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The influence of organic mulches on soil biological properties

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Abstract

The application of organic mulches as a soil cover is effective in improving the quality of soil and increasing crop yield, especially in organic farming. The field experiment was carried out in 2008–2009 in the Pomological Garden of the Lithuanian University of Agriculture (54º53′N, 23º50′E). The soil type – *Calc(ar)i-Endohypogleyic Luvisol* (*LVg-n-w-cc*). Factor A – mulching: 1) without mulch, 2) straw, 3) peat, 4) sawdust, 5) grass. Factor B – thickness of mulch layer: 1) 5 cm, 2) 10 cm. The aim of this investigation was to evaluate the influence of different organic mulches and different thickness of mulch layer on the soil enzymes activity and earthworm population.

The tendency of higher activity of urease in the soil in plots mulched with sawdust and grass in 2008–2009 was established. A positive significant effect of grass mulch on saccharase activity in the soil was estimated. Mulching with straw and sawdust had a positive effect on saccharase activity in all experimental years. Straw mulch significantly increased the amount and biomass of earthworms. Grass mulch positively influenced the amount (significantly compared with unmulched plots) and biomass of earthworms. The thickness of mulch layer had no significant effect on soil hydrolytic enzymes and earthworm abundance.

Key words: mulching, soil, enzymes, earthworms.

Introduction

The main advantages of organic mulches are organic matter and nutrient supply not only for plants but also for soil organisms (Cherr et al., 2006). Soil quality is the result of the interaction between chemical, physical and biological soil properties (Karlen et al., 2001). Soil enzymes have been suggested as potential indicators of soil quality because of their relationship to soil biology, ease of measurement, and rapid response to changes in soil management (Bandick, Dick, 1999). Trasar-Cepeda et al. (2000) emphasized that enzyme activities have been indicated as soil properties suitable for use in the evaluation of the degree of alteration of soils in both natural and agroecosystems. Soil enzymes may respond to changes in soil management more quickly than other soil variables and therefore might be useful as early indicators of biological changes.

Soil enzymes occupy a pivotal role in catalysing reactions associated with organic matter decomposition and nutrient cycling. They catalyze all biochemical reactions and are an integral part of nutrient cycling in the soil. Enzyme activities vary seasonally and depend on soil chemical, physical and biological characteristics (Niemi et al., 2005). Investigations on a limited number of enzymes show that agricultural management practices affect their activities (Dick, 1994). Hydrolytic enzymes urease and saccharase play a key role in carbon (C) and nitrogen (N) cycling in soils, the activities of these enzymes can provide a potential tool to evaluate the long-term changes in organic carbon and nitrogen pools (Jin et al., 2009). Urease was included because of its role in releasing inorganic N in the N cycle, and saccharase because of its role in releasing organic C.

Research findings showed that enzyme activities were generally higher in the mulched plots (Yang et al., 2003). Some authors (Svirskienė, Magyla, 1997; Svirskienė, 1999; Marcinkevičienė, Pupalienė, 2009) reported soil enzyme activities to be significantly and positively correlated with organic C content. These data support a more general theory of enzyme activity increasing with organic inputs, regardless of the source.

As pointed out by Blanchart et al. (2006), soil macrofauna play an essential role in physical, chemical and biological functions, which condition the soil quality and plant productivity of the agroecosystems. Soil cover improves environmental conditions for soil organisms by protecting the habitat against water and wind erosion, drastic variations in humidity and temperature, and by increasing organic matter as a food source, thus providing a more stable environment for soil and litter dwelling invertebrates (Kladivko, 2001). Mulching positively influences the biodiversity and abundance of soil fauna (Brévault et al., 2007). The quantity and quality of plant residues are properties affecting soil fauna. Rapid growth and reproduction of earthworms has been attributed to litter with a high N content and a low level of secondary metabolites (Boström, 1987).

Results of some investigations indicate that the presence of earthworms strongly affected soil enzyme activities, and the enhanced enzyme activities of earthworm casts probably contributed to the surrounding soil enzyme activities (Tao et al., 2009).

The aim of our investigation was to evaluate the influence of different organic mulches and different thickness of mulch layer on the soil enzymes activity and earthworm population.

Materials and methods

A two-factor field experiment was carried out in 2008–2009 in the Pomological Garden of the Lithuanian University of Agriculture (54º53′N, 23º50′E). The soil type – *Calc(ar)i-Endohypogleyic Luvisol* (*LVg-n-w-cc*). Soil texture: medium clay loam on heavy clay loam and clay. Soil pH_{KCl} – 6.4–6.7, the content of: total nitrogen – 0.119–0.142%, organic C – 1.56–3.13%, available nutrients: phosphorus – 219.7–234.9 mg kg^{-1}, potassium – 134.3–180.5 mg kg^{-1}.

Treatments of the experiment: Factor A – mulch: 1) without mulch, 2) straw (chopped wheat straw), 3) peat (medium decomposed fen peat), 4) sawdust (from various tree species), 5) grass (regularly cut from grass-plots). Factor B – thickness of mulch layer: 1) 5 cm, 2) 10 cm.

Individual plot size was 2 x 6 m, with each plot replicated 4 times. In 2008 in each plot *Solanum tuberosum* L. variety *Anabela* was grown in rows with an interrow spacing of 0.7 m, in 2009 – *Phaseolus vulgaris* L. variety *Igoloneska* in rows with an interrow spacing of 0.5 m.

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

Soil biological activity was established by activity of soil hydrolytic enzymes urease and saccharase. The criteria for choosing enzyme assays were based on their importance in nutrient cycling and organic matter decomposition and the simplicity of the assay. Analyses of soil enzyme activity were done as follows: urease – by Hofman and Schmid (1953), saccharase – by Hofman and Seegerer (1950) methods, modified by Chiunderova (Чундерова, 1973). Soil was sampled from each plot after harvest. Soil samples were taken from the plough layer (0–25 cm) using an auger 2 cm in diameter. A composite sample of 10–15 drillings was taken from each plot.

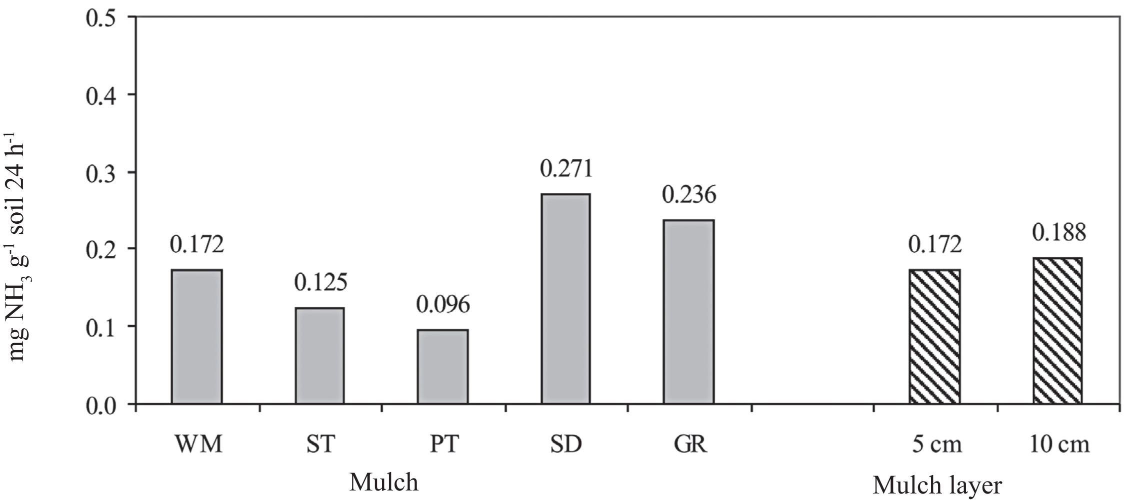
Earthworms were sampled at the beginning of autumn after harvest in daytime (Atlavinytė, 1975). The soil inside the frame 50 × 50 cm (4 positions in each plot) was dug to a depth of 25 cm and hand-sorted.

The means were compared using the least significant difference test at $P_{(level)} < 0.05$ with *Systat 10*. Data of number and biomass of earthworms, which did not meet the law of normal distribution were transformed (Tarakanovas, 2002). To estimate the relationships between the activity of enzymes and soil agrochemical properties as well as the amount of earthworms and soil enzyme activities regression analyses were performed using *Systat 10* (SPSS Inc., 2000).

Results and discussion

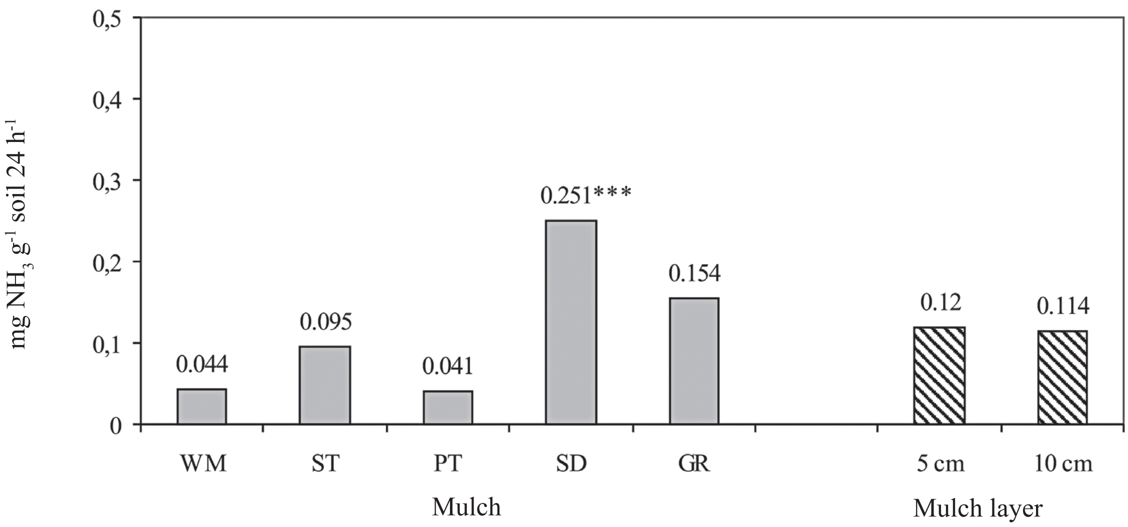
The examined organic mulches were very distinct by chemical composition (amount of C, N, P, K; ratio C and N), by decomposition rate and other properties. Soil biota starts mulch mineralization and humification after mulch is spread on soil surface. And when mulch residues (after harvest) are ploughed in, biodestruction continues (Tripolskaja, 2005). Decomposition process is lengthy – lasts from several months to 3–10 years (Blanchette, 2000). Decomposition of grass mulch is fast, but that of other mulches is slow. A complex of microorganism communities and enzymes participate in biodestruction process (Varnaitė et al., 2008).

Several trends in enzyme activity were observed in this investigation. Mulching with sawdust and grass positively influenced the activity of urease (Fig. 1, 2). Both in 2008 and 2009, the highest urease activity (0.271–0.251 mg NH_3 g^{-1} soil 24 h^{-1}) was established in the soil in plots mulched with sawdust – 1.6–6.2 times respectively higher compared with unmulched plots (0.172–0.044 mg NH_3 g^{-1} soil 24 h^{-1}). The activity of urease was higher in the soil in grass mulched plots (0.236–0.154 mg NH_3 g^{-1} soil 24 h^{-1}) too, but its activity was only 1.4–3.8 times higher than that in the plots without mulch. The ratio of C and N (C:N) in grass used as mulch was favourable for releasing ammonia. But the ratio C:N in sawdust was not favourable. No fertilizes were used in the experimental plots during the experimental period. Nitrogen as a crop nutrient was used purely as nitrogen released during the biological decomposition processes in soil and nitrogen from rainfall. In the plots mulched with grass the yield of been seeds was 1.8 time higher compared with that in the plots without mulch and 26.7 times higher compared with that in the plots with sawdust mulch. Nitrogen from the soil in the



Notes. WM – without mulch, ST – straw, PT – peat, SD – sawdust, GR – grass. * – 95% probability level, ** – 99% probability level, *** – 99.9% probability level.

Figure 1. The influence of organic mulches and different thickness of mulch layer on the urease activity LUA Pomological Garden, 2008



Note. Explanations under Figure 1.

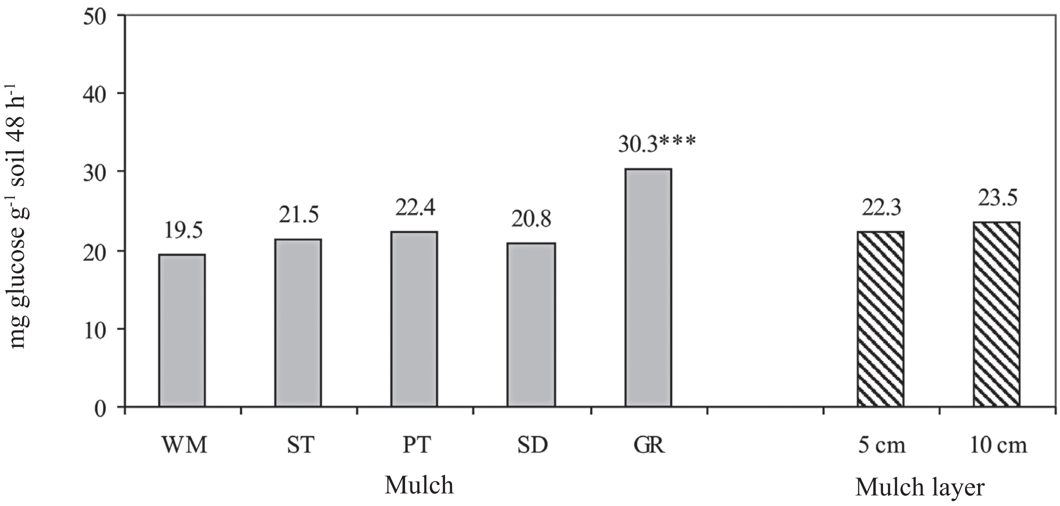
Figure 2. The influence of organic mulches and different thickness of mulch layer on the urease activity LUA Pomological Garden, 2009

plots mulched with grass was used for crop growth and N uptake from the soil with higher been seed yield was considerably higher. In the plots mulched with grass, crops were better supplied not only with nitrogen but also with potassium and phosphorus (Sinkevičienė et al., 2009). The urease activity was the lowest in the plots mulched with peat. Although peat is rich in nitrogen, the decomposition of peat in soil is slow and nitrogen is badly available for crops.

The thickness of mulch layer had no significant effect on the activity of soil enzyme urease −0.172 mg NH_3 g^{-1} soil 24 h^{-1} in the plots mulched with 5 cm thick mulch layer and 0.188 mg NH_3 g^{-1} soil 24 h^{-1} in the plots mulched with 10 cm thick mulch layer in 2008; 0.0120 mg NH_3 g^{-1} soil 24 h^{-1} in the plots mulched with 5 cm thick mulch layer and 0.114 mg NH_3 g^{-1} soil 24 h^{-1} in the plots mulched with 10 cm thick mulch layer in 2009.

The grass mulch significantly increased soil enzyme saccharase activity in 2008–2009 (Fig. 3, 4). Other examined organic mulches had no significant influence on saccharase activity in the soil. The straw and sawdust mulch had no negative effect on soil saccharase activity – 19.0–21.5 mg glucose g^{-1} soil 48 h^{-1}, 17.1–20.8 mg glucose g^{-1} soil 48 h^{-1}, accordingly.

Marcinkevičienė and Pupalienė (2009) indicated that catch crop for green manure significantly influenced the activity of saccharase. Our findings are consistent with those in providing evidence of a positive contribution of plant raw mass (in this instance – grass) to the activity of saccharase and urease.



Note. Explanations under Figure 1.

Figure 3. The influence of organic mulches and different thickness of mulch layer on the saccharase activity

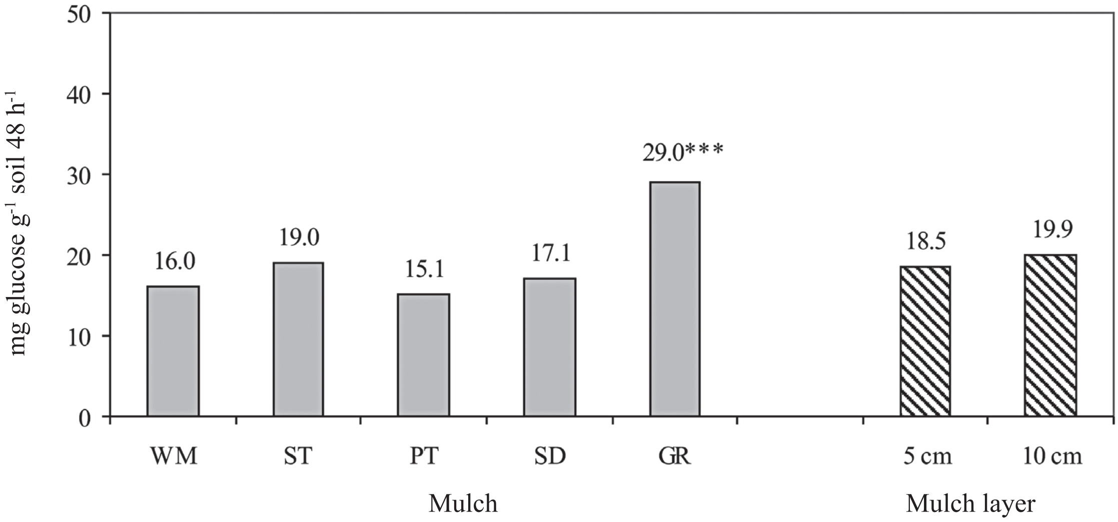
LUA Pomological Garden, 2008

The activity of saccharase directly depended on agrochemical soil properties. Significant positive correlations between saccharase activity and available phosphorus ($r = 0.85$, $P < 0.01$) in soil and between saccharase activity and available potassium ($r = 0.86$, $P < 0.01$) were established in 2008.

But no significant correlation between saccharase activity and amount of organic carbon was estimated. Organic mulches used in our experiment strongly varied by C and N ratio, by decomposition rate and other properties.

In 2009 like in 2008, the positive strong significant relationships were established between saccharase activity and available phosphorus ($r = 0.88$, $P < 0.01$) in the soil and between saccharase activity and available potassium ($r = 0.81$, $P < 0.01$). Conversely, the data of experiments of Marcinkevičienė and Pupalienė (2009) suggest that no significant correlation between activity of urease and amount of total nitrogen, between activity of urease and amount of organic carbon was estimated.

Some authors suggested that enzyme activities were closely correlated to the total amounts of nitrogen and carbon (Kheyrodin, Antoun, 2008). On the contrary, the data of Stark (2005) showed that no relationships existed between enzyme activities and nitrogen mineralization, and that enzyme activities are more closely associated with inherent soil and environmental factors, which makes them less useful as early indicators of changes in soil quality.



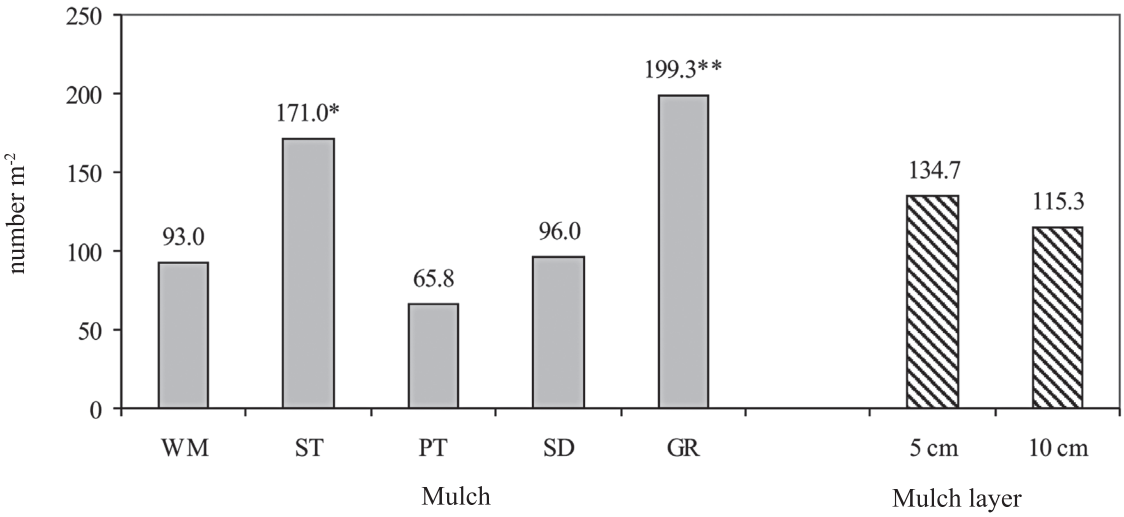
Note. Explanations under Figure 1.

Figure 4. The influence of organic mulches and different thickness of mulch layer on the saccharase activity

LUA Pomological Garden, 2009

The different density of earthworms was observed in plots with different organic mulches at the initial stage of the experiment. Six years after the beginning of the experiment in 2009 earthworms were examined.

The highest mean density of earthworms (*Lumbricidae*) was established in the experimental plots mulched with grass. Grass mulch supported 2.1 times higher earthworm population than the control – no mulch (Fig. 5). Grass mulch was easily decomposed and would support high densities of earthworms. C:N ratio in grass was favourable for earthworms. Straw mulch increased earthworm density by 1.8 times. Although the C:N ratio in straw was not favourable for earthworms, wheat straw provided conditions for earthworms as organic mulch (plant residue on soil surface). Barley straw was not suitable for mulching – toxic phenolic substances from decomposing barley straw negatively influenced the activity of decomposer organisms. Sawdust mulch had no significant influence on earthworm density. Peat mulch decreased the number of earthworms by 29.3% compared with unmulched plots, but not significantly. Peat is relatively well humified acidic organic material and it is unlikely that earthworms could digest it (Bonkowski et al., 2000).

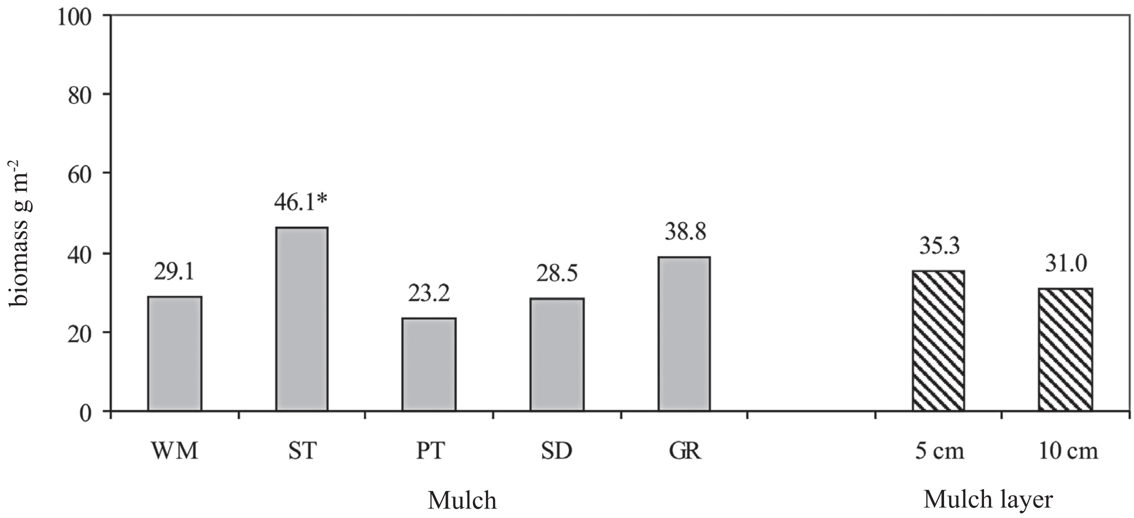


Note. Explanations under Figure 1.

Figure 5. The influence of organic mulches and different thickness of mulch layer on the earthworm density

LUA Pomological Garden, 2009

The similar tendencies were established when earthworm biomass was investigated. In the plots mulched with straw and grass, the mass of earthworms was higher compared with that in the plots without mulch (Fig. 6). The biomass of earthworms in straw mulched plots was higher by 58.4% compared with that in unmulched plots. Grass mulch increased earthworm biomass by 33.3%. Sawdust mulch had no effect on earthworm biomass. Peat mulch affected negatively both earthworm density (29.2%) and biomass (by 20.3%). The data of other researchers showed that the biomass of earthworms was greater under mulch compared with no mulching (Razafimbelo et al., 2006).



Note. Explanations under Figure 1.

Figure 6. The influence of organic mulches and different thickness of mulch layer on the earthworm biomass

LUA Pomological Garden, 2009

The smallest mass per earthworm was recorded in the plots mulched with grass. Since the very beginning of research, a lot of small earthworms had been noted under the grass mulch. The results indicate that grass mulch creates and sustains favourable conditions for earthworms. In the plots with straw mulch where both earthworm density and biomass were high, the mass per earthworm was lower compared with unmulched and mulched with peat and sawdust plots. This indicated that straw mulch created and sustained favourable conditions for earthworms too. The biggest earthworms were found in the peat mulched plots – 0.35 g. Kukkonen et al. (2004) pointed out that peat mulch increased the abundance of juvenile *Aporrectodea caliginosa* by 74% in three growing seasons, but had no effect on adult numbers. *Lumbricus terrestris* numbers were not increased by peat treatment. Mulching with sawdust had no effect on mass per earthworm. Approximately equal mass per earthworm was recorded in the plots mulched with sawdust and in unmulched plots 0.30 and 0.31 g, respectively.

The tendency of lower density and biomass of earthworms in the plots mulched with thicker (10 cm) layer of organic mulches was established.

Tiunov et al. (2001) stated that earthworms can stimulate the microbial activity of soil during passage through their guts. Our findings are consistent with those – the activity of saccharase was significantly correlated with the amount of earthworms in the soil ($r = 0.76$, $P < 0.05$). The relationship between the activity of urease and the amount of earthworms in the soil was not established. It is clear that earthworms had a positive effect on the amount of plant nutrients in the soil. Results of our investigation support this idea. Big amount of earthworms supported bigger amount of available phosphorus and potassium in the soil – the correlation between the amount of earthworms and available phosphorus content; between amount of earthworms and available potassium content was strong and significant ($r = 0.82$, $P < 0.01$; $r = 0.79$, $P < 0.01$ accordingly).

Conclusions

1. Mulching with sawdust and grass positively influenced the activity of urease in *Calc(ar)i-Endohypogleyic Luvisol* (*LVg-n-w-cc*).

2. The grass mulch significantly increased the activity of soil enzyme saccharase.

3. The thickness of mulch layer had no significant effect on the activity of soil enzymes saccharase and urease.

4. Grass and straw mulches positively affected earthworm density and biomass. The trend of lower density and biomass of earthworms in the plots mulched with thicker (10 cm) layer of organic mulches was established.

5. The positive strong significant relationships were established between saccharase activity and available phosphorus ($r = 0.88$, $P < 0.01$) in the soil and between saccharase activity and available potassium ($r = 0.81$, $P < 0.01$).

6. The activity of saccharase was significantly correlated with the amount of earthworms in the soil ($r = 0.76$, $P < 0.05$).

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Organinio mulčio įtaka dirvožemio biologinėms savybėms

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Lietuvos žemės ūkio universitetas

Santrauka

Dirvos paviršiaus padengimas organiniu mulčiu yra efektyvi dirvožemio kokybės gerinimo ir žemės ūkio augalų derliaus didinimo priemonė, ypač ūkininkaujant ekologiškai. Tyrimai atlikti 2008–2009 m. Lietuvos žemės ūkio universiteto pomologiniame sode, ekologiniame sertifikuotame plote. Dirvožemis – karbonatingas giliau glėjiškas išplautžemis (IDg4-k) *Calc(ar)i-Endohypogleyic Luvisol* (*LVg-n-w-cc*). Bandymo variantai: A veiksnys – mulčias: 1) nemulčiuota, 2) šiaudai, 3) durpės, 4) pjuvenos, 5) žolė; B veiksnys – mulčio sluoksnio storis: 1) 5 cm, 2) 10 cm. Tyrimų tikslas – įvertinti įvairaus organinio mulčio ir jo sluoksnio storio įtaką dirvožemio fermentų aktyvumui ir sliekų populiacijai.

2008–2009 m. pjuvenomis ir žole mulčiuotuose laukeliuose nustatyta didesnio ureazės aktyvumo tendencija. Nustatyta teigiama esminė žolės mulčio įtaka sacharazės aktyvumui. Per visą tyrimų laikotarpį mulčiavimas šiaudais ir pjuvenomis turėjo tendenciją didinti sacharazės aktyvumą. Šiaudų mulčias iš esmės padidino sliekų kiekį ir biomasę. Žolės mulčias jų kiekiui ir biomasei turėjo teigiamos įtakos (esminės, palyginti su nemulčiuotais laukeliais). Mulčio sluoksnio storis neturėjo esminės įtakos dirvožemio hidrolitinių fermentų aktyvumui ir sliekų kiekiui bei biomasei.

Reikšminiai žodžiai: mulčiavimas, dirvožemis, fermentai, sliekai.