ISSN 1392-3196
Žemdirbystė=Agriculture, vol. 98, No. 3 (2011), p. 227–234
UDK 631.417.1:631.46:631.51.01

Changes in soil humified carbon content as influenced by tillage and crop rotation

Inga LIAUDANSKIENĖ[1], Alvyra ŠLEPETIENĖ[1], Aleksandras VELYKIS[2]

[1]Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry
Instituto 1, Akademija, Kėdainiai distr., Lithuania
E-mail: inga@lzi.lt

[2]Joniškėlis Experimental Station, Lithuanian Research Centre for Agriculture and Forestry
Joniškėlis, Pasvalys distr., Lithuania

Abstract

Soil organic matter (SOM) has been increasingly considered as an indicator of soil quality, one of the components of biosphere sustainability and stability. Soil disturbance by tillage was a primary cause of the loss of the soil organic carbon (SOC), and substantial SOC sequestration can be accomplished by changing from conventional ploughing to less intensive sustainable tillage. Degree of humification was estimated to determine SOM structural and qualitative changes occurring during the humification process.

The objective of the current study was to find alterations in soil humified carbon content between different tillage practices. Humus content was determined by Tyurin method modified by Nikitin. SOM fractional composition was identified according to classical Tyurin method modified by Ponomariova and Plotnikova. The field experiment was carried out at the Lithuanian Institute of Agriculture's Joniškėlis Experimental Station on a drained clay loam *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*). Two technologies – sustainable tillage (ST) and conventional tillage (CT) were compared in the crop rotations with different proportion of wintering and spring crops (0, 25, 50, 75 and 100% of wintering crops).

Experimental evidence suggests that ST had a positive effect on humic substances' carbon content. ST promoted formation of all humic acid fractions, fulvic acids of FA1 and FA3 fractions in the entire plough layer. Both ST and increasing proportion of wintering crops in the rotation had a positive significant influence on humification degree of soil organic matter in the entire plough layer.

Key words: humic acids, fulvic acids, carbon, soil, sustainable tillage.

Introduction

Depending on climatic conditions and land use, soils can be a source or sink of atmospheric CO_2. The C source/sink capacity of soil is determined by the dynamic equilibrium between the processes of C inputs from primary biomass production and C outputs by mineralization (Baker et al., 2007; Kögel-Knabner et al., 2008). Croplands are estimated to be the largest biosphere source of carbon lost to the atmosphere in Europe each year. The biological potential for carbon storage in European croplands is of the order of 90–120 Mt C per year with a range of options available including reduced and zero tillage, perennial crops and deep rooting crops, more efficient use of organic amendments, improved rotations, extensification, organic farming, and conversion of arable land to grassland (Smith, 2004).

This reservoir mainly consists of well processed and transformed detritus in all stages of mineralization and transformation ranging from fresh plant litter to humic substances and usually is referred to as soil organic matter (SOM) (Schimel, 1995). During the initial decay of plant litter in the soil, fresh carbon is metabolized by microbes. The organic matter that does not degrade completely to carbon dioxide forms humic substances through secondary synthesis reactions (Lichtfouse et al., 1998). Humic substances account for 65% to 75% of the SOM (Brady, Weil, 2010). They are high molecular weight substances that are stabilized by humification processes and are considered to be highly resistant to further biodegradation, thus belonging provide a long-term sink for carbon in soils (Hayes, Clapp, 2001; West, Post, 2002; Kõlli et al., 2004). Humic substances are also important aspects of soil fertility as they are involved in the stabilization of soil aggregates and binding of metals and anthropogenic organic chemicals (Donisa et al., 2003). Hence, their stability and turnover rates are important factors in interpreting the effects of agricultural and land use changes on soil system dynamics and carbon cycling (Spaccini et al., 2006).

Although the content and quality of humic substances in the soil is in correlation with soil genesis, the intensification of agriculture has substantial influence on the balance of SOM. The intensity of cultivation supports the process of mineralization and decrease of organic matter in the soil, which often causes the deterioration of physical, chemical and biological properties of soil. While no-till and reduced tillage usually promote carbon storage in the surface soil, incorporation of crop residues by mouldboard ploughing can increase the SOC content at or near the bottom of the plough layer (Feiziene et al., 2007; Poirier et al., 2009). In arable cropping systems, organic matter storage in soil is usually positively related to C input, which includes above-ground residues and root biomass. For many plants as much as 30–50% of the C fixed in photosynthesis is initially trans-located below-ground. Root biomass increased by mineral fertilization does not always cover SOM mineralization losses. The way the root biomass will continue in the soil – whether it will fully mineralize and increase CO_2 emission and plant nutrient reserves, will assimilate and be fixed in microorganism biomass or partly changed will be incorporated into much more stable humic substances composition – will depend on root chemical composition and environmental conditions (Moran et al., 2005). Evidence also indicates that below-ground plant C is a major source for subsequent conversion into more stable forms of SOC (Wilts et al., 2004; Baker et al., 2007).

One of the most important purposes in agriculture is stable supplementation of organic matter in the soil and balanced transformation of them into humus (Velykis et al., 2005). The aim of this research was to explore the influence of sustainable soil tillage in the rotations with a different proportion of winter crops on humus content, carbon content in chemical humus pools, and humification degree of soil organic matter at different plough layers.

Materials and methods

Site description and soil. The field experiment was conducted during the period 1998–2006 at the Joniškėlis Experimental Station of the Lithuanian Institute of Agriculture, located in the northern part of Central Lithuania's lowland (56º21′ N, 24º10′ E). The average annual temperature over the last 40 years in this region has been 6.1ºC, and the average precipitation – 547.4 mm. During the investigation period, the annual precipitation varied considerably: 533.1 mm in 2004, 398.3 mm in 2005 and 479.2 mm in 2006, respectively.

The parent soil material is glacial lacustrine clay lying on morainic loam. Predominant soil type of the larger part of this region according to FAO/UNESCO (1997) is *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*), with an average particle size distribution of 50.3% silt, 27% clay and 22.7% sand in the plough horizon (0–30 cm). The pH_{KCl} at 0–30 cm soil layer was neutral and ranged between 6.9 and 7.2. The arable soil layer is medium in humus (2.20%), medium in phosphorus (P_2O_5 154 g kg^{-1} soil) and high in potassium (K_2O 304 g kg^{-1} soil).

Soil chemical analyses were done at the Chemical Research Laboratory of the Lithuanian Institute of Agriculture. Detailed studies of humic substances were conducted in the last (second) crop rotation of the experiment (2004–2006).

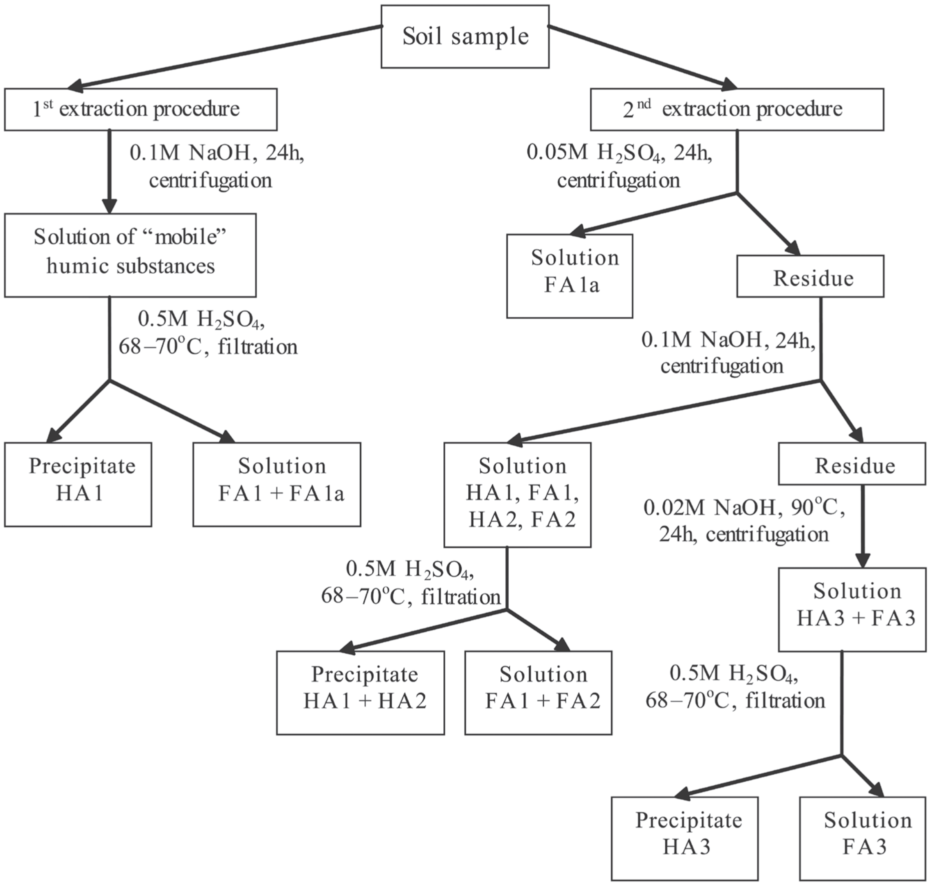
Experimental design and parameters. The effects of conventional and sustainable soil tillage in the rotations with different proportion of wintering and spring crops on the distribution of soil carbon in chemical humus fractions were investigated observing the following experimental design: 1) conventional tillage CT (mouldboard ploughing), 2) sustainable tillage ST (mouldboard ploughing after grasses for wheat, ploughless – after all cereals). Research was conducted in the crop rotations with a different proportion of wintering and spring crops: 1) without wintering crops (spring vetch and spring oat → spring wheat → spring triticale → spring barley), 2) 25% of wintering crops (red clover and timothy → spring wheat → spring triticale → spring barley with under sown perennial grasses), 3) 50% of wintering crops (red clover and timothy → winter wheat → spring triticale → spring barley with under sown perennial grasses), 4) 75% of wintering crops (red clover and timothy → winter wheat → winter triticale → spring barley with under sown perennial grasses), 5) 100% of wintering crops (red clover and timothy → winter wheat → winter triticale → winter barley with under sown perennial grasses).

The field experiment was established using the fully expanded crop rotation method. All crops were grown every year in 4 replicates. The area of each plot was 90 m^2 and the area of record sub-plot was 34.5 m^2 for cereals and 44 m^2 for grasses. The plots were arranged in blocks having the same crops in the rotation treatments as numbered. According to tillage systems, the blocks were arranged in a chess order.

General conditions of the experiment. The main tillage in CT was ploughing by a mouldboard plough at a depth of 23–25 cm. In ST, the ploughing by a mouldboard plough was done at the same depth only for wheat after grasses, and after cereals the soil was loosened without turning at the same depth as ploughing. After harvesting, cereal straw was removed from the experimental plots, the soil was tilled by a stubble breaker at a depth of 10–12 cm (except for the plots with perennial grasses under crop).

Soil sampling and preparation. For soil sampling, eight sub-samples per plot for all plots were taken randomly with a steel auger. Each soil sample core was separated into 0–15 and 15–25 cm depth, and combined across sub-samples by depth for each plot. All samples were air-dried, visible roots and plant residues were manually removed. Then the samples were crushed, sieved through a 2-mm sieve and homogeneously mixed. For the analyses of humus content and humic acids' fractional composition an aliquot of the soil samples was passed through a 0.25-mm sieve. The sieved soil samples were dried in an oven at 60–65ºC for 24 h until a constant weight. Then the soil samples were weighed.

Humus carbon content was determined by the Tyurin method modified by Nikitin (Никитин, 1999). SOM was fractionated into 3 humic acid (HA) and 4 fulvic acid (FA) fractions by Ponomariova and Plotnikova version of classical Tyurin method (Пономарева, Плотникова, 1980) according to the scheme presented in Figure 1.



Note. HA1, HA3, and FA1a fractions carbon was determined directly; FA1 carbon was determined by subtracting FA1a and HA1 carbon from the carbon in the extract of 1st procedure; HA2 carbon was determined by subtracting HA1 carbon from the carbon obtained in 0.1 M NaOH extract after decalcification, and FA2 carbon was determined in the same way. FA3 carbon was determined by subtracting HA3 carbon from the carbon obtained in 0.02 M NaOH extract after decalcification.

Figure 1. The scheme of humus fractionations (according to Ponomareva and Plotnikova, 1980)

For humus fractional composition we used solutions of different concentrations for extraction: 0.1 M NaOH (room temperature), 0.02 M NaOH (hot extraction) also 0.05 M H_2SO_4 for decalcification (room temperature) at a soil to solution ratio 1:20. The extracted humic substances were separated into humic and fulvic acid fractions by acidifying the extract to pH 1.3–1.5 using 0.5 M H_2SO_4 at 68–70ºC and humic acids were separated by filtering. Separated humic acids were re-dissolved in 0.1 M NaOH solution. Some humic and fulvic acid solutions of each extract were evaporated, then oxidised and organic carbon content was determined with a spectrophotometer at the wavelength of 590 nm using glucose as a standard after wet combustion according to Nikitin (1999).

The following humic acid fractions were identified: HA1 – the mobile fraction, free or weakly bound with clay minerals, HA2 – fraction bound with calcium, HA3 – fraction strongly bound with soil clay minerals. The fulvic acid fractions were determined: FA1a – the so-called “aggressive” fulvic acid fraction, FA1 – the mobile fraction, free or weakly bound with clay minerals, FA2 – the fraction bound with calcium, FA3 – the fraction strongly bound with soil clay minerals.

The experimental data were analysed by a two-factor analysis of variance recommended in agronomy science. Significance of the differences between the means was determined according to the least significant difference (LSD) at 0.05 probability level. The data were processed using software *Anova* (Tarakanovas, Raudonius, 2003).

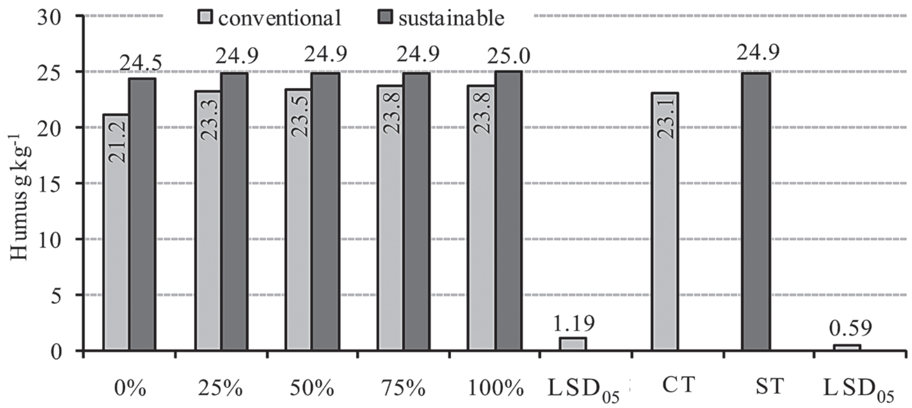
Results and discussion

There are some studies about cover crops, green manure and straw effect on soil agrochemical properties, and similarly about humic substances content in soil done in Lithuania (Magyla et al., 1994;

Bučienė et al., 2003; Velykis et al., 2005; Arlauskienė, Maikštėnienė, 2006; Šlepetienė, Kinderienė, 2007; Tripolskaya et al., 2008; Arlauskienė et al., 2009). In the present farming situation, the largest part of phytomass produced by plants as marketable production is removed from field. In our experiment, cereal straw was removed from the experimental plots after harvesting too, only below-ground plant residues were left in the soil. The influence of the different proportion of wintering and spring crops and sustainable soil tillage applied in the crop rotations on the soil humus content was evaluated in 0–15 and 15–25 cm soil layers.

In the sustainable soil tillage (ST), a significantly higher humus content was established in 0–15 cm soil layer compared with the conventional tillage (CT) – 24.9 g kg^{-1} and 23.1 g kg^{-1}, respectively (Fig. 2). Humus amount in the rotations with different proportion of wintering crops under ST differed slightly; conversely, significant increases in humus content were established in CT after wintering crops had been introduced into the crop rotation.

Meanwhile, in the 15–25 cm soil layer significant differences in humus content between CT and ST were not determined (Fig. 3). However, we found a significant influence of the proportion of wintering crops in the rotation on humus content in both tillage systems applied. The introduction of perennial grasses instead of annual grasses had a crucial influence on humus content in the soil plough layer, whereas the replacement of spring cereals by winter cereals had no significant influence.



Note. CT – conventional tillage, ST – sustainable tillage; 0%, 25%, 50%, 75%, 100% – proportion of wintering crops in the rotation.

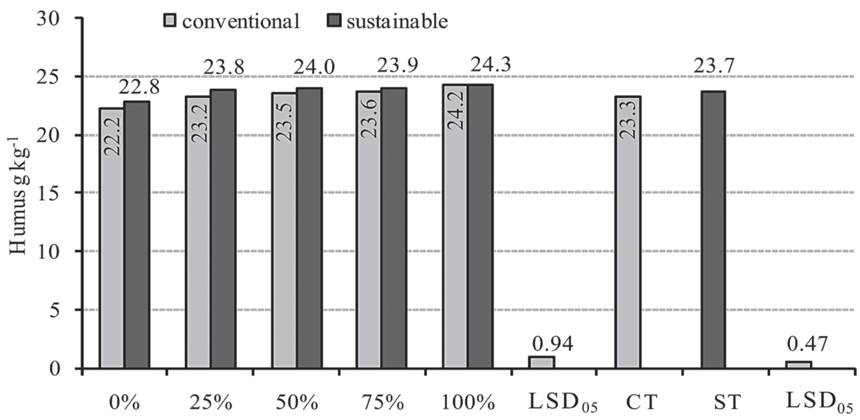
Figure 2. The effect of soil tillage and proportion of wintering crops on the humus content (SOC × 1.724) in 0–15 cm soil layer, 2004–2006

The data on the influence of the conventional and sustainable tillage systems in the rotations with different proportion of wintering crops on humus fractional composition are presented in the Table. The carbon amounts of aggressive fulvic acid fraction (FA1a) were not significantly different between the soil tillage systems applied. Significantly higher carbon content of humic acids bound with calcium (HA2) was established at ST compared with CT – respectively 1.79 to 1.58 g kg^{-1} in 0–15 cm layer, and 1.59 to 1.47 g kg^{-1} in 15–25 cm layer. Conversely, carbon content of fulvic acids bound with calcium (FA2) decreased substantially due to the application of ST in the bottom of the plough layer compared with CT. The strong association of humic substances with the inorganic soil components is regarded as a means by which carbon is protected against microbial degradation (Baldock, Skjemstad, 2000; Six et al., 2002; Kögel-Knabner et al., 2008).

Thus, the findings provided in the Table indicate that significantly higher HA3 and FA3 fractions' carbon contents in both layers were identified in ST treatment. Since HA3 and FA3 fractions are strongly bound with soil clay minerals, an increase in their contents improves the stability of soil humic substances.

The introduction of wintering crops into the rotation and increasing of their proportion determined the formation of humic substances and their accumulation in the whole plough layer. Significantly higher carbon amounts were established in all humic acids fractions in all-wintering crop rotation compared with the rotation without wintering crops. The rotations with different proportion of wintering crops had a similar influence to that of ST in terms of carbon content in fulvic acid fractions: FA1 and FA3 were increased, FA1a remained unchanged, and FA2 was decreased.

The contents of total extractable humic substances (ΣHA + ΣFA) in the both soil layers were significantly higher in ST compared with CT, and in all-wintering crop rotation compared with the rotation without wintering crops. One of the most resumptive indicators of humus quality is the ΣHA to ΣFA ratio. This ratio increased in the upper plough layer from 0.97 to 1.07, and in the bottom plough layer – from 0.98 to 1.05 due to applied ST compared with CT. Significant differences in the ΣHA:ΣFA ratio were established in the crop rotations with ≥25% of wintering crops compared with the rotation without wintering crops. The organic matter in general became richer in humic acids.



Note. Explanations under Figure 2.

Figure 3. The effect of soil tillage and proportion of wintering crops on the humus content (SOC × 1.724) in 15–25 cm soil layer, 2004–2006

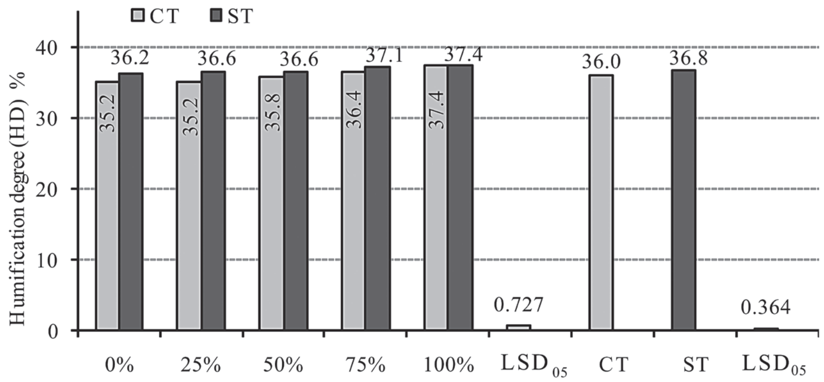
Table. The effect of soil tillage systems and proportion of wintering crops on the carbon content of humus fractions in different soil layers, g kg^{-1} soil (mean 2004, 2006)

Proportion of wintering crops % (A)	Soil layer cm	Humic acids				Fulvic acids				
		HA1	HA2	HA3	Σ HA	FA1	FA1a	FA2	FA3	Σ FA
1	2	3	4	5	6	7	8	9	10	11
Soil tillage systems (B)										
1. Conventional tillage (CT)										
0	0–15	0.61	1.50	1.90	4.01	0.63	0.68	1.09	1.96	4.36
	15–25	0.58	1.30	1.89	3.77	0.56	0.66	0.84	1.91	3.98
25	0–15	0.61	1.53	1.92	4.06	0.64	0.68	1.03	1.95	4.30
	15–25	0.64	1.43	2.13	4.20	0.73	0.67	0.85	2.04	4.28
50	0–15	0.68	1.52	2.03	4.23	0.66	0.69	1.08	2.00	4.43
	15–25	0.62	1.42	2.06	4.09	0.72	0.67	0.91	1.97	4.27
75	0–15	0.68	1.62	2.08	4.38	0.67	0.68	1.08	1.98	4.41
	15–25	0.72	1.55	2.25	4.52	0.77	0.69	0.94	2.02	4.41
100	0–15	0.74	1.75	2.11	4.60	0.71	0.68	1.03	2.02	4.44
	15–25	0.69	1.67	2.21	4.57	0.78	0.68	1.05	2.03	4.54
Mean across CT	0–15	0.67	1.58	2.01	4.26	0.67	0.68	1.06	1.98	4.39
	15–25	0.65	1.47	2.11	4.23	0.71	0.67	0.92	1.99	4.29
2. Sustainable tillage (ST)										
0	0–15	0.78	1.84	2.15	4.77	0.69	0.70	1.21	2.02	4.62
	15–25	0.70	1.52	2.14	4.36	0.70	0.69	0.90	2.11	4.40
25	0–15	0.86	1.81	2.30	4.97	0.76	0.69	1.09	2.09	4.63
	15–25	0.77	1.54	2.28	4.59	0.71	0.70	0.81	2.07	4.28
50	0–15	0.86	1.82	2.34	5.02	0.80	0.69	0.94	2.13	4.56
	15–25	0.79	1.56	2.32	4.67	0.80	0.71	0.82	2.17	4.50
75	0–15	0.90	1.75	2.37	5.02	0.83	0.69	0.93	2.14	4.59
	15–25	0.77	1.61	2.27	4.64	0.79	0.72	0.84	2.08	4.44
100	0–15	0.90	1.75	2.43	5.08	0.84	0.68	0.98	2.19	4.69
	15–25	0.77	1.71	2.54	5.02	0.83	0.72	0.82	2.30	4.67
Mean across ST	0–15	0.86	1.79	2.32	4.97	0.79	0.69	1.03	2.11	4.62
	15–25	0.76	1.59	2.31	4.65	0.77	0.71	0.84	2.15	4.46
Mean across proportion of wintering crops (A)										
0	0–15	0.70	1.67	2.03	4.40	0.66	0.69	1.15	1.99	4.49
	15–25	0.64	1.41	2.01	4.06	0.63	0.68	0.87	2.01	4.19
25	0–15	0.74	1.67	2.11	4.52	0.70	0.69	1.06	2.02	4.47
	15–25	0.70	1.48	2.21	4.39	0.72	0.68	0.83	2.05	4.28
50	0–15	0.77	1.67	2.19	4.63	0.73	0.69	1.01	2.06	4.49
	15–25	0.70	1.49	2.19	4.38	0.76	0.69	0.87	2.07	4.39

Table continued

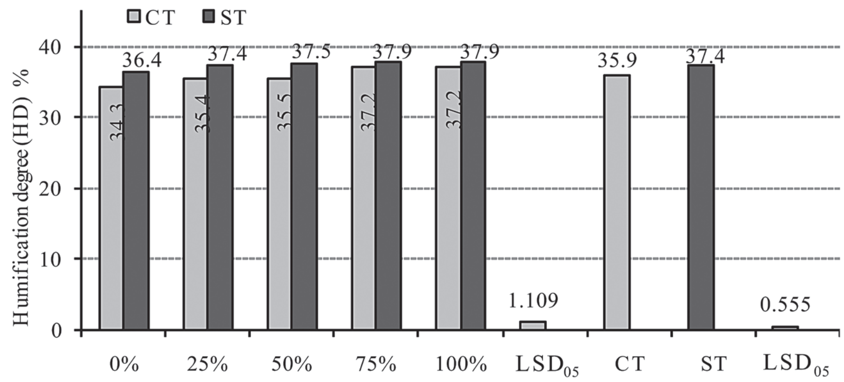
1	2	3	4	5	6	7	8	9	10	11
75	0–15	0.79	1.69	2.23	4.71	0.75	0.69	1.00	2.06	4.50
	15–25	0.73	1.58	2.26	4.57	0.78	0.70	0.89	2.05	4.42
100	0–15	0.82	1.75	2.27	4.84	0.78	0.68	1.00	2.10	4.56
	15–25	0.74	1.69	2.38	4.81	0.80	0.70	0.93	2.17	4.60
LSD_{05} A	0–15	0.094	0.073	0.112	0.186	0.084	0.023	0.063	0.087	0.182
	15–25	0.095	0.157	0.176	0.347	0.106	0.030	0.121	0.138	0.288
LSD_{05} B	0–15	0.047	0.036	0.056	0.093	0.042	0.012	0.032	0.044	0.091
	15–25	0.048	0.078	0.088	0.173	0.053	0.015	0.060	0.069	0.144
LSD_{05} AB	0–15	0.141	0.109	0.168	0.279	0.126	0.036	0.095	0.130	0.273
	15–25	0.143	0.235	0.256	0.520	0.159	0.045	0.181	0.207	0.432

Note. HA1 – mobile humic acids, free or weakly bound with clay minerals; HA2 – humic acids bound with calcium; HA3 – humic acids strongly bound with soil clay minerals; Σ HA – total content of humic acids in all fractions; FA1 – mobile fulvic acids, free or weakly bound with clay minerals; FA1a – so called "aggressive" fulvic acids; FA2 – fulvic acids bound with calcium; FA3 – fulvic acids strongly bound with soil clay minerals; Σ FA – total content of fulvic acids in all fractions.



Note. Explanations under Figure 2.

Figure 4. The effect of soil tillage and proportion of wintering crops on humification degree (HD) in 0–15 cm soil layer (mean data 2004, 2006)



Note. Explanations under Figure 2.

Figure 5. The effect of soil tillage and proportion of wintering crops on humification degree (HD) in 15–25 cm soil layer (mean data 2004, 2006)

When estimating soil humification processes, humification degree is an important factor which indicates a share of humic acids' carbon in the total soil organic carbon. According to Orlov and Grishina (1981) the humification degree (HD) of soil organic matter, determined by the Ponomareva-Plotnikova (1980) method, is considered to be high in the range 30–40%, medium – 20–30% and low – 10–20%. Applying both CT and ST the humification degree was high in the whole plough layer (Figs 4 and 5). The HD in the rotations with different proportion of wintering crops under ST varied slightly in the top plough layer, but averaged data from CT system suggest that the HD basically increased from 35.2% in the rotation without wintering crops to 37.4% in all-wintering crop rotation. In the bottom plough layer we found the HD increase in both tillage systems applied. Significant differences in HD were determined in the crop rotations with ≥50% of wintering crops compared with the treatments without wintering crops in both soil layers. Averaged data suggest that HD was significant higher in ST compared with CT in the whole plough layer.

The highest values of humification degree in our experiment were observed in the plots with 100% of wintering crops in the rotation, which suggests that more ramified root system of wintering crops, especially of perennial grasses, may favour the formation of more recalcitrant humic substances. By systematically growing wintering crops in the rotation in combination with the sustainable soil tillage it is possible to achieve more effective accumulation of humic substances in the heavy clay loam soil, improve quality parameters of soil, and protect sensitive soil from degradation.

Conclusions

1. Sustainable soil tillage (ST) significantly increased humus content in the whole plough layer compared with conventional tillage (CT). The highest humus content (25.0 g kg^{-1} in 0–15 cm and 24.3 g kg^{-1} in 15–25 cm soil layer) was established in the sustainable tillage system in the rotation with 100% of wintering crops. These results demonstrate the role of wintering crops in SOM conservation.

2. The effect of sustainable soil tillage in the rotations with a different proportion of wintering and spring crops on the distribution of soil carbon in chemical humus fractions was evaluated. Application of the sustainable soil tillage significantly increased the content of humic and fulvic acids, strongly bound with the soil clay minerals (HA3, FA3), and the content of humic acids, bound with calcium (HA2), in the whole plough layer; whereas the content of fulvic acids, bound with calcium (FA2), decreased significantly due to the applications of sustainable tillage in 15–25 cm soil layer. Increasing the proportion of wintering crops in the rotation to 100% tended to increase this effect.

3. Sustainable soil tillage compared to conventional tillage shows more favourable values of the ΣHA to ΣFA ratio in the whole plough layer, thereby soil organic matter in general became richer in humic acids, which means that the quality of humus improved.

4. Both ST and increasing proportion of wintering crops in the rotation had a positive significant influence on humification degree of SOM in the entire plough layer. An increase in humification degree (or degree of SOM recalcitrance) means that C is mainly gained by the recalcitrant fractions of SOM or lost mainly from the fractions of high decomposability.

Received 28 06 2011
Accepted 08 09 2011

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ISSN 1392-3196
Žemdirbystė=Agriculture, vol. 98, No. 3 (2011), p. 227–234
UDK 631.417.1:631.46:631.51.01

Žemės dirbimo ir sėjomainos įtaka dirvožemio humifikuotos anglies kiekiui

I. Liaudanskienė[1], A. Šlepetienė[1], A. Velykis[2]

[1]Lietuvos agrarinių ir miškų mokslų centro Žemdirbystės institutas
[2]Lietuvos agrarinių ir miškų mokslų centro Joniškėlio bandymų stotis

Santrauka

Dirvožemio organinė medžiaga (DOM) yra laikoma jo kokybės rodikliu, viena svarbiausių biosferos pastovumo ir stabilumo sudėtinių dalių. Dirvožemio struktūros suardymas žemės dirbimo metu yra pagrindinė dirvožemio organinės anglies (DOA) praradimo priežastis, todėl, keičiant tradicinį arimą plūgu į mažiau intensyvų tausojamąjį žemės dirbimą, galima pasiekti efektyvų DOA sekvestravimą. Humifikacijos metu įvykę struktūriniai ir kokybiniai DOM pokyčiai dažniausiai yra vertinami pagal DOM humifikacijos laipsnį.
Tyrimų tikslas – nustatyti taikyto tausojamojo žemės dirbimo ir sėjomainos žiemojančių augalų dalies įtaką dirvožemio humifikuotos anglies kiekiui. Humuso kiekis nustatytas Nikitino modifikuotu Tiurino metodu. DOM grupinė ir frakcinė sudėtis nustatyta Ponomariovos ir Plotnikovos modifikuotu Tiurino metodu. Lauko bandymas vykdytas Lietuvos žemdirbystės instituto Joniškėlio bandymų stotyje drenuotame giliau karbonatingame giliau glėjiškame sunkaus priemolio rudžemyje (RDg4-k2), *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*). Lygintas tradicinis ir tausojamasis žemės dirbimas sėjomainose su skirtinga žiemojančių ir vasarinių augalų dalimi (0, 25, 50, 75 ir 100 % žiemojančių augalų). Nustatyta, kad taikant tausojamąjį žemės dirbimą armenyje kaupėsi huminių medžiagų anglis. Tausojamasis žemės dirbimas visame armenyje skatino visų frakcijų huminių rūgščių ir FA1 bei FA3 frakcijų fulvinių rūgščių anglies kiekio didėjimą. Tausojamasis žemės dirbimas ir žiemojančių augalų dalies sėjomainoje didinimas turėjo esminę teigiamą įtaką DOM humifikacijos laipsniui visame armenyje.

Reikšminiai žodžiai: huminės rūgštys, fulvinės rūgštys, anglis, dirvožemis, tausojamasis žemės dirbimas.