DE GRUYTER OPEN

Agriculture (Poľnohospodárstvo), 62, 2016 (4): 149−154

Short communication DOI: 10.1515/agri-2016-0015

CHANGES IN SOIL ORGANIC MATTER PARAMETERS DURING THE PERIOD OF 18 YEARS UNDER DIFFERENT SOIL MANAGEMENT PRACTICES

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ŠIMANSKÝ, V.: Changes in soil organic matter parameters during the period of 18 years under different soil management practices. Agriculture (Poľnohospodárstvo), vol. *62*, 2016, no. 4, pp. 149–154.

Quantity and quality of soil organic matter (SOM) is very important from view point of sustainable agriculture; therefore, during the years 1994–2011, the influence of different soil management practices on changes in SOM parameters in loamy Haplic Luvisol was evaluated in a field experiment in the locality of Dolná Malanta. The field experiment included two types of soil tillage – (1) conventional tillage (CT) and (2) reduced tillage (RT) – and also two treatments of fertilisation – (1) crop residues together with added NPK (nitrogen, phosphorus and potassium) fertilisers (CR + NPK) and (2) added NPK fertilisers. Contents of humic substances (HS) and fulvic acids (FA) under RT increased by 1.6% and 4.4%, respectively, compared to CT during the years 1994–2011. On the other hand, contents of humic acids (HA), HA-to-FA ratios, colour quotient of HS and colour quotient of HA under CT increased by 2.0%, 2.5%, 1.8% and 2.3%, respectively, compared to RT. In CT and RT, HS declined at an average speed of 0.33% and 0.53% per year, respectively. In CR + NPK treatments and application, only NPK fertiliser caused a decline of HS at an average speed of 0.52% and 0.33 % per year, respectively. In CT, RT and CR + NPK treatments, the linear trends (statistical significant) in decline of FA were observed. All in all, the CT had a slightly better effect on the quality of SOM, whilst the stability of SOM was improved by RT. Applications of mineral fertilisers along with crop residues resulted in better quality but lower stability of SOM.

Key words: soil tillage; fertilisation; humic substances, humic and fulvic acids, tillage

A key element of soil quality is soil organic matter (SOM) (Reeves 1997). The content of SOM is the result of a balance between the processes of mineralisation and humification. Changes in the landscape related to tillage and land use significantly affect the carbon cycle at the regional level as well as globally (Lal 2002). The rate of SOM decline varies depending on the soil type, tillage, crop and climate system (Nardi *et al.* 2004; Derpsch *et al.* 2014).

As mentioned earlier, agro-technical operations and environmental changes modify the amount and turnover of SOM. Accumulation and distribution of organic C in soil is affected by different tillage practices and time after initiation of tillage. Generally, intensive tillage systems are the main reason of SOM decline (Norton *et al.* 2012; Khorramdel *et al.* 2013). Ismail *et al.* (1994) observed a decrease in organic C during the first 5 years because of soil cultivation; however, organic C was higher in no-till (NT) than that in mouldboard ploughing (MP) system. Šoltýsová and Danilovič (2007, 2008) observed higher content of humic substances (HS) in conventional tillage (CT) than in NT and SOM quality in CT was better when compared to that of NT. Several authors (Paré *et al.* 1999; Dou & Hons 2006) showed that the quality of SOM in cultivated soil is better; therefore, humus has higher portion of condensed structure units that are resistant to microbial attack. Conservation tillage and residue management are the options for enhancing soil or-

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ganic carbon stabilisation (Choudhury *et al.* 2014). High residue-producing crops in combination with NT increase SOM (Havlin *et al.* 1990), whilst SOM declines with low residue-producing crops in combination with MP (Edwards *et al.* 1992). Crop residues have residual effects on crop growth, organic C and N availability (Christensen *et al.* 1994). Crop residue retention is also important for sequestering soil organic carbon (SOC), controlling soil erosion and improving soil quality (Blanco-Canqui & Lal 2007). Mineral fertilisers can also improve residue quantity and quality, but this does not necessarily increase the SOC pool. However, fertilisers may also decrease SOC concentration when compared to unfertilised soil (Halvorson *et al.* 2002). Improving the quantity and quality of SOM in arable soils is important if requirements of sustainable agriculture are to be satisfied.

Content of SOC in different soil tillage and fertiliser treatments in the Haplic Luvisol have been assessed (Šimanský 2017); however, contents of HS and other quantitative parameters of SOM in these treatments were not evaluated. Therefore, the objective of this paper was to determine the effects of differing tillage and fertilisation practices on changes in SOM parameters (mainly qualitative) of the intensively farmed Haplic Luvisol over the period of 18 years.

The study was conducted in the experimental station of the Slovak University of Agriculture Nitra, Dolná Malanta Nitra (48°19′00″ N; 18°09′00″ E). The experimental area was flat, with a slight inclination towards south. The geological substratum consisted of little previous rocks (biotite quartz diorite, triassic quartzites with phyllite horizonts, crinoid limestones and sandy limestone) with high quantities of fine materials. Young Neogene deposits were composed of various clays, loams and sand gravels on which loess was deposited in the Pleistocene epoch. The soil was loamy Haplic Luvisol (WRB 2006) and, on an average, in A horizon, it contained 12.9 g/kg of SOC, 14.7 cmol/kg of CEC and the base saturation percentage was 92.6%. On an average, the soil pH (soil:water = 1:2.5) was 6.96. The average annual temperature was 9.8°C, and the precipitations per year were 573 mm (Španik *et al.* 2002). Monthly mean temperature in January was from −1 to −3, and on an average, the temperature for the vegetation (April–September) was 15–17°C. Mean annual rainfall was 540 mm, and the rainfall between June and August was in the range 150–200 mm.

In 1994, a field experiment was established by the Department of Plant Production of SAU-Nitra. Two tillage treatments replicated four times were (1) conventional tillage (CT), which consisted of MP (22–25 cm deep) in autumn and then followed by disking, rolling/levelling and planting, and (2) reduced tillage (RT), which consisted of disking to a depth of 10–12 cm in autumn, followed by rolling/levelling and planting. The two fertilisation treatments replicated four times were (1) crop residues added together with NPK (nitrogen, phosphorus and potassium) fertilisers (CR + NPK) and (2) added NPK fertilisers. In CR + NPK treatments, the crop residues were incorporated into the soil. The fertilisers used were mainly nitre ammonium with dolomite (LAV 27), potassium chloride and triple superphosphate. The doses of NPK were calculated by the balance method. The field experiment had the following crop rotation: (1) cowgrass (*Trifolium pratense* L.), (2) pea *(Pisum sativum* L. *subsp. Hortense* (Neitr.), (3) winter wheat (*Triticum aestivum* L.), (4) maize (*Zea mays* L.) and (5) spring barley (*Hordeum vulgare* L.).

Soil samples in all the treatments were collected from the depth of 0–20 cm in spring during the period of 18 years. For each sampled zone (including all treatments of tillage and fertilisation), six different locations were chosen randomly. On each location, soil samples were collected and mixed to produce an average sample. Soil samples were dried at laboratory temperature and grinded. The quantification of the HS, humic acids (HA) and fulvic acids (FA) was done by the method described by Belchikova and Kononova (Dziadowiec & Gonet 1999). The method is based on the extraction and separation of the alkali-soluble HA and FA using 0.1 M NaOH and separation of HA from FA using 1 N HCl. Based on the contents of HA and FA, HA-to-FA ratios were calculated. The absorbance of HS and HA was measured at 465 and 650 nm (using a Jenway Model 6400 spectrophotometer) to calculate the colour quotients of HS ($Q^{4/6}_{HS}$) and HA ($Q^{4/6}_{HA}$). Statistical analysis was performed using the Statgraphics Centurion XV.I (Statpoint Technologies, Inc., USA) to determine the statistical significance of treatment effects. Differences in means (HS, HA, FA, HA-to-FA ratios, $Q^{4/6}_{HS}$ and $Q^{4/6}_{HA}$) were determined by calculating the least significant difference (LSD) at the 5% level. To evaluate the trends of the SOM dynamics during the years 1994–2011, the simple linear regression model was used.

Means of SOM parameters in different soil management practices in Haplic Luvisol during the years 1994–2011 are shown in Figure 1A and B. Contents of HS and FA under RT increased by 1.6% and 4.4%, respectively, compared to CT. On the other hand, during the period of 18 years of this study, the contents of HA, HA-to-FA ratios, $Q^{4/6}_{HS}$ and $Q^{4/6}_{HA}$ under CT increased by 2.0%, 2.5%, 1.8% and 2.3%, respectively, compared to RT. As reported by Zhang *et al.* (1988), soil tillage has significant influence on the contents of HS, but our results showed that soil tillage in Haplic Luvisol did not produce significant changes in SOM parameters (Figure 1 A and B). Incorporation of crop residues into the soil was shown to increase SOM (Sharma & Acharya 2000; Abdullah 2014). Our data on Haplic Luvisol during the 18-year study period did not confirm this knowledge. The application of NPK fertilisers does not significantly increase the contents of HS, HA and HA-to-FA ratios, but, on the other hand, it decreased (no significant) the contents of FA and humus stability compared to CR + NPK.

The effects of different soil management practices (tillage and fertilisation) on SOM dynamics were assessed during the 18-year study period. Indeed, notwithstanding the high variability of SOM amongst the years, in all soil management practices, we observed a significant linear decline of extracted HS. Several authors also confirmed the loss of SOM by intensive tillage systems (Franzluebbers *et al.* 1995; Dou & Hons 2006) and usage of fertilisers (Halvorson *et al.* 2002; Šimanský 2014). Higher oxidation of HS decreases the content of C and H but increases O in both HA and FA (Miglierina & Rosell 1995). In CT and RT, HS was declined at an average speed of 0.33% and 0.53% per year, respectively. During the 18-year study period, a decrease of 5.94% and 9.54% extracted HS in the soil was observed in CT and RT treatments, respectively. Incorporation of crop residues together with NPK and the application of NPK fertiliser only caused a decline of HS at an average speed of 0.52% and 0.33% per year, respectively. During the 18 years of the study, these represented a decrease of 9.36% and 5.94% HS in the soil in CR+NPK and NPK treatments, respectively. It is very surprising because according to these findings in Haplic Luvisol, rather reduced than conventional as well as added crop residues with NPK than only NPK decreased more intensively contents of HS. Similarly, Kubát *et al.* (2002) found contradictory results in the extraction

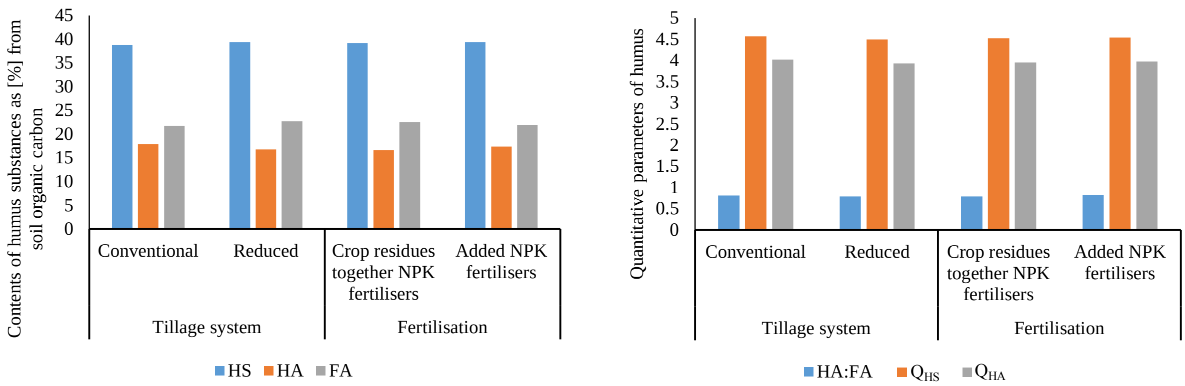

Figure 1. Analyses of variance of soil organic matter parameters

HS – humic substances; HA – humic acids; FA – fulvic acids; HA:FA – humic acids to fulvic acids ratio; Q_{HS} – colour quotient of humic substances; Q_{HA} – colour quotient of humic acids
There are no statistically significant differences according to *LSD* test.

of HS. HS form a more conservative SOM fraction that is strongly site specific. The extraction of HS by the application of fresh organic matter into soil was decreased (Zaujec & Šimanský 2006), because easy decomposable and instable sources from organic matter added to soil were available and they were influenced by the extraction. The contents of HA did not decrease significantly during the 18-year period in all soil management practices. In CT, RT and CR + NPK treatments, the linear trends (statistical significant) in the decline of extracted FA were observed (Table 1). Since FA content decreased faster than the HA, it led to a slight improvement in the quality of humus in all soil management practices; however, this did not have a statistically linear course. Several authors (Paré *et al.* 1999; Dou & Hons, 2006) showed the fact that the quality of SOM in cultivated soil is better. Results of Šimanský (2014) showed that NPK fertilisers had positive effect on statistically significant increase (linear) in humus quality (evaluated by HA-to-FA ratios). During the 18-year study period, the humus stability (based on $Q^{4/6}_{HS}$

T a b l e 1

Trends in the SOM parameters during the years 1994–2011 (y = SOM parameters) with time (x = years)

Treatments	Equations	R^2	Trend	Level of significance
HS				
Conventional tillage	y = −0.33x + 699.9	0.1459	Decrease	++
Reduced tillage	y = −0.53x + 1,090.4	0.2519	Decrease	+++
Crop residues together with added NPK fertilisers	y = −0.52x + 1,074.4	0.2437	Decrease	++
Added NPK fertilisers	y = −0.33x + 693.8	0.1282	Decrease	+
HA				
Conventional tillage	y = −0.11x + 239.2	0.0459	Decrease	n.s.
Reduced tillage	y = −0.13x + 281.7	0.0677	Decrease	n.s.
Crop residues together with added NPK fertilisers	y = −0.14x + 291.4	0.0876	Decrease	n.s.
Added NPK fertilisers	y = −0.10x + 206.6	0.0411	Decrease	n.s.
FA				
Conventional tillage	y = −0.22 + 460.6	0.1009	Decrease	+
Reduced tillage	y = −0.39x + 808.7	0.1391	Decrease	++
Crop residues together with added NPK fertilisers	y = −0.38x + 783.1	0.1335	Decrease	+
Added NPK fertilisers	y = −0.23x + 486.3	0.0716	Decrease	n.s.
HA:FA				
Conventional tillage	y = 0.0031x – 5.4	0.0109	Increase	n.s.
Reduced tillage	y = 0.0044x – 8.2	0.0178	Increase	n.s.
Crop residues together with added NPK fertilisers	y = 0.0056x – 10.5	0.0296	Increase	n.s.
Added NPK fertilisers	y = 0.0015x – 2.2	0.0026	Increase	n.s.
$Q^{4/6}_{HS}$				
Conventional tillage	y = −0.016x + 37.04	0.0177	Decrease	n.s.
Reduced tillage	y = 0.003x – 0.84	0.0004	Increase	n.s.
Crop residues together with added NPK fertilisers	y = −0.001x + 6.18	0.0001	Decrease	n.s.
Added NPK fertilisers	y = −0.004x + 12.33	0.0011	Decrease	n.s.
$Q^{4/6}_{HA}$				
Conventional tillage	y = 0.004x – 3.28	0.0017	Increase	n.s.
Reduced tillage	y = 0.015x – 26.35	0.0366	Increase	n.s.
Crop residues together with added NPK fertilisers	y = 0.010x – 16.93	0.0144	Increase	n.s.
Added NPK fertilisers	y = 0.009x – 13.96	0.0141	Increase	n.s.

HS – humic substances; HA – humic acids; FA – fulvic acids; HA:FA – humic acids to fulvic acids ratio; $Q^{4/6}_{HS}$ – colour quotient of humic substances; $Q^{4/6}_{HA}$ – colour quotient of humic acids; n.s. – non-significant; $^{+++}P \leq 0.001$; $^{++}P \leq 0.01$; $^{+}P \leq 0.05$

and $Q^{4/6}_{HA}$) fluctuated, however, without statistical significance (Table 1). Fertilisation has a significant impact on the stability of humus (Tobiašová & Šimanský 2009) because added nutrients are the sources for microorganism that are responsible for the decomposition of SOM. Manure (Riffaldi *et al.* 1998) and also the fresh crop residues added to the soil (Zaujec & Šimanský 2006) are an important source of labile organic matter that reduces the humus stability. Also, application of fertilisers can reduce the stability of the SOM (Tobiašová & Šimanský 2009; Šimanský 2014).

The results clearly showed that in all soil management practices, no significant changes in the SOM parameters were observed. CT had a slightly better effect on the quality of SOM, whilst the stability of organic matter was improved by reduced tillage. Applications of mineral fertilisers along with crop residues resulted in better quality but lower stability of organic matter. The results showed that the period of 18 years is not a sufficient time span for the evaluation of changes in SOM quality under different soil management practices investigated in Haplic Luvisol. For responsible assessment of the quality of the soil, there are also several soil properties (chemical and physical) that have to be quantified.

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Received: November 4, 2016