 (Linkeš et al., 1996). The 30-year mean annual precipitation in this locality is 550 mm, during vegetation season 348 mm. The 30-year mean annual air temperature is 8.9 °C, during vegetation season 16.0 °C (Mikulová et al., 2008).

Gleyic Fluvisol (FM_G) in Milhostov is characterized as heavy, clay-loamy soil, with average content 53.80% of clayey particles (<0.01 mm) in topsoil. The topsoil has lump aggregate structure with high binding ability and has a weak pervious in whole profile. The coherent layer of dark-grey to yellowish-grey clay is usually in the depth 0.7–0.8 m. the high content of clay particle has significant effect on agronomic properties and tillage of Gleyic Fluvisol.

Three soil tillage technologies were studied as follows: CT – conventional tillage, it is traditional tillage with plowing; MT – minimal tillage, soil before sowing was prepare by using skive plough-harrow; NT – no-tillage, it is direct sowing without plowing. Field treatment was carried out in natural conditions without irrigation. The area of treatment variant was 414 m^2 (18 × 23 m).

Physical properties of Gleyic Fluvisol were determined from undisturbed soil samples taken once a year in spring (14-day after sowing of spring crops). Topsoil was sampled in cylinders of 100 cm^3 in depth 0.0–0.3 m with four replications. Soil bulk density (ρ_d, kg m^{-3}), total porosity (Pt, %) and maximum capillary capacity (θ_{MCC}, %) were determined by methods as published Hrivňáková, Makovníková et al. (2011).

The average results of physical properties and their time development are presented in the tables and on the graphs. Obtained data was tested by mathematical-statistical methods from which analysis of variance was used (Statgraphic software package).

For modelling of the development of soil parameters the trend analysis was used. The development of the trend component was expressed by equation $y = a + b \times x$ (Chajdiak, 2005). The trend lines can be assumed as the major trend of the development of selected soil parameters.

3. Results and discussion

Tillage of soil and physical soil properties are interacting and optimal conditions of soil environment are necessary for growth and development cultivated plants. The bulk density is basic property of soil and it is influenced by tillage technology of soil.

Between years 2006 and 2010 the long-time effect of different soil tillage on changes of physical properties were observed. Average values of bulk density of Gleyic Fluvisol topsoil are shown in table 1.

Between years 2006 and 2010, at conventional tillage, values of the bulk density were in range 1448–1541 kg m^{-3}, with the lowest value in year 2006 and the highest value in year 2007. Bulk density for minimum tillage variant had values in interval 1412–1499 kg m^{-3} and the lowest value was determined in year 2010. The highest value for

Table 1 Average bulk density of Gleyic Fluvisol topsoil inkg m^{-3}

Soil tillage	Year					
	2006	**2007**	**2008**	**2009**	**2010**	$\bar{x}$ **Y**
CT	1448	1541	1497	1539	1479	1501
MT	1413	1476	1499	1450	1412	1450
NT	1446	1533	1479	1542	1542	1508
$\bar{x}$ T	1436	1517	1492	1510	1478	1486

$\bar{x}$ T – average for soil tillage, $\bar{x}$ Y – average for experimental year

Table 2 Average total porosity for Gleyic Fluvisol topsoil in %

Soil tillage	Year					
	2006	**2007**	**2008**	**2009**	**2010**	$\bar{x}$ **Y**
CT	45.21	41.68	43.33	41.73	43.65	43.12
MT	46.54	44.12	43.27	45.08	46.19	45.04
NT	45.26	41.99	44.02	41.62	41.23	42.82
$\bar{x}$ T	45.67	42.60	43.54	42.81	43.69	43.66

$\bar{x}$ T – average for soil tillage, $\bar{x}$ Y – average for experimental year

this variant was determined in year 2008. Similar values of bulk density for heavy soils of the East Slovak Lowland published by several authors, such as Sedlák et al. (1980), Ivanová (1985), Kotorová and Šoltysová (1992), Šútor et al. (1995), Kotorová (2001, 2007), Mati and Kotorová (2007), Kotorová and Mati (2008a, b). Bulk density for no-till variant was higher and its values were in interval from 1446 kg m^{-3} (year 2006) to 1542 kg m^{-3} (year 2009). For systems without ploughing for example Ledvina et al. (2004), Dam et al. (2006), Glab and Kulig (2008), Elder and Lal (2008) found yet unfavourable values.

Presented data indicate that five-year period the more favourable of the bulk density were under minimum tillage variant (in average 1450 kg m^{-3}). In average the bulk density was increased as follows: MT < CT < NT. In individual experimental the bulk density was increased as follows: 2006 < 2010 < 2008 < 2009 < 2007. Evaluated the time-series is relatively short, but it can be said that for soils with high content of clay particles in the topsoil, as is also Gleyic Fluvisol in Milhostov, from point of view of bulk density changes the minimum tillage for these soil is progressive. The total development of bulk density values suggests that minimum tillage technologies are suitable for the heavy soils. Similar conclusion published Kováč and Žák (1999), Alvarez and Steinbach (2009), Kotorová et al. (2010) and others.

The time course of the bulk density for observed tillage variants is shown on Fig. 1. Bulk density in observed period follows the trend line without significant changes. During the 5-years period, values of bulk density were increased by 30 kg m^{-3} for CT variant and significant increased by 100.5 kg m^{-3} for NT. For MT variant the values of bulk density were decreased by 14 kg m^{-3}. Similar results published Kotorová and Mati (2008) and Kotorová et al. (2010).

The total porosity is function of bulk density (Table 2) and it is in negative correlation to bulk density. The values of total porosity, at conventional tillage, were in range 41.68–45.21 %. Higher total porosity at lower bulk density was determined for minimum tillage variant (43.27–46.54 %). For no-tillage variant the bulk density was the highest, and

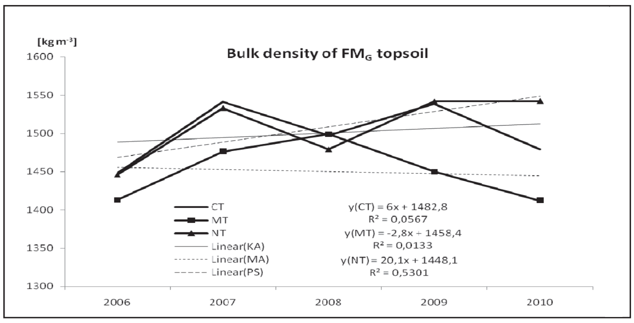

Figure 1 Trend development of bulk density for Gleyic Fluvisol

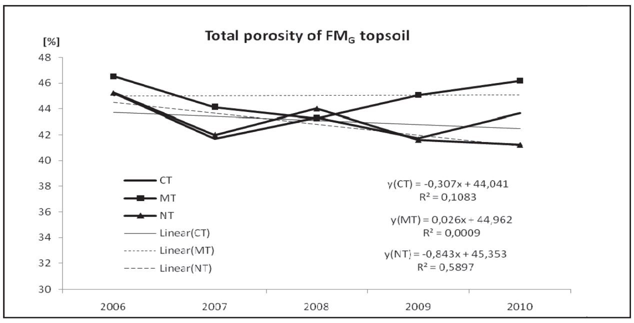

Figure 2 Trend development of total porosity for Gleyic Fluvisol

Table 3 Average maximum capillary capacity for Gleyic Fluvisol topsoil in %

Soil tillage	Year					
	2006	2007	2008	2009	2010	$\bar{x}$ Y
CT	39.75	37.20	39.30	38.74	39.29	38.86
MT	40.32	37.58	39.10	39.20	40.19	39.28
NT	39.51	36.34	37.74	37.32	38.94	37.97
$\bar{x}$ T	39.86	36.98	38.71	38.42	39.47	38.70

$\bar{x}$ T – average for soil tillage, $\bar{x}$ Y – average for experimental year

Table 4 Statistical evaluation of physical properties of Gleyic Fluvisol at different soil tillage

Parameter	Source of variation	Degree of freedom	Calculated F-value	*P* significance
ρ_d	year	4	21.22	++
	tillage system	2	34.22	++
	residual	50		
	total	59		
P_t	year	4	20.95	++
	tillage system	2	34.21	++
	residual	50		
	total	59		
θ_{MCC}	year	4	201.09	++
	tillage system	2	125.05	++
	residual	50		
	total	59		

++$P < 0.01$ +$P < 0.05$
P – effect of factor significant at the level $\alpha = 0.05$ or $\alpha = 0.01$, ρ_d – bulk density, P_t – total porosity, θ_{MCC} – maximum capillary capacity

so the total porosity was the lowest and its values were in range 41.23–45.26 %.

From point of view the effect of soil tillage systems on the total porosity, this soil parameter was decreased as follows: MT < CT < NT. For individual experimental years the total porosity was increased as follows: 2007 < 2009 < 2008 < 2010 < 2006. Also in our experiment the statistically significant effect of the experimental year and tillage system on total porosity was confirmed. Similar results for shorter, abut also for longer time periods published Kotorová (2007) and Kotorová et al. (2010).

The trend of total porosity development is shown on Fig. 2. For total porosity linear trend also was kept, similarly as

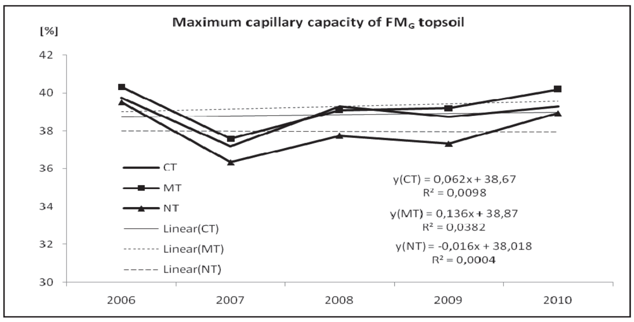

Figure 3 Trend development of maximum capillary capacity for Gleyic Fluvisol

for bulk density, but with opposite development. And so the trend analyse predicts decreasing of the total porosity by 1.45 % for CT variant and by 4.22 % for NT variant. For MT variant it predicts statistically no-significant increasing by 0.13 %.

The maximum capillary capacity is one from hydrophysical parameters, which is connected mainly with the content of clay particles and the water storage in soil profile. For the soils with very high content of clay particles is typical the large interval of maximum capillary capacity (Fulajtár, 2006). This large range is conditional on horizontal and vertical heterogeneity of heavy soils. The values of maximum capillary capacity for the Gleyic Fluvisol are listed in Table 3.

In observed time-series for all tillage variants the values of maximum capillary capacity were in interval 36.34–40.32 %. In average the maximum capillary capacity was the highest for MT variant (39.28 %), lower it was for CT variant (38.86 %) and the lowest it was for NT variant (37.97 %). From point of view of experimental year the maximum capillary capacity was increased as follows: 2006 < 2010 < 2008 < 2009 < 2007. For heavy the Gleyic Fluvisol on the East Slovak Lowland similar results were published by Šútor et al. (2002), Kotorová and Jakubová (2007), Kotorová and Mati (2008).

The trend analyse (Fig. 3) of observed time-series predicts slightly increasing of maximum capillary capacity by 0.31% for conventional tillage and by 0.68 % for minimum tillage, but its no-significant decreasing (by 0.08 %) for NT variant.

Statistically significant effect of soil tillage systems and experimental year on observed soil physical parameters was confirmed by the analysis of variance (Table 4).

Conventional tillage and direct sowing (no-till system) had more significant effect on bulk density then minimum tillage system, where its values were lower. Year 2007 had most effect on bulk density values. The effect of soil tillage system on total porosity was opposite as for bulk density and the highest effect on total porosity had year 2006. Minimum tillage had the most effect on values of the maximum capillary capacity, similarly also year 2006.

4. Conclusions

Effect of different soil tillage systems on changes of physical properties of heavy Gleyic Fluvisol on the East Slovak Lowland was evaluated between 2006 and 2010 years. From obtain data may be formulated the following conclusions:

On Gleyic Fluvisol at direct sowing without ploughing (no-tillage) we ascertained higher bulk density and lower total porosity in comparison with conventional tillage and minimum tillage, too. Maximum capillary capacity was relatively equal and ascertained values were typical for given soil type.

From evaluation of 5-years time series influenced significant increasing of bulk density under conventional tillage and direct sowing without ploughing and its decreasing under minimum tillage. The total porosity was lower under CT and NT variants and higher under MT variant. Maximum capillary capacity was slightly increasing under conventional and minimum tillage systems, but it was no-significant decreasing under direct sowing (no-till system).

The soil protective technologies, minimum tillage and also direct sowing without ploughing, are one method for keeping and conservation of the soil fertility. For their successful is needful application as whole the farming system and the continuity of this system is very important. Using of the protective technologies may also contribute to keeping of stability of ecologically sensitive the heavy soils.

5. References

ALVAREZ, R. and STEINBACH, H. S. (2009) A review of the effects of tillage systems on some physical properties, water content, nitrate availability and crops yield in the Argentine Pampas. In *Soil Tillage Res.*, vol. 104, no. 1, 2009, pp. 1–15.

DAM, R. F. et al. (2006) Soil bulk density and crop yield under eleven consecutive years of corn with different tillage and residue practices in a sandy loam soil in central Canada. In *Soil Tillage Res.*, vol. 84, no. 1, pp. 4–53.

DEMO, M. et al. (2000) *Regulation technologies in production process of agricultural crops*. Nitra: SPU (in Slovak).

ELDER, J. W. and LAL, R. (2008) Tillage effect on physical properties of agricultural organic soils of north central Ohio. In *Soil Tillage Res.*, vol. 98, no. 2, pp. 208-210. DOI: 10.1016/j.still.2007.12.002

FULAJTÁR, E. (2006) *Physical properties of soils*. Bratislava: Výskumný ústav pôdoznalectva a ochrany pôdy (in Slovak).

GŁĄB, T. and KULIG, B. (2008) Effect of mulch and tillage system on soil porosity under wheat (*Triticum aestivum*). In *Soil Tillage Res.*, vol. 99, no. 2, pp. 169–178.

GOMEZ, E., et al. (2001) Changes in some soil properties in a Vertic Argiudoll under short-term conservation tillage. In *Soil Tillage Res.*, vol. 61, no. 3 – 4, pp. 179–186.

HORÁK, J. et al. (2009) Modelling of conventional tillage and no tillage management practises and their effects on various fluxes of carbon (C) and nitrogen (N) in agrosystem of selected site in Slovak Republic. In *Ecological modelling for enhanced sustainability in management*. Quebec: International Society for Ecological Modelling.

HRIVŇÁKOVÁ, K. et al. (2011) *Standard working procedures for soil analyses*. Bratislava: VÚPOP (in Slovak).

HUSNJAK, S., FILIPOVIĆ, D. and KOŠUTIĆ, S. (2002) Influence of different tillage systems on soil physical properties and crop yield. In: *Rostlinná výroba*, vol. 48, no. 6, pp. 249–254.

CHAJDIAK, J. (2005) *The statistical works and solves them in Excel*. Bratislava: Statis (in Slovak).

IVANOVÁ, H. (1985) *The effect of different agro-technology on soil fertility and soil properties: Final Report*. Michalovce: KPVS.

KOTOROVÁ, D. (2001) *The production process of winter wheat (Triticum aestivum L.) on the East Slovak Lowland*. Michalovce: OVÚA.

KOTOROVÁ, D. (2007) The changes of clay-loamy soil properties at its different tillage. In *Agriculture (Poľnohospodárstvo)*, vol. 53, no. 4, pp. 183–190.

KOTOROVÁ, D. and JAKUBOVÁ, J. (2007) Analysis of weather factors effect on soil properties. In *Acta Hydrologica Slovaca*, vol. 8, no. 2, pp. 217–223.

KOTOROVÁ, D. and MATI, R. (2008a) Properties and moisture regime of heavy soils in relation to their cultivation. In *Cereal Research Communications*, vol. 36, Suppl., pp. 1751–1754.

KOTOROVÁ, D. and MATI, R. (2008b) The trend analyse of water storage and physical properties in profile of heavy soils. In *Agriculture (Poľnohospodárstvo)*, vol. 54, no. 4, pp. 155–164.

KOTOROVÁ, D. and ŠOLTYSOVÁ, B. (1992) Effect of the crop rotation with higher cereal representation on the changes of physical-chemical soil properties on the East-Slovak lowland region. In *Rostlinná výroba*, vol. 38, pp. 671–676 (in Slovak).

KOTOROVÁ, D. and ŠOLTYSOVÁ, B. (2011) *Physico-chemical properties of heavy soils*. Piešťany: CVRV – Výskumný ústav agroekológie Michalovce.

KOTOROVÁ, D., ŠOLTYSOVÁ, B. and MATI, R. (2010) *Properties of Fluvisols on the East Slovak Lowland at their different tillage*. Piešťany: CVRV – Výskumný ústav agroekológie Michalovce.

KOTOROVÁ, D. et al. (2011) Soil tillage in relation to soil properties and yields of crop. In *Agriculture (Poľnohospodárstvo)*, vol. 56, no. 3, pp. 67–75.

KOVÁČ, K. and ŠVANČÁRKOVÁ, M. (2003) The influence of various agrotechnical factors on soil physical properties. In *Agriculture (Poľnohospodárstvo)*, vol. 49, no. 12, pp. 608–618.

KOVÁČ, K. and ŽÁK, Š. (1999) The effect of various methods of soil tillage on its physical and hydro-physical properties. In *Rostlinná výroba*, vol. 45, no. 8, pp. 359–364.

LAL, R., REICOSKY, D. L. and HANSON, J. D. (2007) Evolution of the plow over 10,000 years and the rationale for no-farming. In *Soil Tillage Res.*, vol. 93, no. 1, pp. 1–12.

LEDVINA, R. et al. (2004) Soil protective technologies for field crops cultivation. In: Collection of Scientific Papers. In *Series for Crop Sciences*, vol. 21, no. 2, p. 61–66.

LINKEŠ, V., PESTÚN, V. and DŽATKO, M. (1996) Manual for using of maps of site pedo-ecological units. 3. ed. Bratislava: VÚPÚ (in Slovak).

MACÁK, M. et. al. (2008) Effect of basic cultivation of soil and precipitation on soil bulk density. In *Lucräri stiintifice Facultatea de Agriculture*, vol. 40, no. 2, pp. 93–98.

MATI, R. and KOTOROVÁ, D. (2007) The effect of soil tillage system on soil bunk density and other physical and hydrophysical characteristics of Gleyic Fluvisol. In *Journal of Hydrology and Hydromechanics*, vol. 55, no. 4, pp. 246–252.

MATI, R. et.al. (2011) Development of evapotranspiration and water supply of clay-loamy soil on the East Slovak Lowland. In *Agricultural Water Management*, vol. 98, no. 7, pp. 1133–1140. DOI: 10.1016/j.agwat.2011.02.007.

MIKULOVÁ, K. et al. (2008) *Climatological standards 1961–1990 of meteorological elements the air temperature and precipitation: Final report of research project.* [CD-ROM]. Bratislava: SHMÚ (in Slovak).

NAIL, E. L., YOUNG, D. L. and SCHILLINGER, W. F. (2007) Diesel and glyphosate price changes benefit the economics of conservation tillage versus traditional tillage. In *Soil Tillage Res.*, vol. 94, no. 2, pp. 321–327.

SEDLÁK, Š. (1980) *Effect of differentiated agro-technology on properties of heavy soils: Final report*. Michalovce: KPVS (in Slovak).

ŠÚTOR, J. et al. (1995) *Hydrology of the East Slovak Lowland.* Michalovce: Media Group.

ŠÚTOR, J. et al. (2002) *Characteristics of the aeration zone of heavy soils of the East Slovak Lowland*. Bratislava: ÚH SAV, Michalovce: OVÚA.

ŠÚTOR, J. et.al. (2007) *Water in the aeration zone of soils in the East Slovak Lowland.* Bratislava: ÚH SAV, Michalovce: SCPV – Ústav agroekológie (in Slovak).

VILČEK, J. (2005) *Pedo-geographical specifics of soils of the East Slovak Lowland.* Michalovce: VÚRV – Ústav agroekológie (in Slovak).