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DEPENDENCE OF HEAVY SOIL TRANSPORT FUNCTION ON SOIL PROFILE DEPTH

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The aim of this work was to quantify the effect of soil profile depth on the transport function of heavy soils. Treatments were carried out between 2006 and 2009 in Milhostov. Two variants were examined : the (conventional soil tillage and long-time no-tilled variant). Soil samples were taken in spring and autumn from soil profile depth of 0.00–0.60 m from each 0.10 m. For further evaluation the average values were used. Particle size composition, bulk density, total porosity and maximum capillary capacity were determined. Content of clay particles in soil profile was in interval 59.64–68.53% and such soils are characterised in the range from clay-loamy soil to clayey soil. The bulk density increased with the depth of soil profile and its values reached 1 184–1 646 kg m^{-3}. The total porosity was in range 37.68–55.17% and it decreased with the depth of soil profile. The values of maximum capillary capacity were characterised for heavy soils with high content of clay particles. The depth had statistically significant effect on all observed parameters. In average, on both variants the bulk density was higher than 1 400 kg m^{-3}, the total porosity was lower than 47% and the content of clay was higher than 30%, pointing to the possibility of soil compaction, which will result in reduced transport function of heavy soils.

Key words: heavy soil, transport function, particle-size distribution, physical soil properties

The permanent sustainable development of the society is very strongly connected with the quality of environment. Basic production material in plant production is soil with its fertility. For soil are typical also its functions, mainly production and environmental functions. Production function is usually simplified to agricultural function. The interest about ecological, environmental or no production functions of soil has increased only during the latest decades. Common aim of farmers and ecologists is the permanent sustainable development of agriculture, hence production and ecological functions of soil. Soil functions should be understood in the wider context, not only in relation of soil to living organisms, but also to rock, water and atmosphere (Blum et al. 2006).

Juráni (in Demo et al. 1998) assigned the no production functions as follows: filtration, buffering, transformation, accumulation, transport, biological habitat and gene fund, sanitation, soil as historical medium, soil as pool of energy and row materials, soil as space for human activity.

One of the important no production functions of soil is its transport function, which is closely connected with further soil functions and also with water regime of soil and the structure of soil profile. The transport function is the ability of soil to move substances not only in soil profile, but also outside. The transport medium in soil is predominately the soil water, in minimum extent it is soil air. It follows, that transport of substances and nutrients is dependent on the type of water regime of soil (Bedrna 2002). At larger coherence of soil particles, more energy for their release is needed. On the other hand the infiltration ability of soil is greater, the discharge is lesser and so the eroding

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and transport ability is lower as well. Blum (2002) and Doran & Parkin (1996) published that the transport function is connected mostly with the movement of water because soil water serves as the most frequent transport medium. The transport and movement of water can be realised not only in vertical direction (down or up), but also in lateral direction.

The range of substances transport depends on the depth of the plough, granulometric composition and structural status of soil. The dimension and course of transport of substances through the soil water is given by the structure of soil profile. The substances transport of Fluvisols (Demo et al. 1998) is significantly dependent on their granulometric composition, for example on Gleyic Fluvisol during dry and warm periods, the transport of substances from ground water up to the soil profile occurs.

Karlen et al. (1997) and Manrique and Jones (2001) emphasised the evaluation of all soil functions based on using of selected basic data of soil parameters and characteristics such as evaluation of the productive potential. Novák et al. (2010) published the evaluation of soil quality in compliance with potential of productive and environmental soil functions.

The aim of this contribution was to obtain the knowledge about the dependence of transport function of heavy soils of the East Slovak Lowland on the depth of soil profile and about dimension of pore space.

MATERIAL AND METHOD

Transport function of heavy soils was studied between 2006 and 2009 in Milhostov at the place of the experiment at Plant Production Research Center Piešťany – Research Institute of Agroecology Michalovce, where Gleyic Fluvisols are situated.

Gleyic Fluvisol (FM_G) in Milhostov is characterized as heavy, clay-loamy soil with the average content of clay particles higher than 53%. Gleyic Fluvisol was formed on heavy alluvial sediments during the long-time contact with groundwater and surface water. The topsoil has lump aggregate structure with high binding ability and it has a weak perviousness in its whole profile. In the depth 0.7–0.8 m of soil profile, a layer of dark grey clay is found. The level of underground water is high. Agronomical properties of Gleyic Fluvisol are significantly influenced by the high content of clay particles.

Variability of soil properties is caused by the impact of parent material on the particle-size composition of soil. Individual categories of soil granularity have various diameters of particles. Kopecký (in Kutílek 1978) characterised four categories of soil particles size as follows: I. category – clay particles, II. category – dust, III. category – powdered sand, IV. category – sand. The soil, according to the content of clay particles (< 0.01 m) is divided into soil textures

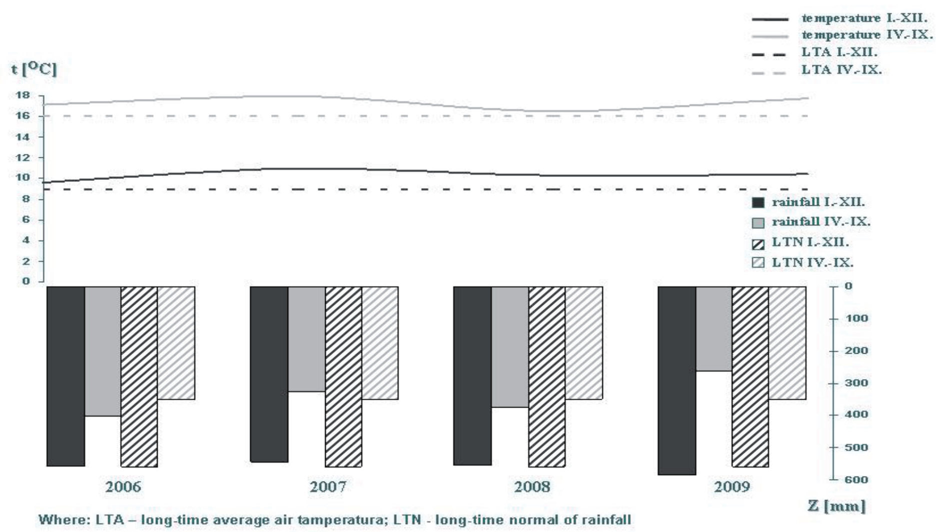


Fig. 1. Weather conditions of experimental season

and their basic categories appear on the Novák classification scale of granularity (Linkeš et al. 1996; Velebný et al. 2000; Fulajtár 2006; Zaujec et al. 2009).

Experimental area is characterized as warm and very dry lowland continental climate region T 03 (Linkeš et al. 1996). The precipitation was compared to long-time normal (LTN) from years 1951–1980 (Horecká & Valovič 1991) and the average air temperature was compared to long-time average (LTA) from years 1951–1980 (Petrovič & Šoltís 1984). Climatic conditions at the site Milhostov in experimental years 2006–2009 are shown on Figure 1.

The vegetation seasons between 2006 and 2009 and also the whole years from the point of view of the sum precipitation were normal (Kožnarová & Klabzuba 2002).

The transport function of heavy soil was measured from basic physical and hydro-physical parameters in soil profile depth 0.00–0.60 m from each 0.10 m. Soil parameters were analysed as follows: bulk density (BD, kg m^{-3}), total porosity (TP, %), maximum capillary capacity (MCC, %). These parameters were determined by the methods published by Fiala et al. (1999) The individual fractions of granulometric composition were analyzed by pipetting method as follows: 1st fraction – clay (< 0.001 mm); 2nd fraction – fine and medium dust (0.001–0.01 mm); 3rd fraction – coarse dust (0.01–0.05 mm); 4th fraction – fine sand (0.05–0.25 mm); 5th fraction – medium sand (0.25–2.00 mm). The content of the I. category (diameter of particles < 0.01 mm) was calculated as the sum of 1st and 2nd granulometric fractions, i.e. the sum of the content of clay and fine and medium dust.

The soil samples were taken twice per year: in spring (March – April) and in autumn (October). For the evaluation of selected soil indicators the average values from spring and autumn sampling were used. Results presented in this work are the averages from two tillage variants and two samplings during observed years. All analyses were made with four replications.

The two variants for research of transport function were realized as follows:

– EXP – experimental variants with conventional tillage of soil (traditional method with ploughing);

– CONT – control variant, long-time no-tilled variant.

Obtained data were tested by mathematical-statistical methods from which analysis of variance was used (the Statgraphics software package).

T a b l e 1

Average granulometric composition [%] of heavy soil

Depth [m]	Variant	Diameter of particles [mm]					
		< 0.001	0.001–0.01	0.01–0.05	0.05–0.25	0.25–2.00	< 0.01
0.1	EXP	32.40	32.39	27.09	7.28	0.84	64.79
	CONT	31.93	33.25	26.25	7.93	0.65	65.18
0.2	EXP	32.91	32.68	25.82	7.99	0.60	65.59
	CONT	32.59	32.79	26.49	7.43	0.70	65.38
0.3	EXP	32.90	32.96	25.12	8.57	0.45	65.86
	CONT	32.11	34.14	25.36	7.88	0.51	66.25
0.4	EXP	32.46	31.43	26.69	8.79	0.64	63.89
	CONT	33.22	31.70	26.90	7.59	0.59	64.92
0.5	EXP	31.48	30.87	27.62	9.31	0.73	62.34
	CONT	33.32	31.02	26.31	8.83	0.54	64.32
0.6	EXP	30.32	31.76	27.63	9.74	0.55	62.08
	CONT	34.45	29.12	26.51	9.40	0.52	63.57

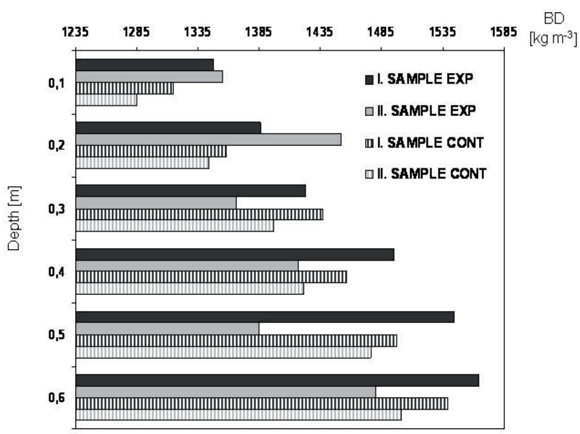
EXP – experimental variant with conventional tillage; CONT – no-tilled variant

RESULTS AND DISCUSSION

Soil forming process is long-lasting and very complicated. Result from this process is the genesis of soil from enlivened parent material. The parent material has significant influence mainly to granulometric composition, depth and mineral power of soil. This material also affects soil processes and the way of weathering.

The transport of individual granulometric fractions in the profile of experimental and control variants is characterised by the average values in particular layers (Table 1) in soil profile. The obtained results indicate that the differences at minimum and maximum contents of evaluated fractions are significant. According to Novák classification scale (Zaujec et al. 2009), soil with minimum value 59.14% of clay particles is clay-loamy soil. The soil with maximum value 68.53% of clay particles is clayey soil. Experimentally obtained data confirm the marked heterogeneity of soil situation on the East Slovak Lowland, where soil textures alternate within short distances (Vilček 1998; Kotorová 2007; Mati & Kotorová 2007).

The vertical variability of granulometric fractions in soil profile was also significant. The average contents of individual granulometric categories are shown in Table 1. The content of clay (1st fraction) in soil profile depth was in range 14.47–39.78% and in all observed depths it was quite variable. The vertical variability appeared as a difference not only between minimal values (average Δ = 14.17%; at least 14.47% in depth 0.5–0.6 m; the most 29.17% in depth 0.3–0.4 m), but also as significant difference between the highest and the lowest maximal value (in average Δ = 11.07%; at lest 5.92% in depth 0.3–0.4 m; the most 25.31% in depth 0.5–0.6 m). The fine and medium dust (2nd fraction) reached values from 26.05% to 45.17%. The lowest value from minimal and maximal values (26.05%) was determined for depth 0.4–0.5 m.



EXP – experimental variant with conventional tillage;
CONT – control no-tilled variant
I sample – spring sampling;
II sample – autumn sampling

Fig. 2. Average bulk density (BD) in soil profile

The content of coarse dust in soil profile is characterized by 3rd fraction. High variability was also found at this fraction. According to Fulajtár (2006), the particles of coarse dust form reasonably large pores, which are susceptible to leak water, even the air. The dust particles have relatively large surface which favourably affects the binding of nutrients and water in soil profile. In the study of soil profiles the content of dust was in range 13.72–33.72%. Maximal and also minimal content of coarse dust was analyzed in depth 0.5–0.6 m. The impact of high level of ground water at Gleyic Fluvisols on the content of 3rd fraction can be expected. The content of fine sand (4th fraction) was in interval 1.99–16.96%. The coarse dust in the sampled soil profiles reached values from 0.08% to 1.99%.

The bulk density is a basic characteristic of the physical status of soil. In our experiments, its increasing with the soil profile depth was confirmed (Fig. 2). In soil depth 0.5–0.6 the highest average, minimal and maximal values of bulk density were ascertained. By Šútor et al. (2009) the spatial variability of bulk density is expressed mainly in vertical line of soil profile. This fact was confirmed also in our experiments. In all sampling profiles the bulk density was variable and reached values from interval 1 184–1 646 kg m^{-3}. The obtained data confirmed the predictions of authors such as Guspan et al. (1975) and Šútor et al. (2002) that at higher content of clay particles the bulk density is lower.

Figure 2 demonstrates that, for the experimental variant the bulk density in upper layer of soil profile (to 0.2 m) was lower in spring sampling but higher in autumn sampling. From depth 0.3 m reversely, the bulk density in autumn sampling was higher in comparison with spring sampling. Ameliorative effect of root system of cultivating plants on bulk density values is possible. The bulk density of control variant in the whole soil profile was higher in spring sampling in comparison with autumn sampling (in average Δ = 30 kg m^{-3}).

A very strong relationship exists between the bulk density and total porosity. The total porosity decreased with the soil profile depth (Fig. 3). Its average values were from 42.42% to 49.82%. The calculated porosity also depends on the specific gravity of soil. The lowest total porosity (37.68%) was found in soil depth 0.4–0.5 m and the highest (55.17%) in soil depth 0.1–0.2 m.

Maximum capillary capacity is hydro-physical parameter which is closely associated with granulometric composition of soil, porosity and heterogeneity of soil profile. The large range of maximum capillary capacity from 33.03% (in depth 0.0–0.1 m) to 47.65% (depth 0.1–0.2 m) is specific for soils with high content of clay particles. Similar values for soils of the East Slovak Lowland published e.g. Fulajtár (1986), Šútor et al. (2002, 2007), Kotorová (2007) and Kotorová and Mati (2008a, b).

The analysis of variance (Table 2) resulted in statistically significant effect of soil profile depth on all observed physical and hydro-physical parameters. The date of sampling had significant effect on values of bulk density and total porosity. The course of climatic conditions in a given year influenced the values of bulk density, total porosity and maximum capillary capacity. The values and standard error of observed parameters are shown in Table 3.

The transport function of soil is dependent on the size of pores space in soil profile. This space is the main transport way for water and nutrients. Because the bulk density is connected with the total porosity, in field conditions the experimentally ascertained values of these parameters may be the indicator for determination of transport function. Zrubec (1998) published for heavy clay-loamy and clayey soils the critical values of soil parameters: bulk density > 1 400 kg m^{-3}, porosity < 47%, clay content > 30%. In our experiment, on both tillage variants and in all sampling, the bulk density increased with the soil profile depth and its average value 1 426 kg m^{-3} indicates the possibility of soil compaction in subsoil. Decreasing of transport

Table 2

Analyse of variance of physical parameters

Parameter	Source of variation	Degree of freedom	Mean Square	P value
I. category	sampling	1	2.47	0.445
	year	3	4.44	0.371
	variant	1	68.95	0.000
	depth	5	99.70	0.000
	residual	370	4.24	–
	total	383	–	–
BD	sampling	1	155526.00	0.000
	year	3	164520.00	0.000
	variant	1	23064.00	0.018
	depth	5	308803.00	0.000
	residual	370	4090.92	–
	total	383	–	–
TP	sampling	1	223.26	0.000
	year	3	236.77	0.000
	variant	1	32.53	0.019
	depth	5	442.63	0.000
	residual	370	5.87	–
	total	383	–	–
MCC	sampling	1	3.15	0.445
	year	3	378.00	0.000
	variant	1	72.42	0.000
	depth	5	104.35	0.000
	residual	370	5.38	–
	total	383	–	–

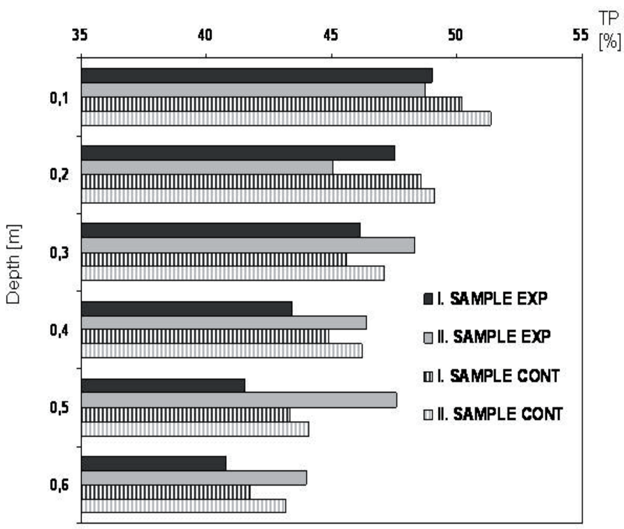
I. category – content of clay particles, BD – bulk density, TP – total porosity, MCC – maximum capillary capacity

T a b l e 3

Mean values ± standard errors of clay particles, bulk density, total porosity and maximum capillary capacity in the depth of soil profile

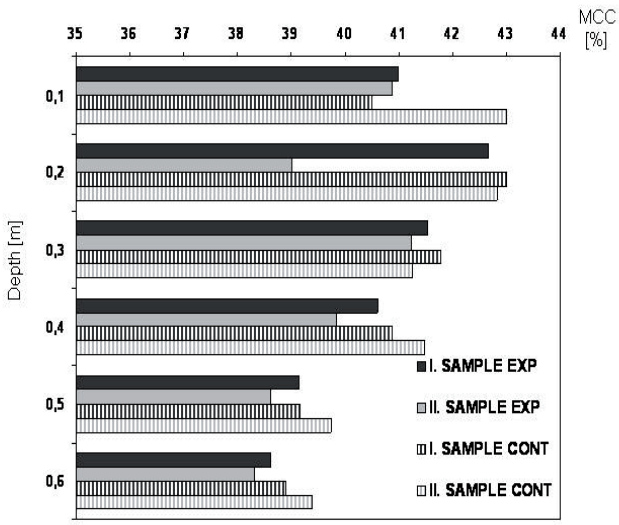
Depth [m]	I. category	BD	TP	MCC
0.1	64.99±0.257	1325±7.995	49.82±0.303	41.35±0.290
0.2	65.48±0.257	1385±7.995	47.57±0.303	41.88±0.290
0.3	66.05±0.257	1405±7.995	46.79±0.303	41.45±0.290
0.4	64.40±0.257	1447±7.995	45.22±0.303	40.70±0.290
0.5	63.34±0.257	1475±7.995	44.14±0.303	39.17±0.290
0.6	62.82±0.257	1520±7.995	42.42±0.303	38.81±0.290

I. category – content of clay particles, BD – bulk density, TP – total porosity, MCC – maximum capillary capacity



EXP – experimental variant with conventional tillage;
CONT – control no-tilled variant
I sample – spring sampling;
II sample – autumn sampling

Fig. 3. Average total porosity (TP) in soil profile



EXP – experimental variant with conventional tillage;
CONT – control no-tilled variant
I sample – spring sampling;
II sample – autumn sampling

Fig. 4. Average maximum capillary (MCC) capacity in soil profile

soil function on EXP variant was determined in depth 0.2 m. From this depth to the depth 0.6 m the bulk density was increased from average 1 419 kg m^{-3} to 1 522 kg m^{-3}. Similarly it was with the total porosity, when its values decreased with the soil profile depth (46.28% in depth 0.2 m; 42.39% in depth 0.6 m). On CONT variant the transport function was decreased from depth 0.3 m. Average values of bulk density were in interval 1 417–1 520 kg m^{-3}. Total porosity was lower than critical 47% about 0.64–4.55 %.

The comparison of transport function indicators for experimental and control variant showed higher average bulk density (Δ = 10 kg m^{-3}) and lower total porosity (Δ = 1.1 %) for EXP variant. In average, higher bulk densities and lower porosities were determined for spring sampling in comparison to autumn sampling.

The results of our experiments indicate higher probability of deterioration of transport function already in topsoil of conventional tillage variant (EXP). For long-time no-tillage variant (CONT) this deterioration of transport function was determined in subsoil. Our results also point to the possibility of soil compaction on the experimental and control variant. In this case is also possible the decreasing of transport function in heavy soils.

CONCLUSION

From the results obtained between 2006 and 2009 we made the following conclusions about the effect of soil profile depth on the transport function of heavy soils:

The content of clay particles of observed variants was in interval 59.64–68.53% and such soils are characterised in the range from clay loamy soil to clayey soil. This confirmed the significant heterogeneity of soils on the East Slovak Lowland.

The bulk density increased with the soil profile depth and its values reached 1 184 –1 646 kg m^{-3}. The total porosity was in range 37.68–55.17% and it decreased with the soil profile depth. The values of maximum capillary capacity were characterised for heavy soils with high content of clay particles. Statistical tests confirmed the significant effect of the soil profile depth on all observed parameters.

The results of our experiments indicate higher probability of deterioration of transport function already from depth 0.2 m for conventional tillage variant and for long-time no-tillage variant from depth 0.3 m. Obtained data indicate the soil compaction on experimental and control variant and that the decreasing of transport function of heavy soils is possible.

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