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Effect of organic mulches on the content of organic carbon in the soil

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Abstract. Natural organic mulch eventually breaks down and adds organic material to the soil. The increase of the amount of soil organic carbon (SOC) is regarded as the main advantage of organic mulches. The aim of our investigation was to evaluate the effect of different organic mulches and different thicknesses of the mulch layer on the content of SOC. The field experiment was carried out in the Pomological Garden of Aleksandras Stulginskis University (54°53′N, 23°50′E) in a certified organic field. The soil was *Calc(ar)i-Endohypogleyic Luvisol*. The following treatments were applied: factor A – mulch: (1) without mulch, (2) straw, (3) peat, (4) sawdust, and (5) grass. Factor B – thickness of mulch layer: (1) 5 cm and (2) 10 cm. The influence of organic mulches was investigated in 2004–2009 and their residual effect in 2010–2011. In the article the data of 2008–2011 are presented. A higher content of SOC was established in all mulched experimental plots compared with the unmulched plots. A significant influence of peat mulch was observed during the whole period reported. Sawdust mulch significantly increased the content of SOC (2008–2009) but its residual effect (2010–2011) was not significant. The influence of straw mulch on the content of SOC was significant only in 2009. The thicker (10 cm) mulch layer significantly (by 0.35–0.52 percentage points) incresed the content of SOC compared with the thinner (5 cm) layer. A very strong positive linear correlation ($r = 0.994$, $P \leq 0.01$) between the amount of organic C carried into the soil with mulch and the content of organic C in the soil was established.

Key words: mulching, soil organic carbon.

INTRODUCTION

The content of organic carbon has long been recognized as a key component of soil quality (Reeves, 1997), and thus maintenance of soil organic carbon (SOC) in cropland soils is a major determinant of the productivity and long-term stability of agricultural systems (Carter, 2002). Soil organic matter (SOM) is composed of plant, animal, and microbial residues at varying stages of decomposition and amorphous humic substances (Jenkinson et al., 1992). An increase in the total content of SOC in organic farming was established by Marinari et al. (2010).

Natural organic mulch eventually breaks down and becomes a part of the soil and a source of plant nutrients (Sharma et al., 1998; Bond & Grundy, 2001; Gruber et al., 2008). Increasing the amount of SOC is regarded as the main advantage of

organic mulch (Paustian et al., 1997; Saroa & Lal, 2003). The influence of mulch on soil agrochemical properties depends on the chemical composition of mulch.

It is recommended that in ecological farming soil should be covered with composts, chopped straw, and other organic residues to provide crops with nutrients, especially nitrogen (Relf, 2009). During the mineralization process of the mulch small amounts of nutrients become available for plants. However, it is not a sufficient supply of plant nutrients. Organic mulch is a source of nutrients for soil microorganisms, and as a result of their activity organic residues used for mulching are decomposed to available plant nutrients and a very important substance in soil – humus (Blanchart et al., 2006).

Different opinions on the influence of organic mulches on SOM exist. A significant increase of SOC was observed in plots mulched with organic mulches (Relf, 2009). However, Kukkonen et al. (2004) stated that peat mulch has no significant influence on the amount of SOC. Oats and vetch grown for green manure and sprayed on soil surface were found to increase the amount of SOC and nitrogen in the soil compared with green manure inserted into the soil (Yadav, 1995; Astier et al., 2006). Cadavid et al. (1998) registered an increase of SOC and a decrease of the soil pH in plots covered with grass mulch. According to Blanco-Canqui & Lal (2007), mulching with straw during 10 years increased SOC by 33%. This means that 2/3 of the applied wheat straw was not converted into SOC and most probably was lost as emissions of CO_2 and CH_4. Mulching even has the potential of reducing greenhouse gas emissions from soil by increasing its SOM content (Mulumba & Lal, 2008; Jordán et al., 2010).

Our hypothesis was that the influence of organic mulch of different chemical composition on SOC will be unequal. The aim of the investigation was to evaluate the effect of various organic mulches and different thicknesses of the mulch layer on the SOC content.

MATERIALS AND METHODS

The two-factor field experiment was carried out in the Pomological Garden of Aleksandras Stulginskis University (formerly Lithuanian University of Agriculture) on a certified organic field (54°53′N, 23°50′E) in 2004–2011. The soil type of the experimental field is *Calc(ar)i-Endohypogleyic Luvisol*; its texture is medium clay loams on heavy clay loams and clays. Soil agrochemical characteristics are the following: pH_{KCl} 6.4–6.7, the content of total nitrogen 0.119–0.142%, organic carbon 1.56–3.13%, available phosphorus 219.7–234.9 mg kg^{-1}, and potassium 134.3–180.5 mg kg^{-1}. The sum of active temperatures (>10 °C) in Lithuania is about 2100–2200 °C, rainfall about 550–840 mm per year.

The following treatments were used in the experiment: factor A – mulch: (1) without mulch, (2) straw, (3) peat, (4) sawdust, and (5) grass; factor B – thickness of the mulch layer: (1) 5 cm and (2) 10 cm. The direct influence of organic mulches was investigated in 2004–2009, and their residual effect in 2010–2011. In the article the data of 2008–2011 are presented.

The plots were 2 m × 6 m in size. Each plot was replicated four times. Each year the same crop was grown on all plots: in 2008 *Solanum tuberosum* L. var. Anabela in rows spaced 0.7 m apart, in 2009 *Phaseolus vulgaris* L. var. Igoloneska in rows spaced 0.5 m apart, in 2010 *Allium cepa* L. var. Stuttgarter Rysen in rows spaced 0.5 m apart, and in 2011 *Beta vulgaris* subsp. *vulgaris* var. *vulgaris* in rows spaced 0.5 m apart.

The following organic materials were used for mulching: chopped wheat straw, regularly cut grass from grass-plots, sawdust of different tree species, and medium decomposed fen peat. Mulch was spread manually in 5 cm and 10 cm thick layers shortly after sowing (planting). Remains of mulch were incorporated into the soil by ploughing after harvest in autumn.

Soil sampling was performed once every year of the experiment after crop harvesting (altogether 5 treatments × 2 factors × 4 replications). For one sample samples were taken from 15 places of each plot from the 0–20 cm layer using a soil auger.

Organic carbon was calculated (divided by 1.724) after determining humus content by the infrared ray analytical system PSCO/ISI IBM-PC 4250 NIR – 42 according to the calibrations developed from the databank. The C : N ratio was calculated using the results of chemical analyses of mulch material: straw 51 : 1, peat 40 : 1, sawdust 133 : 1, and grass 11 : 1.

The means were compared using the least significant difference test (LSD test) at $P < 0.05$ with the two-way ANOVA of the software SYSTAT 10 (SPSS Inc., 2000). Regression analysis to estimate the relationship between the amount of organic carbon carried into the soil with mulch and the content of SOC was performed also with SYSTAT 10.

RESULTS AND DISCUSSION

The SOM content is the result of an equilibrium between the processes supplying new organic inputs and the rate of mineralization of the existing SOM (Stockdale et al., 2002). Lal & Kimble (1997) pointed out that the addition of organic amendments can increase the accumulation of total organic carbon in the soil. As the remains of mulch were returned into the soil by ploughing after harvest in autumn quite large amounts of organic residues of different levels of decomposition accumulated in the soil.

A significant increase of SOC (1.5–2.1 times) was observed in the plots mulched with peat and sawdust compared with the unmulched plots in 2008 (Fig. 1). An increased amount of SOC was established in the plots covered with grass and straw mulch.

The influence of the thickness of the mulch layer on SOC was significant in 2008. The content of SOC was 1.2 times higher in the plots mulched with a 10 cm thick mulch layer compared with a 5 cm thick mulch layer. Increases in SOM occur when carbon inputs exceed the rate of oxidation (Sheperd et al., 2002).

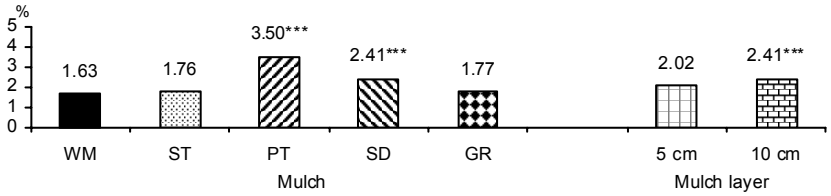

Fig. 1. Influence of organic mulches and the thickness of the mulch layer on the content of SOC in 2008. WM – without mulch, ST – straw, PT – peat, SD – sawdust, GR – grass. Significant at *** 99.9% probability level.

The highest SOC content was established in the peat-mulched plots both in 2008 and 2009. Peat, straw, and sawdust mulch had a positive influence on the SOC content increasing it 1.3–1.9 times. The difference between the SOC content of the grass-mulched plots and the unmulched plots was not significant (Fig. 2).

Like in 2008, the influence of the thickness of the mulch layer on the SOC content was significant in 2009: it was by 15.1% larger in the plots mulched with a 10 cm layer than in the plots mulched with a 5 cm layer.

The residual effect of organic mulches on SOC was studied in 2010 and 2011. In 2010 the content of SOC in the plots previously mulched with peat was 2.2 times higher compared with the unmulched plots (Fig. 3). The residual effect of other examined mulches was not significant. The content of SOC decreased largely compared with 2009 in the plots previously mulched with sawdust and straw but less in the plots mulched with grass and peat mulches. Because of its quick decomposition process grass mulch had had no significant influence on the SOC content the previous year (2009) of the experiment either.

A significant difference of the SOC content between plots treated with a 5 cm and a 10 cm mulch layer was established in 2010 when mulches were not used. The content of SOC in the plots to which a thicker mulch layer had been applied was by 25% higher compared with the plots with the thinner mulch layer (Fig. 3).

Similar tendencies were established in 2011. The significant effect of peat mulch on SOC persisted (Fig. 4). The content of SOC in the plots previously mulched with fen peat was 1.9 times higher compared with the unmulched plots. Peat is a relatively well humified acidic organic material (Bonkowski et al., 2000). Its decomposition into plant-available nutrients is slow. Annual incorporation of

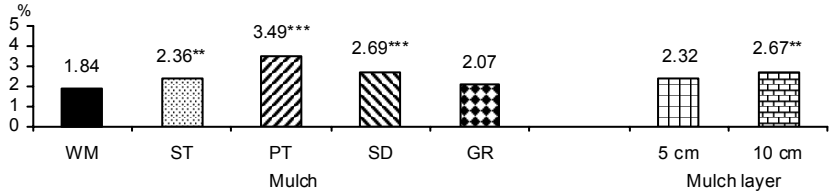

Fig. 2. Influence of organic mulches and the thickness of the mulch layer on the content of SOC in 2009. For abbreviations see Fig. 1. Significant at ** 99% and *** 99.9% probability level.

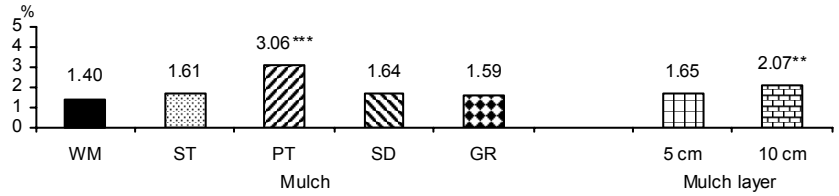

Fig. 3. Residual effect of organic mulches and the thickness of the mulch layer on the content of SOC in 2010. For abbreviations and significance see Figs 1 and 2.

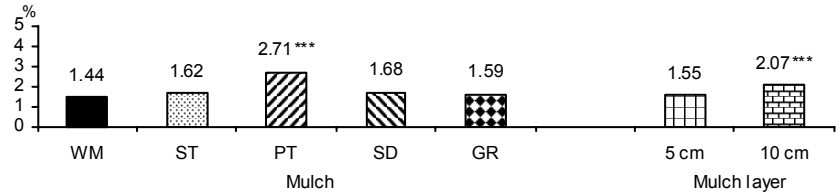

Fig. 4. Residual effect of organic mulches and thickness of mulch layer on the content of SOC in 2011. For abbreviations and significance see Fig. 1.

peat into the soil from 2004 to 2009 caused the highest content of SOC. Plots previously mulched with sawdust, straw, and grass still showed a higher content of SOC than the unmulched plots. Although grass mulch quickly decomposes, the amount of SOM in the plots previously mulched with grass was higher compared with the unmulched plots. The results of many studies confirm that long-term organic farming positively influences the amount of SOM (Schjønning et al., 2002; Tu et al., 2006; Lagomarsino et al., 2009). Like in 2010, the residual effect of the thickness of the mulch layer on the SOC content was significant also in 2011.

All the examined organic mulches increased the content of SOC. A very strong positive linear correlation ($r = 0.994$, $P \leq 0.01$) was established between the amount of organic carbon carried into the soil with mulch and the content of SOC in the soil.

CONCLUSIONS

The influence of various organic mulches and different thicknesses of the mulch layer on the content of organic C in the soil was evaluated. A higher content of SOC was established in all mulched experimental plots compared with the unmulched plots. A significant influence of peat mulch was observed during the experimental period of 2008–2011. Sawdust mulch significantly increased the content of SOC in the years of treatment (2008–2009) but its residual effect (2010–2011) was not significant. The influence of straw mulch on the content of SOC was significant only in 2009. The thicker (10 cm) mulch layer significantly (by 0.35–0.52 percentage points) increased the content of SOC compared with the

thinner (5 cm) mulch layer during 2008–2011. A very strong positive linear correlation ($r = 0.994$, $P \leq 0.01$) between the content of organic C carried into the soil with mulch and the content of organic C in the soil was established.

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