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VPLYV ZRNITOSTNÉHO ZLOŽENIA PÔDY NA KVANTITU A KVALITU PÔDNEJ ORGANICKEJ HMOTY INFLUENCE OF PARTICLE SIZE DISTRIBUTION OF SOIL ON QUANTITY AND QUALITY OF SOIL ORGANIC MATTER

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Influence of particle size distribution of soil on the carbon and nitrogen contents and fractional composition of humus substances was studied in different soil types (Eutric Fluvisol, Haplic Chernozem, Haplic Luvisol, Eutric Regosol). The variants include soils of forest ecosystem (control) and agro-ecosystem with 4 crop rotations. The particle size distribution of soil influenced the content and quality of soil organic matter. It was noted that, the higher proportion of smaller fraction (<0.001 mm) supported, the higher content of soil organic matter ($r = 0.794$; $P < 0.01$) subjected to smaller changes ($r = 0.551$; $P < 0.05$). Higher content of size fraction <0.001 mm supported higher stability of humus substances ($r = -0.755$; $P < 0.01$) and humic acids ($r = -0.533$; $P < 0.05$). The humic acids bound with mineral components and stabile R_2O_3 were dominated. In contrary, higher content of size fraction (0.05 – 0.25 mm) contributed higher content of fulvic acid bound with mobile R_2O_3 and higher content of free fulvic acids. Higher content of organic matter was in forest ecosystem, but its quality was better in arable land.

Key words: particle size distribution, soil organic matter, agro-ecosystem, forest ecosystem

Soil organic matter (SOM) is a key element of soil, which determines its production capacity (Robinson et al., 1994), and the quality of soil (Doran and Parkin, 1994). The SOM content depends on the balance between the carbon inputs and the rate of their decomposition (Saggar et al., 2001; Huang et al., 2002). The carbon content influences the number of factors, including soil types, natural content of organic matter in soil (MacRae and Mehuys, 1985), the annual input of root residues and root exudates (Ushakov et al., 1985) or particle size distribution (Amelung et al., 1998; Šimanský and Horvátová, 2010; Šimanský et al., 2009). The content of the SOM is in positive correlation with clay fraction (Bosatta and Ågren, 1997; Jurčová and Tobiašová, 2002). Jastrow (1996) observed that just clay minerals are in conjunction with a large proportion of organic substances; thereby they contribute to its stabilisation.

Carbon stocks in many agricultural soils in recent decades decreased due to agricultural intensification and inappropriate land use (Hermle et al., 2008). Conversion of natural ecosystems to cropland increases carbon losses due to increased intensity of mineralization and reduced carbon inputs (Gregorich et al., 2005). Conversion of forest to arable land leads primarily to a reduction of carbon content and changes in its distribution (Ross, 1993; Singh and Singh, 1996). In agro-ecosystem, maintenance of organic carbon content is the main role in reducing of soil degradation (Bhattacharyya et al., 2009). In agro-ecosystem, the amount of carbon is also influenced through the management system, including the selection of crops, use of crop residues and tillage intensity (Voroney and Angers, 1995). The carbon content in forest soil is the result of the balance between the organic inputs (plant residues) and losses (microbial degradation, forest fires, erosion and leaching), which vary according to climate, parent rock and time (Jenny, 1994).

The quantity of SOM is given by the contents of total organic carbon and nitrogen (Kubát et al., 2006). The quality of

SOM depends on its distribution between labile and stabile components. The stabile organic compounds in soil include humus substances and other macromolecules, which are naturally resistant to the action of microorganisms, or they are physically protected by their adsorption on mineral surfaces or bound within aggregates (Theng et al., 1989). The labile fractions are represented by carbohydrates, amino acids, amino saccharides, or lipids (Woomer et al., 1994). It is assumed that the quality of SOM is reduced by the process of decomposition (Rovira and Vallejo, 2002).

Table 1 Percentages proportions of crops in fields of different soil types

Locality (1)	Variant	Cereals (2)	Oil crops (3)	Legumes (4)	Forage (5)	Annual forage (6)	Root crops (7)
Nitra	HC-01 (a)	66.7	0	0	0	0	33.3
	HC-02	66.7	0	0	0	0	33.3
	HC-03	86.3	0	0	0	0	16.7
	HC-04	66.7	16.6	0	0	0	16.7
Šafa	EF-01 (b)	42.8	0	0	0	28.6	28.6
	EF-02	42.8	0	0	0	28.6	28.6
	EF-03	57.1	0	0	0	14.3	28.6
	EF-04	71.4	14.3	0	0	0	14.3
Topoľčany	HL-01 (c)	71.4	28.6	0	0	0	0
	HL-02	71.4	28.6	0	0	0	0
	HL-03	71.4	28.6	0	0	0	0
	HL-04	71.4	28.6	0	0	0	0
Topoľčany	ER-01 (d)	57.1	42.9	0	0	0	0
	ER-02	57.1	14.3	0	0	28.6	0
	ER-03	57.1	0	0	42.9	0	0
	ER-04	28.6	28.6	14.2	28.6	0	0

(a) HC-01 – HC-04 – crop rotations on Haplic Chernozem, (b) EF-01 – EF-04 – crop rotations on Eutric Fluvisol, (c) HL-01 – HL-04 – fields on Haplic Luvisol, (d) ER-01 – ER-04 – fields on Eutric Regosol

(a) HC-01 – HC-04 – pozemky na černoze, (b) EF-01 – EF-04 – pozemky na fluvizemi, (c) HL-01 – HL-04 – pozemky na hnedezi, (d) ER-01 – ER-04 – pozemky na regozemi

Tabuľka 1 Percentuálne zastúpenie plodín v osevných postupoch na rôznych pôdnych typoch

(1) lokalita, (2) obilniny, (3) olejiny, (4) strukoviny, (5) krmoviny, (6) jednoročné krmoviny, (7) okopaniny

(Nitra), 568 mm (Šafa), and 607 mm (Topoľčany) (Korec et al., 1997).

The variants included two types of agro-ecosystem (ar

Table 2 Total organic carbon and total nitrogen in soils of different ecosystems

Locality (1)	Variant	TOC (g) v mg.kg ⁻¹	NT (h) v mg.kg ⁻¹
Nitra	HC (a)-AL (e)	20 701	1 932
	HC-FO (f)	22 317	1 955
Šaľa	EF (b)-AL	15 460	1 877
	EF-FO	29 547	3 142
Topoľčany	HL (c)-AL	8 893	1 125
	HL-FO	13 950	1 735
Topoľčany	ER (d)-AL	12 443	1 890
	ER-FO	29 670	3 839

(a) HC – Haplic Chernozem, (b) EF – Eutric Fluvisol, (c) HL – Haplic Luvisol, (d) ER – Eutric Regosol, (e) AL – arable land, (f) FO – forest, (g) TOC – total organic carbon, (h) NT – total nitrogen

(a) HC – černožem, (b) EF – fluvizem, (c) HL – hnadozem, (d) ER – regozem, (e) AL – orná pôda, (f) FO – les, (g) TOC – celkový organický uhlík, (h) NT – celkový dusík

Tabuľka 2 Celkový organický uhlík a celkový dusík v pôdach rôznych ekosystémov
(1) lokalita**Table 3** Particle size distribution in soils of different ecosystems

Locality (1)	Variant	Sand in % (2)	Silt in % (3)	Clay in % (4)
Nitra	HC (a)-AL (e)	23.66	56.15	20.20
	HC-FO (f)	28.80	53.76	17.43
Šaľa	EF (b)-AL	29.67	51.59	18.75
	EF-FO	46.25	42.46	11.29
Topoľčany	H (c)-AL	59.60	27.11	13.05
	HL-FO	66.23	23.00	10.77
Topoľčany	ER (d)-AL	40.72	48.23	10.05
	ER-FO	13.07	45.19	28.67

(a) HC – Haplic Chernozem, (b) EF – Eutric Fluvisol, (c) HL – Haplic Luvisol, (d) ER – Eutric Regosol, (e) AL – arable land, (f) FO – forest

(a) HC – černožem, (b) EF – fluvizem, (c) HL – hnadozem, (d) ER – regozem, (e) AL – orná pôda, (f) FO – les

Table 4 Correlations between the carbon and nitrogen parameters and particle size distribution of soil

	2.00 – 0.25 mm	0.25 – 0.05 mm	0.05 – 0.01 mm	0.01 – 0.001 mm	<0.001 mm
TOC (a)	-0.632 ⁺	-0.757 ⁺⁺	0.709 ⁺	0.473	0.794 ⁺⁺
C _L (b)	-0.521 ⁺	-0.646 ⁺	0.672 ⁺	0.268	0.620 ⁺
C _{NL} (c)	-0.644	-0.766 ⁺⁺	0.697 ⁺	0.518	0.763 ⁺⁺
L _C (d)	-0.123	-0.275	0.366	-0.078	0.150
LI _C (e)	0.312	-0.005	-0.113	0.061	-0.342
CPI (f)	-0.605 ⁺	-0.115	0.325	-0.023	0.619 ⁺
CMI (g)	-0.512 ⁺	-0.151	0.296	0.030	0.551 ⁺
NT (h)	-0.464	-0.823 ⁺⁺	0.675 ⁺	0.671 ⁺	0.446
N _L (i)	-0.616 ⁺	-0.756 ⁺⁺	0.674 ⁺	0.510 ⁺	0.754 ⁺⁺
N _{NL} (j)	-0.433	-0.801 ⁺⁺	0.652 ⁺	0.664 ⁺	0.399
L _N (k)	-0.570 ⁺	-0.583 ⁺	0.568 ⁺	0.319	0.730 ⁺⁺
LI _N (l)	-0.158	-0.480	0.486	0.290	-0.023
NPI (m)	-0.635 ⁺	-0.240	0.418	0.049	0.676 ⁺
NMI (n)	-0.613 ⁺	-0.609 ⁺	0.703 ⁺	0.312	0.565 ⁺

(a) TOC – total organic carbon, (b) C_L – labile carbon, (c) C_{NL} – non-labile carbon, (d) L_C – lability of carbon, (e) LI_C – index of carbon lability, (f) CPI – carbon pool index, (g) CMI – carbon management index, (h) NT – total nitrogen, (i) N_L – labile nitrogen, (j) N_{NL} – non-labile nitrogen, (k) L_N – lability of nitrogen, (l) LI_N – index of nitrogen lability, (m) NPI – nitrogen pool index, (n) NMI – nitrogen management index, ⁺P < 0.05, ⁺⁺P < 0.01

(a) TOC – celkový organický uhlík, (b) C_L – labilní uhlík, (c) C_{NL} – nelabilní uhlík, (d) L_C – labilita uhlíka, (e) LI_C – index lability uhlíka, (f) CPI – index zdroja u

Overall, higher extracted amounts of humic acids were on arable land and conversely, fulvic acids in forest. On the base of Q_{HS} and Q_{HA} , the humus substances extracted from arable land can be considered as more stabilized. Madari et al. (1998) found out that higher aromatisation of humic acids is in tillage soils than in no-tillage, as a result of stronger oxidizing conditions in soils, with constant mechanical disruption and subsequently faster decomposition of SOM, especially aliphatic parts of humic acids. Bayer et al. (2002) showed lower degree of humification of humic acids extracted from no-tillage systems than from conventional, which is the result of lower concentration of stabile semiquinones. The higher the intensity of tillage, the higher the stabilization of humus substances; and therefore their higher stability was recorded on arable land than in forest ecosystem.

The content of size fraction <0.001 mm was in positive correlation with the C : N ratio, and in negative with Q_{HS} and Q_{HA} (Table 5). This means, the higher content of size fraction of <0.001 mm was, the more stabilized were humus substances and humic acids.

Influence of size fraction <0.001 mm was showed also in relation to individual fractions of humus substances. The content of size fraction <0.001 mm was in positive correlation with the humic acid contents, mainly humic acids bound with the mineral components of soil and stabile R_2O_3 (HA 3) and in negative correlation with the free fulvic acids and bound with mobile R_2O_3 (FA 1) and with fulvic acids bound with mineral components of soil and stabile R_2O_3 (FA 3). On the other hand, these fractions of humic acids HA 3 and fulvic acids FA 1 were in opposite correlation with the size fraction 0.05 – 0.25 mm. This points to higher proportion of HA 3 in clay fraction (0.001 mm) and FA 1 in fine sand fraction (0.05 – 0.25 mm). Even according to Ellerbrock et al. (1999) extraction of humus substances is influenced also by the stability of clay itself.

It is interesting that the highest contents of humic acids bound with Ca^{2+} were on the fields, in which the cereals had the highest proportions. Conversely, the contents of fulvic acids bound with Ca^{2+} were the lowest just in the fields with the highest proportion of cereals.

Conclusion

The particle size distribution influenced quantity as well as quality of soil organic matter. The higher the content of smaller size fractions (<0.05 mm), the higher the content of soil organic matter; and it is subjected to smaller changes. The higher proportion of size fraction <0.001 mm was, the higher was stability of humus substances and humic acids, and humic acids bound with mineral components and stabile R_2O_3 were dominating. The amount of organic matter was higher in natural ecosystem, but its quality was higher in arable land.

Na štyroch pôdnych typoch (fluvizem, černoze, hnedozem,

zmenám ($r = 0,551$; $P < 0,05$). Vyšší obsah frakcie do 0,001 mm podporil stabilitu humusových látok ($r = -0,755$; $P < 0,01$) aj humínových kyselín ($r = -0,533$; $P < 0,05$), pričom dominovali humínové kyseliny viazané s minerálnymi zložkami a stabilnými R_2O_3 . Naopak vyšší obsah frakcie 0,05 – 0,25 mm prispel k vyššiemu obsahu fulvokyselín viazaných s mobilnými R_2O_3 a voľných fulvokyselín. Obsah organickej hmoty bol síce vyšší v prirodzenom ekosystéme, ale jej kvalita na ornej pôde bola lepšia.

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References

- SEN, E. – KNOX, E. – FLACH, W. 1998. Carbon, nitrogen and sulfur pools in particle-size fractions as influenced by climate. In: Soil Sci. Soc. Am. J., roč. 62, 1998, s. 172 – 181.
- BARANČÍKOVÁ, G. 2002. Zhodnotenie jednotlivých frakcií organického uhlíka na vybraných pôdnych typoch základnej siete monitoringu pôd SR. In: Agrochémia, roč. 42, 2002, č. 4, s. 6 – 9.
- BASILE-DOELSCH, I. – AMUNDSON, R. – STONE, W. – MASIÉLO, C. – BOTTERO, J. – COLIN, F. – MASIN, F. – BORSCHNECK, D. – MEUNIER, J.D. 2005. Mineral control of soil organic carbon dynamic in an allophanic soil (La Réunion). In: Eur. J. Soil Sci., vol. 56, 2005, p. 689 – 703.
- BAYER, C. – MARTIN-NETO, L. – MIELNICZUK, J. A. – SAAB, S. C. – MILORI, D. M. P. – BAGNATO, V.S. 2002. Tillage and cropping system effects on soil humic acid characteristics as determined by electron spin resonance and fluorescence spectroscopies. In: Geoderma, vol. 105, 2002, p

- FIALA, K. – KOBZA, J. – MATÚŠKOVÁ, Ľ. – BREČKOVÁ, V. – MAKOVNÍKOVÁ, J. – BARANČÍKOVÁ, G. – BŮRIK, V. – LITAVEC, T. – HOUSKOVÁ, B. – CHROMANIČOVÁ, A. – VÁRADIOVÁ, D. – PECHOVÁ, B. 1999. Závazné metódy rozborov pôd. Čiastkový monitorovací systém – Pôda. Bratislava : VUPOP, 1999, 142 s.
- GREGORICH, E. G. – ROCHETTE, P. – VANDENBYGAART, A. J. – ANGERS, D. A. 2005. Greenhouse gas contributions of agricultural soils and potential mitigation practices in Eastern Canada. In: *Soil Till. Res.*, vol. 83, 2005, p. 53 – 72.
- HERMLE, S. – ANKEN, T. – LEIFELD, J. – WEISSKOPF, P. 2008. The effect of the tillage system on soil organic carbon content under moist, cold-temperate conditions. In: *Soil Till. Res.*, vol. 98, 2008, p. 94 – 105.
- HUANG, Y. – LIU, S. – SHEN, Q. – ZONG, L. 2002. Influence of environmental factors on the decomposition of organic carbon in agricultural soils. In: *Chin. J. Appl. Ecol.*, vol. 13, 2002, no. 6, p. 709 – 714.
- JASTROW, J. D. 1996. Soil aggregate formation and the accrual of particulate and mineral-associated organic matter. In: *Soil Biol. Biochem.*, vol. 28, 1996, p. 665 – 676.
- JENNY, H. 1994. *Factors of Soil Formation. A System of Quantitative Pedology*. New York : Dover Press.
- JURČOVÁ, O. 1998. Význam rastlinných zvyškov ako zdroja organických látok. In: *Naše pole*, 1998, č. 3, s. 18 – 19.
- JURČOVÁ, O. – TOBIAŠOVÁ, E. 2002. Mineralization of plant residues in conditions with different soil texture. In: *Poľnohospodárstvo*, vol. 48, 2002, no. 1, p. 26 – 34.
- KALBITZ, K. – SCHMERWITZ, J. – SCHWESIG, D. – MATZNER, E. 2003. Biodegradation of soil-derived dissolved organic matter as related to its properties. In: *Geoderma*, vol. 113, 2003, p. 273 – 291.
- KOREC, P. – LAUKO, V. – TOLMAČI, L. – ZUBRICKÝ, G. – MIČIE-TOVÁ, E. 1997. Kraje a okresy Slovenska. Nové administratívne členenie. Q111: Bratislava, 1997, 391 s.
- KUBÁT, J. – CERHANOVÁ, D. – NOVÁKOVÁ, J. – LIPAVSKÝ, J. 2006. Total organic carbon and its composition in long term field experiments in the Czech Republic. In: *Arch. Agron. Soil Sci.*, vol. 52, 2006, p. 495 – 505.
- LOGINOV, W. – WISNIEWSKI, W. – GONET, S.S. – CIESCINSKA, B. 1987. Fractionation of organic carbon based on susceptibility to oxidation. In: *Pol. J. Soil Sci.*, vol. 20, 1987, p. 47–52.
- MACRAE, R. J. – MEHUYS, G. R. 1985. The effect of green manuring on the physical properties of temperate-area soils. In: *Adv. Soil Sci.*, vol. 3, 1985, p. 71 – 94.
- MADARI, B. – MICHELI, E. – CZINKOTA, I. – JOHNSTON, C.T. – GRAVEEL, J.G. 1998. Soil organic matter as indicator of changes in the environment. Anthropogenic influences: tillage. In: *Agrokémia és Talajtan*, vol. 47, 1998, p. 1 – 4.
- MEERSMANS, J. – DE RIDDER, F. – CANTERS, F. – DE BAETS, S. – VAN MOLLE, M. 2008. A multiple regression approach to assess the spatial distribution of Soil Organic Carbon (SOC) at the regional scale (Flanders, Belgium). In: *Geoderma*, vol. 143, 2008, p. 1 – 13.
- NANNIPIERI, P. 1993. *Ciclo della Sostanza Organica nel Suolo*. Patron: Bologna, 1993.
- ORLOV, D. S. – GRIŠINA, L. A. 1981. *Analyses of Humus Chemistry*. Moskva : IMU.
- PONOMAREVA, V. V. – PLOTNIKOVA, T. A. 1975. Opređenje gruppovogo i frakcionnogo sostava gumusa po scheme I. V. Ĺurina, v modifikaciji V. V. Ponomarevoj i T.A. Plotnikovej [Group and fractional composition of humus according to I. V. Tyurin, in modification of V.V. Ponomareva and T.A. Plotnikova]. In: *Agrochimičeskije metody issledovanija počv*. Moscow : Nauka, 1975, p. 47 – 55.
- RIFFALDI, R. – LEVI-MINZI, A. – SAVIOZZI, A. – BENETTI, A. 1998. Adsorption on soil of dissolved organic carbon from farmyard manure. In: *Agric. Ecosyst. Environ.*, vol. 69, 1998, p. 113 – 119.
- ROBINSON, C. A. – CRUSE, R. M. – KOHLER, K.A. 1994. Soil management. In: *Hatfield, J.L. – Karlen, D.L. (Eds.): Sustainable agriculture systems*. Boca Raton, FL : Lewis Publ., 1994, p. 109 – 134.
- ROSS, S. M. 1993. Organic matter in tropical soils: current conditions, concern and prospects for conservation. In: *Progress in Physiographic and Geography*, vol. 17, 1993, p. 265 – 305.
- ROVIRA, P. – VALLEJO, V. R. 2002. Labile and recalcitrant pools of carbon and nitrogen in organic matter decomposing at different depths in soil: an acid hydrolysis approach. In: *Geoderma*, vol. 107, 2002, p. 109 – 141.
- SAGGAR, S. –