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The effect of non-chemical weed control on soil biological properties in a spring oilseed rape crop

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Abstract

The current study was aimed to establish the effects of non-chemical weed control methods on the activity of soil enzymes and abundance of earthworms in an organically grown spring oilseed rape crop in the soil with a regular (23–25 cm) and thickened (45–50 cm) humus layers. A field experiment was conducted during the 2013–2015 period at Aleksandras Stulginskis University on a *Calc(ar)i-Endohypogleyic Luvisol* (*LVg-n-w-cc*). The following three non-chemical weed control methods were explored: 1) thermal (using water steam), 2) mechanical (inter-row loosening) and 3) smothering (self-regulation). In the thermal and mechanical weed control treatments, spring oilseed rape was grown with an inter-row spacing of 48 cm and in weed smothering treatments with an inter-row spacing of 12.0 cm.

The highest root dry biomass of spring oilseed rape (on average 1.68 t ha^{-1}) had been produced in the soil with a regular humus layer in the mechanical weed control treatment. Spring oilseed rape root dry biomass depended on the crop density (r = 0.82–0.96, P < 0.05). In the soil with a regular humus layer, the different non-chemical weed control methods tested exerted little impact on soil enzyme activity. In the soil with a thickened humus layer, a significantly stronger activity of saccharase and urease enzymes, compared with the other weed control methods applied, was recorded for the plots under the thermal weed control treatments using water steam, while in a dry year of 2015 – in the plots under smothering treatments. Compared with a regular humus layer, the activity of urease enzyme in the thickened humus layer was significantly (1.5–1.6 times) higher in the plots where in 2013 and 2015 thermal weed control had been applied, while in 2015 – in the smothering treatment (2.8 times). The activity of saccharase significantly (1.8 times) increased in 2015 in the plots under smothering treatment. Significantly the highest number of earthworms and their biomass were determined in the plots with a thickened humus layer in which in 2013 thermal weed control had been applied and in 2014 and 2015 in the plots under smothering treatment. Compared with a regular humus layer, in the thickened humus layer the number and biomass of earthworms significantly (1.5 and 1.6 times) increased in the plots in which in 2014 mechanical weed control had been applied, and in 2015 in the plots under smothering treatment (2.6 and 3.1 times, respectively). Soil enzyme activity and abundance of earthworms depended on the meteorological conditions and soil agrochemical properties. The number of earthworms in the soil correlated with the soil enzyme activity. Positive strong and very strong statistically significant correlations were established between saccharase activity and number of earthworms (r = 0.89, P < 0.05), urease activity and number of earthworms (r = 0.99, P < 0.01) as well as between urease activity and earthworm biomass (r = 0.94, P < 0.01).

Key words: *Brassica napus*, earthworms, organic agriculture, roots, smothering, soil enzymes, thermal and mechanical weed control.

Introduction

Organic agriculture is currently receiving increasingly more interest and recognition worldwide. With Lithuania's accession to the European Union (EU), organic agriculture has become an attractive trend in the agricultural development since organic agricultural products certified in the EU are welcomed by environment and health-conscious consumers, willing to pay a higher price than for conventionally grown produce; moreover,

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organic agriculture is a state-subsidised branch. Organic agriculture is based on a crop growing technology whose primary objective is to produce high-quality agricultural products, to sustain the environment and improve soil quality (García-Ruiz et al., 2008). Soil enzyme activity is an important soil quality indicator in the organic agriculture system (Lebrun et al., 2012). Furthermore, it is closely related to soil agro-physical and agro-chemical properties (Liu et al., 2010), microorganism activity and biomass, it plays an important role in mediating biochemical transformation, including organic residue decomposition and plant nutrient cycling in the soil (Shukla, Varma, 2011). Soil enzyme activity is a sensitive indicator of changes in the soil microorganism activity and soil fertility (Yang et al., 2008). Numerous researchers have documented the effects of crop rotations, tillage and fertilization on soil enzyme activity (Melero et al., 2008; Wang et al., 2011). Organic farming has been found to increase the overall enzyme activity (García-Ruiz et al., 2008; Moeskops et al., 2010); however, the activity of specific enzymes can vary depending on the availability of nutrients and their status as well as on the soil type and its characteristics, including structure, pH (Acosta-Martínez et al., 2007; Stursová, Baldrian, 2010). Soil enzyme activity is closely related to another important soil quality indicator – abundance of earthworms (Lemtiri et al., 2014). Research conducted in China (Tao et al., 2009) suggests that high abundance of earthworms in the soil strongly activates soil enzyme activity. Earthworms play an important and many-sided role in the soil. By processing plant residues and accelerating humification, earthworms enhance soil fertility, microorganism activity and soil aeration, and improve crop growth conditions (Lemtiri et al., 2014). Large quantities of various organic matter incorporated into the soil of a crop rotation sequence strengthen soil enzyme activity (Lebrun et al., 2012; Siwik-Ziomek, Lemanowicz, 2014) and increase the abundance of earthworms (Pommeresche, Løes, 2009). The soil under organic production is typically characterised by a stronger enzyme activity (García-Ruiz et al., 2008) and higher earthworm abundance (Riley et al., 2008) compared with that under conventional agricultural production. Mohammadi et al. (2011) have ascertained that with increasing concentration of oilseed rape in the crop rotation and with no cultivation of green manure crops, the soil enzyme activity decreased. Plant roots have a marked impact on the build-up of micro-organisms and organic matter in the soil (Mandal et al., 2010). It has been established that the effects of agricultural crops on soil enzyme activity can be direct, i.e. through the release of extracellular enzymes from plant roots during the metabolic processes, and through the release of cellular enzymes during plant residue decomposition by microorganisms, and indirect, i.e. by providing living space for soil microflora. Soil enzyme activity directly correlated with plant root biomass (Kong et al., 2009).

There is evidence in literature suggesting that non-chemical weed control methods have influence on soil biological properties. Mechanical weed control in inter-rows tended to decrease the activity of soil enzymes (Gajda et al., 2013) and the number and mass of earthworms (Schreck et al., 2012). Band-steaming application to control weeds also had negative influence on soil enzyme activity (Elsgaard et al., 2010). Little research has been done on this subject so far in Lithuania. However, the existing evidence suggests that the thickness of the plough layer also impacts on plant root biomass (Cai et al., 2014), soil enzyme activity (Rivera et al., 2014) and earthworm abundance (Baltramaitytė et al., 2000).

Our study hypothesizes that different non-chemical weed control methods (thermal, mechanical and smothering) will exert diverse effects on soil enzyme activity and earthworm abundance in organically grown spring oilseed rape crop in the soil differing in humus thickness layer.

The aim of the current study was to identify the effects of non-chemical weed control methods on plant root biomass, soil enzyme activity, and earthworm abundance in an organically grown spring oilseed rape crop in the soil with a regular and thickened humus layer.

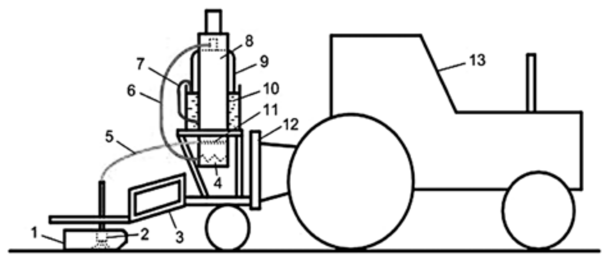
Material and methods

A field experiment was conducted during the 2013–2015 period at the Experimental Station of Aleksandras Stulginskis University (54°53′ N, 23°50′ E). The study explored the effects of different non-chemical weed control methods on soil biological properties in the agrocenoses of spring oilseed rape (*Brassica napus* L. spp. *oleifera*). Spring oilseed rape was grown in the soil with a regular (23–25 cm) and with a thickened (45–50 cm) humus layer. The soil of the experimental site is *Calc(ar)i-Endohypogleyic Luvisol* (*LVg-n-w-cc*). The agrochemical properties of the regular humus layer (average data for 2013, 2014 and 2015) were as follows: pH – 6.71, organic carbon (C_{org}) – 1.11%, available nutrients in the soil: phosphorus (P_2O_5) – 227.5 mg kg^{-1}, potassium (K_2O) – 113.1 mg kg^{-1} and those of the thickened humus layer were as follows: pH – 6.56, C_{org} – 1.46%, available nutrients in the soil: P_2O_5 – 175.6 mg kg^{-1}, K_2O – 93.8 mg kg^{-1}.

Treatments. The following non-chemical weed control methods were investigated: 1) thermal (using water steam), 2) mechanical (inter-row loosening) and 3) smothering (self-regulation). A spring oilseed rape cultivar 'Fenja' (W. von Borries-Eckendorf GmbH & Co, Germany) was grown in the experiment. The crop was sow at a seed rate of 8 kg ha^{-1} in all plots by a sowing machine Rabe Multidrill M 300 ("Rabewerk", Germany). In 2013, spring rape was sown on 30 April, in 2014 on 22 April and in 2015 on 25 May. In the thermal and mechanical weed control treatments, the oilseed rape crop was grown with an inter-row spacing of 48 cm (sowing every fourth row – closing three seed tubes). In the thermal weed control treatment, weeds were controlled using a tractor-mounted water steam unit at a 3–4 leaf growth (BBCH 13–14) stage of spring oilseed rape. The thermal power of the device is 90 kW, capacity – 120 kg h^{-1} steam, the device is run on liquefied gas. The temperature of steam is 99°C, thermal treatment time – 2 s (Sirvydas, Kerpauskas, 2012).

The principal scheme of the tractor-mounted thermal weed control unit using water steam is presented in Figure 1.

Description of operation of the mobile thermal weed control unit. Liquefied gas is fed through tube (6) into the combustion chamber (4) of demountable steam boiler (8). There the burning gas heats water in the steam boiler (8). The water steam which has formed in steam boiler (8) gets into the steam separator, in which steam



1 – protectors of steam diffusers, 2 – steam diffusers, 3 – diffusers height adjustment mechanism, 4 – combustion chamber, 5 – tube by which water steam is fed to steam diffusers, discharges, 6 – tube by which gas is fed to combustion chamber, 7 – tube by which hot water is fed to the heating tank of gas cylinder, 8 – demountable steam boiler, 9 – gas cylinder, 10 – heating tank of gas cylinder, 11 – steam overheater, 12 – mounting device of thermal weed control unit, 13 – tractor

Figure 1. The principal technological scheme of the tractor-mounted thermal weed control unit

dampness is reduced. Then the water steam which has passed through the steam overheater (11) is fed through the tube (5) into steam diffusers (2), which spread/distribute steam in the environment of target weeds. The height of the steam diffusers is adjusted by the height adjustment mechanism (3). To prevent the liquefied gas from cooling, the gas cylinder (9) is placed into the heating tank (10). Hot water from steam boiler (8) is fed into the gas cylinder's heating tank (10) through tube (7). The mobile thermal weed control unit is mounted on a tractor (13) with a mounting device (12).

In the mechanical weed control treatment, the inter-rows were loosened with an inter-row cultivator KOR-4.2-01 (Machinery Factory, Ukraine) using two passes. In the weed control treatment involving weed smothering (self-regulation) the spring oilseed rape was grown with 12.0 cm inter-row spacing. Spring oilseed rape was not fertilised and no chemical and biological plant protection products were applied.

The size of the total plot was 84 m^2, and that of the harvested experimental plot was 20 m^2. The experimental treatments were replicated four times. The spring oilseed rape crop replaced bare fallow (mouldboard plough) in an organic farming system. The experimental plots were set up in a systematic arrangement.

Soil sampling. Agrochemical characteristics of the soil were determined prior to the spring oilseed rape sowing. Samples were taken from the 0–25 cm soil layer of each experimental plot using a soil sampling auger. Soil pH was measured potentiometrically in 1 n KCl extract, available P_2O_5 and K_2O (mg kg^{-1} soil) were estimated by the Egner-Riehm-Domingo (A-L) method, C_{org} was determined by a Heraeus instrument by combusting the samples at 900°C temperature. Soil analyses were conducted at the Agrochemical Research Laboratory of Lithuanian Research Centre for Agriculture and Forestry. Soil type of the experimental site was determined according to the WRB (2014).

The dry biomass (DM t ha^{-1}) of main roots of plants was estimated at spring rape flowering (BBCH 65) stage. Ten plants were uprooted from each experimental plot, aboveground plant part and roots were separated, washed, dried and weighed, two composite root samples were taken and dried at 105°C temperature. The root dry biomass t ha^{-1} was estimated: average root mass per plant multiplied by crop density. The crop density (plants m^{-2}) of the spring oilseed rape crop was estimated by counting the plants in each experimental plot in four 0.25 m^2 sampling plots before harvesting (BBCH 79).

The activity of soil hydrolases (urease and saccharase) was measured as follows: urease (mg NH_3 (ammonia) g^{-1} soil 24 h^{-1}) according to Hofmann and Schmidt (1953) methods, saccharase (mg glucose g^{-1} soil 48 h^{-1}) by Hofmann and Seegerer (1950) methods, modified by Chunderova (1973). Soil samples for the analyses were collected from each plot in 15 spots per plot with a soil sampling auger at a depth of 0–25 cm at the flowering (BBCH 65) stage of spring rape. Field humidity soil samples were dried in slightly open boxes under the ambient temperature of the laboratory. Analyses were carried out at the Laboratory of Raw Materials for Food, Zootechnical and Agronomic Analyses of Aleksandras Stulginskis University.

The number of earthworms in the soil was determined after spring oilseed rape harvesting. In two places of each experimental plot, pits 50 × 50 cm in size and 25 cm in depth were dug. The earthworms were collected, counted and weighed. Earthworm number (earthworms m^{-2}) and mass (g m^{-2}) were calculated.

Statistical analysis. The significance of differences between the means was estimated using the *t* criterion, the interplay between the traits was determined by the correlation-regression methods (Clewer, Scarisbrick, 2001). The statistical analysis of the experimental data was performed using the software *STAT* from the package *SELEKCIJA* (Tarakanovas, Raudonius, 2003). The experimental data that did not fit the normal distribution law, prior to the statistical evaluation, were transformed using the function $y = lnx + 1$.

Meteorological conditions. In 2013, the spring was cold and late. Agricultural crops resumed growth as late as in the second ten-day period of April. May was by 3.8°C warmer than usual; the total monthly rainfall exceeded the long-term average by 10.0 mm. The monthly hydrothermal coefficient (HTC) was 1.3 (optimal humidity). The temperature in June was by 2.9°C higher than the long-term average and the amount of rainfall was by 16.7 mm lower than usual. The monthly HTC was 0.8 (insufficient humidity). July was warm and wet. The average monthly temperature exceeded the long-term average by 1.0°C and the amount of rainfall was by 37.3 mm higher than usual. The monthly HTC was 2.0 (excess humidity). During the growing season of spring oilseed rape (from emergence to harvesting) the sum of active temperatures (≥10°C) amounted to 1803.4°C, rainfall – to 287.9 mm and HTC was 1.6 (excess humidity).

In 2014, the spring was dry and warm. The average monthly temperature of April was by 3.0°C higher than the long-term average and the amount of rainfall by 17.1 lower than usual and the monthly HTC was 1.2 (optimal humidity). May was by 0.9°C warmer than usual, the total monthly rainfall was by 30.4 mm higher than the long-term average, the monthly HTC was 2.4 (excess humidity). June was cold and dry, the monthly HTC was 1.2 (optimal humidity). The July temperature exceeded the long-term average by 2.9°C, and the amount of rainfall was by 28.7 mm lower than usual, the monthly HTC was 0.8 (insufficient humidity). During the spring oilseed rape growing season the sum of active temperatures amounted to 1831.1°C, the amount of rainfall – 260.4 mm, and the HTC – 1.4 (optimal humidity).

In 2015, the monthly temperature of April was by 1.0°C higher than the long-term mean and the amount of rainfall was close to the long-term average. May was by 0.9°C colder than usual and the amount of rainfall was close to the long-term average, the monthly HTC was 1.5 (optimal humidity). The monthly temperature of June was close to the long-term average and the amount of rainfall was by 46.2 mm lower than usual, the monthly HTC was 0.4 (dry). There was a shortage of moisture for the spring oilseed rape crop. The average monthly temperature and amount of rainfall in July were close to the long-term average, the monthly HTC was 1.3 (optimal humidity). The amount of rainfall in August was as low as 6.9 mm, which was 11.6 times less than the long-term average. The monthly temperature was by 3.7°C higher than the long-term average, HTC – 0.1 (very dry). During spring rape growing season the sum of active temperatures (≥10°C) was 1941.7°C, the amount of rainfall – 132.5 mm, HTC – 0.7 (droughty).

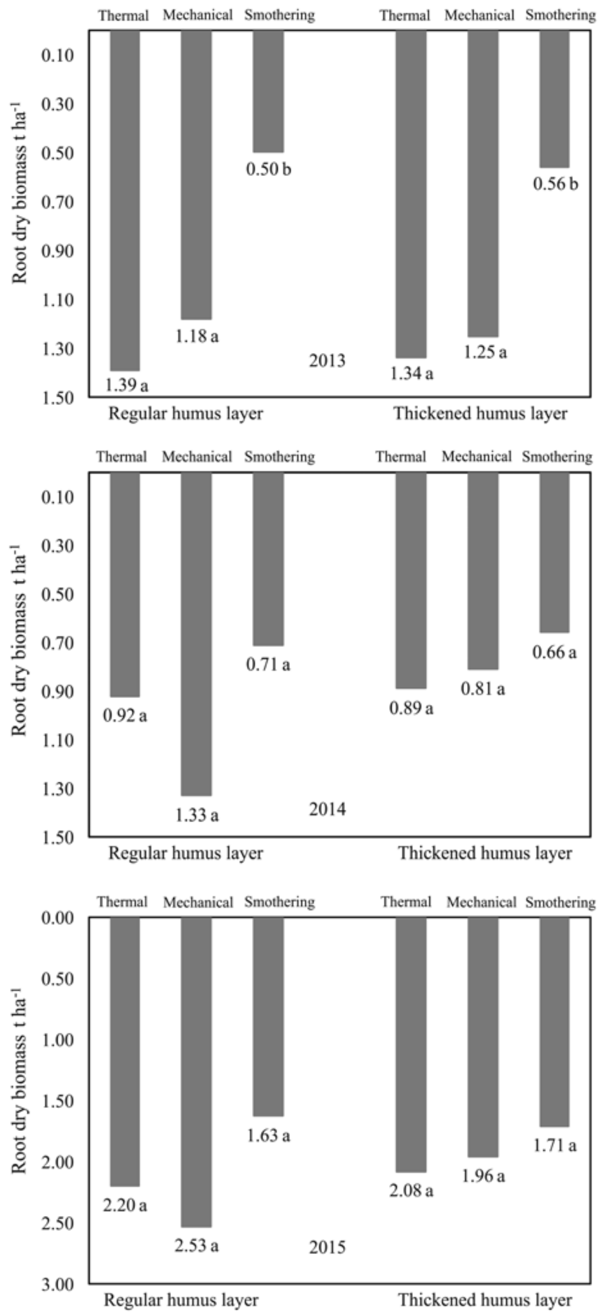
Results and discussion

Dry biomass of plant roots. The findings of this study showed that in 2013, thickening of the humus layer did not have any significant effect on spring rape root dry biomass (Fig. 2). However, comparison of the different non-chemical weed control methods tested revealed that in both humus layers (regular and thickened) significantly the least root mass was produced in the crop where spring oilseed rape had been cultivated with narrow inter-row spacing (12 cm), i.e. in the smothering treatment, the root mass was from 2.4 to 2.8 times and from 2.2 to 2.4 times lower compared with that for the other weed control methods. In the plots of smothering weed control treatments, low root mass was produced due to the competition between crop plants and weeds, which resulted in a thinner crop.

No significant effects of either soil humus layer thickness or different weed control methods on spring oilseed rape root mass were identified in 2014 and 2015. The largest spring oilseed rape root mass was produced in the mechanical weed control treatments with a regular humus layer (on average 1.93 t ha^{-1}). However, comparison with the other weed control methods revealed no significant differences. Han et al. (2010) have indicated that plant root biomass depends on the supply of plants with nutrients. It is likely that inter-row loosening promoted organic matter mineralisation. Moreover, rape roots tend to branch more profusely. Contrary data can be found in the literature. Mechanical weed control in inter-rows results in damage to both roots and aboveground part of crop plants. Kerpauskas et al. (2009) have reported that thermal weed control using water steam does not cause root damage. Cai et al. (2014) have indicated that with deepening of the ploughlayer to 50 cm, plant root biomass increased compared with that in the 30 cm layer.

Spring rape root dry biomass depended on the plant density of the crop. These two indicators were found to positively, strongly and very strongly statistically significantly correlate: in 2013 – r = 0.96, P < 0.05; in 2014 – r = 0.94, P < 0.05; in 2015 – r = 0.82, P < 0.05.

Activity of soil enzymes. It was found that in 2013 the non-chemical weed control methods tested did not exert significant effect on the activity of soil

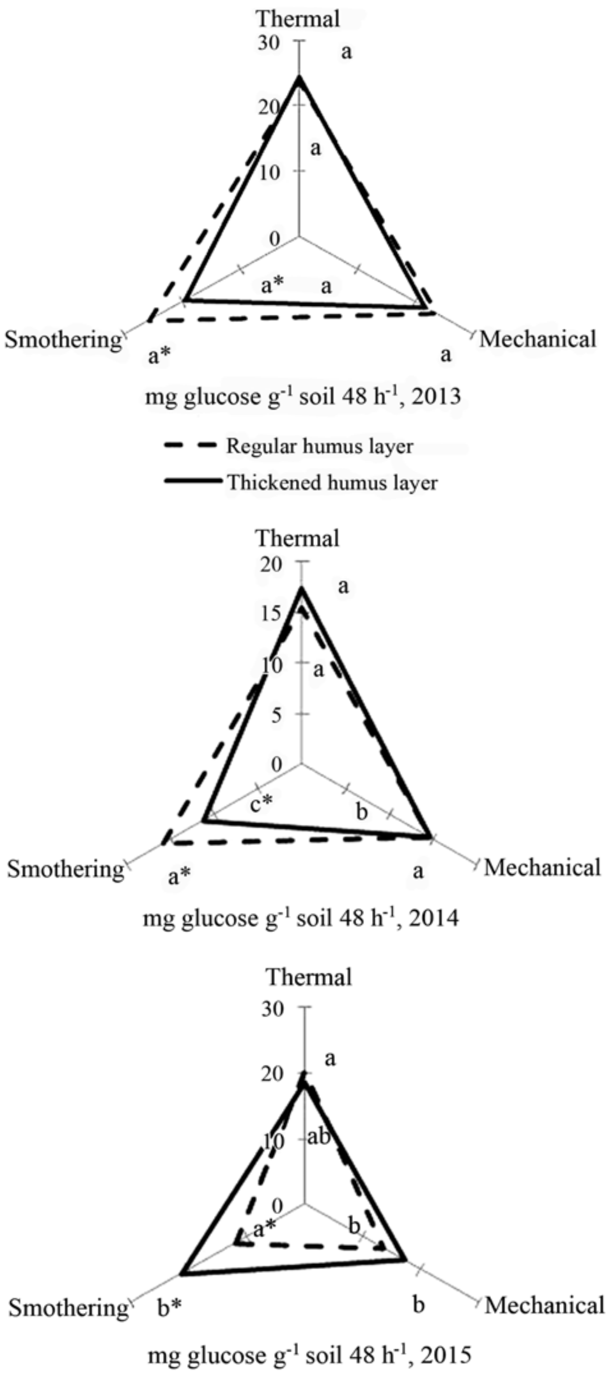


Note. Means not sharing a common letter (a, b) (factor A) are significantly different (P < 0.05).

Figure 2. Root dry biomass of spring oilseed rape crop

enzyme saccharase (Fig. 3). In the regular humus layer, the strongest saccharase activity was determined in the weed smothering treatment (25.7 mg glucose g^{-1} soil 48 h^{-1}), and in the thickened humus layer in the crop where spring oilseed rape was grown with wide inter-rows (48 cm) and weeds were controlled with water steam (24.4 mg glucose g^{-1} soil 48 h^{-1}). However, significant differences were not estimated, compared with the other weed control methods.

In 2014, in the soil with a regular humus layer the activity of saccharase did not differ significantly between the weed control methods tested. In the soil with a thickened humus layer a significantly higher (19.2–52.6%) saccharase activity was recorded in the thermal weed control treatment compared with mechanical and smothering weed control methods. In 2013 and 2014,



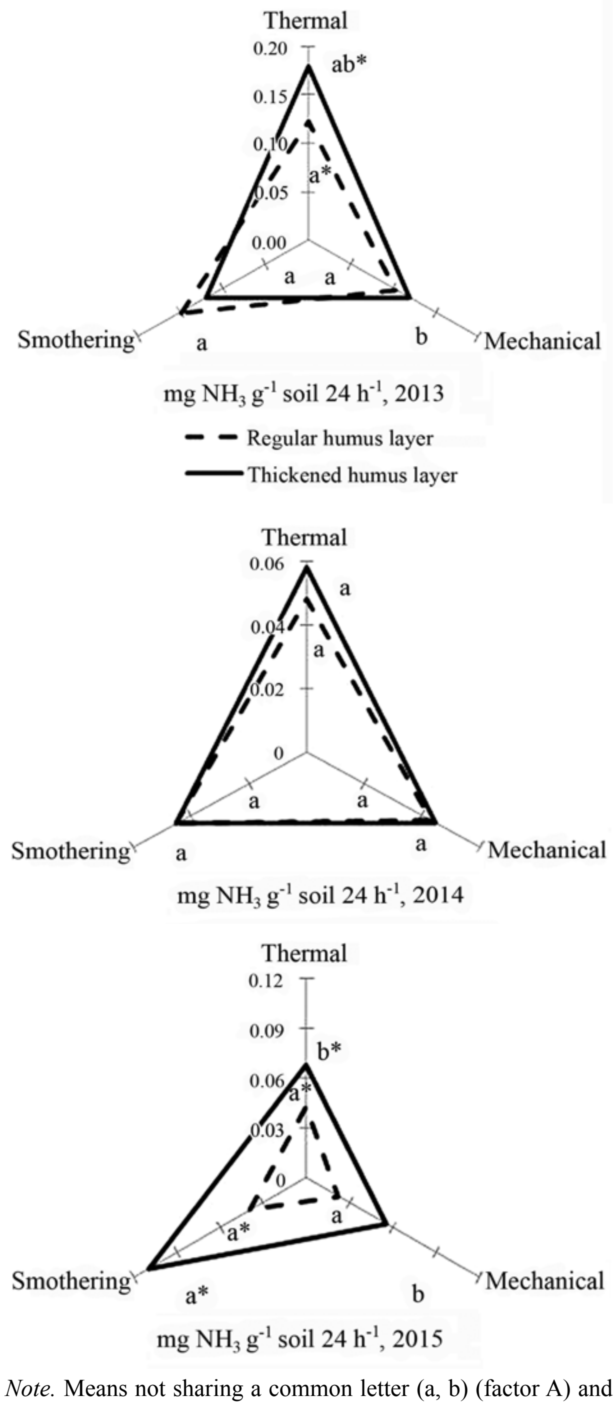
Note. Means not sharing a common letter (a, b, c) (factor A) and with asterisk (factor B) are significantly different ($P < 0.05$).

Figure 3. Activity of soil enzyme saccharase (2013–2015)

in the smothering weed control treatment with a regular humus layer, significantly 39.5% and 31.1% higher saccharase activity was recorded, compared with that in the plots with a thickened humus layer. In the plots of thermal and mechanical weed control, the thickness of the humus layer did not have significant effect on the activity of soil enzyme saccharase.

In 2015, under the drought conditions, a positive effect of the thickened humus layer on saccharase activity was estimated. In the plots of smothering weed control with a thickened humus layer, saccharase activity was found to be significantly 77.5% higher compared with the plots with a regular humus layer. In the regular humus layer, significantly from 47.4% to 68.3% higher saccharase activity was identified in the thermal weed control treatment compared with that in the mechanical and smothering weed control treatments. In the thickened humus layer, significantly from 15.1% to 23.1% higher saccharase activity was determined in the smothering weed control treatment, compared with the thermal and mechanical weed control treatments.

In 2013, the activity of soil enzyme urease was found to be significantly dependent on the thickened humus layer in the thermal weed control treatment (Fig. 4). Significantly 46.3% higher urease activity was established in the soil with a thickened humus layer



Note. Means not sharing a common letter (a, b) (factor A) and with asterisk (factor B) are significantly different ($P < 0.05$).

Figure 4. Activity of soil enzyme urease (2013–2015)

compared with that in the regular one. In the regular humus layer, significantly 45.6% higher urease activity was recorded in the smothering weed control treatment compared with mechanical weed control. In the thickened humus layer, significantly 50% higher urease activity was found in the plots under thermal weed control compared with mechanical and smothering weed control treatments. In 2014, urease activity did not depend either on the non-chemical weed control method applied or thickness of the humus layer. In 2015, in the regular humus layer none of the weed control methods tested exerted significant effect on urease activity. In the thickened humus layer, significantly from 1.6 to 2 times higher urease activity was determined in the smothering weed control treatment compared with thermal and mechanical weed control treatments. Pupalienė (2004) has found that thickening of the soil humus layer tended to increase saccharase and urease activity in the soil in the organic agriculture system.

Kong et al. (2009) suggests that plant root surface area and activity have a greater impact on soil enzyme activity than biomass. Numerous authors have indicated that soil enzyme activity often correlates with C_{org} and total nitrogen (N_{tot}) content (Melero et al., 2008). According to Yang et al. (2008), soil enzyme activity depends on the ammonia nitrogen (NH_3) and available P_2O_5 content in the soil. In 2013, available P_2O_5 content in the soil was found to positively very strongly, statistically significantly correlate with saccharase activity ($r = 0.93$, $P < 0.05$). In 2015, positive very strong and statistically significant correlations were estimated between urease activity and N_{tot} ($r = 0.96$, $P < 0.05$) and available P_2O_5 content in the soil ($r = 0.93$, $P < 0.05$).

Abundance of earthworms. The number and biomass of earthworms depended on the weather conditions, especially moisture content, during the crop growing season. Because of the moisture shortage, significantly lower abundance of earthworms in the soil was recorded in 2014 and 2015 compared with 2013 (Table).

Table. The number and biomass of earthworms

Weed control method (factor A)	Humus layer (factor B)	Year 2013 number of earthworms m^{-2}	2013 biomass of earthworms g m^{-2}	2014 number of earthworms m^{-2}	2014 biomass of earthworms g m^{-2}	2015 number of earthworms m^{-2}	2015 biomass of earthworms g m^{-2}
Thermal	regular	170 a	64.8 a	28 b	14.0 b	15 a	3.99 a
	thickened	174 a	84.7 a	27 b	12.7 b	21 ab	7.66 a
Mechanical	regular	148 a	64.1 a	22 b*	13.8 b*	10 a	1.77 a
	thickened	144 a	55.6 b	33 b*	22.2 a*	16 b	4.11 a
Smothering	regular	173 a	53.3 a	43 a	20.2 a	12 a*	2.84 a
	thickened	131 a	48.1 b	50 a	23.8 a	31 a*	8.79 a

Note. Means not sharing a common letter (a, b) (factor A) and with asterisk (factor B) are significantly different ($P < 0.05$).

In 2013, thickening of soil humus layer did not exert significant effect on the biomass of earthworms. Both in the regular and thickened soil layers the different non-chemical weed control methods tested did not have significant effect on the number of earthworms. In the soil with a thickened humus layer, significantly 52.3% and 76.1% greater earthworm biomass was determined in the thermal weed control treatment, compared with the mechanical and smothering weed control treatments.

In 2014, both in the regular and thickened humus layer, significantly the highest earthworm number (from 53.6% to 95.5% and from 51.5% to 85.2%) and biomass (from 44.3% to 46.4% and from 7.2% to 87.4%) were recorded in the smothering weed control treatment, compared with the thermal and mechanical weed control. In the plots of mechanical weed control treatment with a thickened humus layer, earthworm number and biomass were determined to be significantly 50.0% and 60.9% higher compared with the plots with a regular humus layer.

In 2015, in the soil with a regular humus layer, the different weed control methods tested did not exert significant effect on earthworm number and biomass. In the soil with a thickened humus layer, earthworm biomass did not change significantly; however, earthworm number significantly 48.4% decreased in the mechanical weed control plots compared with smothering weed control plots. Schreck et al. (2012) have documented that with the application of mechanical weed control the abundance of earthworms significantly decreased. In the smothering weed control treatment, in the soil with a thickened humus layer the number and biomass of earthworms were significantly 2.6 and 3.1 times greater compared with the plots with a regular humus layer. Pupalienė (2004) has indicated that in the soil with a thickened ploughlayer the number of earthworm increased in the year when there was a shortage of moisture in the soil.

Earthworm abundance in the soil depended on the activity of soil enzymes. In 2013, a positive strong and statistically significant correlation was determined between saccharase activity and earthworm number ($r = 0.89$, $P < 0.05$). In 2015, positive, very strong and statistically significant correlations were established between urease activity and earthworm number ($r = 0.99$, $P < 0.01$) and between urease activity and earthworm biomass ($r = 0.94$, $P < 0.01$). Earthworm abundance is usually higher in the soil with a higher nutrient status (Pommereche, Løes, 2009). In 2013, positive very strong statistically significant correlation was identified between available K_2O content in the soil and earthworm biomass ($r = 0.92$, $P < 0.05$). Positive strong and very strong statistically significant correlations were established between N_{tot} and C_{org} content in the soil and earthworm biomass: $r = 0.91$, $P < 0.05$ and $r = 0.87$, $P < 0.05$.

Conclusions

1. The greatest spring rape root dry biomass (on average 1.68 t ha^{-1}) was produced in the soil with a regular humus layer in the treatment where mechanical weed control had been applied. The root dry biomass of spring rape depended on the plant density of the crop ($r = 0.82–0.96$, $P < 0.05$).

2. In the soil with a regular humus layer, the different non-chemical weed control methods tested had little effect on soil enzyme activity. In the soil with a thickened humus layer, significantly stronger activity of soil enzymes saccharase and urease, compared with the other weed control methods, was established in the treatments where weeds had been controlled using a thermal weed control method involving water steam and in a dry year of 2015 in the smothering weed control treatment.

3. In the thickened humus layer, compared with a regular one, the activity of soil enzyme urease was significantly (1.5–1.6 times) higher in the plots where in 2013 and 2014 thermal weed control had been applied, and in 2015 in the plots under smothering weed control (2.8 times). The activity of saccharase significantly increased (1.8 times) in 2015 in the plots under smothering weed control.

4. Significantly the highest number and biomass of earthworms were established in the plots with a thickened humus layer in which in 2013 thermal weed control had been applied and in 2014 and 2015 in the plots under smothering weed control. In the thickened humus layer, compared with the regular one, the number and biomass of earthworms significantly (1.5 and 1.6 times) increased in the plots where in 2014 mechanical weed control had been used and in 2015 in the smothering weed control treatment (2.6 and 3.1 times).

5. Soil enzyme activity and earthworm abundance depended on the weather conditions and soil agrochemical properties. Earthworm abundance in the soil correlated with soil enzyme activity. Positive strong and very strong statistically significant correlations were determined between saccharase activity and earthworm number ($r = 0.89$, $P < 0.05$), between urease activity and earthworm number ($r = 0.99$, $P < 0.01$) and between urease activity and earthworm biomass ($r = 0.94$, $P < 0.01$).

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Necheminės piktžolių kontrolės įtaka dirvožemio biologinėms savybėms vasarinių rapsų pasėlyje

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Santrauka

Tyrimų tikslas – nustatyti necheminių piktžolių kontrolės būdų įtaką dirvožemio fermentų aktyvumui ir sliekų gausumui ekologiškai augintų vasarinių rapsų pasėlyje dirvožemyje su nepastorintu (23–25 cm) ir pastorintu (45–50 cm) humusingu sluoksniu. Lauko eksperimentas atliktas 2013–2015 m. Aleksandro Stulginskio universiteto Bandymų stotyje. Dirvožemis – karbonatingas giliau glėjiškas išplautžemis (IDg4-k). Taikyti necheminiai piktžolių kontrolės būdai: 1) terminis (drėgnuoju vandens garu), 2) mechaninis (tarpueilių purenimas) ir 3) stelbimas (savireguliacija). Taikant terminį ir mechaninį piktžolių kontrolės būdą rapsai auginti 48 cm, stelbimą – 12 cm tarpueiliais.

Didžiausia vasarinių rapsų šaknų biomasė (vidutiniškai 1,68 t ha^{-1}) susiformavo dirvožemyje su nepastorintu humusingu sluoksniu taikant mechaninę piktžolių kontrolę. Rapsų šaknų biomasė priklausė nuo pasėlio tankumo ($r = 0,82–0,96$, $P < 0,05$). Dirvožemyje su nepastorintu humusingu sluoksniu dirvožemio fermentų aktyvumui skirtingi necheminiai piktžolių kontrolės būdai turėjo nedidelę įtaką. Dirvožemyje su pastorintu humusingu sluoksniu esmingai stipresnis fermentų sacharazės ir ureazės aktyvumas, palyginti su kitomis taikytomis priemonėmis, nustatytas laukeliuose, kuriuose piktžolės naikintos termiškai drėgnuoju vandens garu, o sausais 2015 m. – stelbimo laukeliuose. Pastorintame humusingame sluoksnyje, palyginti su nepastorintu, fermento ureazės aktyvumas buvo esmingai (1,5–1,6 karto) didesnis laukeliuose, kuriuose 2013 ir 2015 m. taikyta terminė piktžolių kontrolė, o 2015 m. – stelbimas (2,8 karto). Fermento sacharazės aktyvumas esmingai 1,8 karto padidėjo 2015 m. stelbimo laukeliuose. Esmingai didžiausias sliekų skaičius ir biomasė nustatyti laukeliuose su pastorintu humusingu sluoksniu, kuriuose 2013 m. taikyta terminė piktžolių kontrolė, o 2014 ir 2015 m. – stelbimas. Pastorintame humusingame sluoksnyje, palyginti su nepastorintu, sliekų skaičius ir biomasė esmingai 1,5 ir 1,6 karto padidėjo laukeliuose, kuriuose 2014 m. taikyta mechaninė piktžolių kontrolė, o 2015 m. stelbimas – atitinkamai 2,6 ir 3,1 karto. Dirvožemio fermentų aktyvumas ir sliekų gausumas priklausė nuo meteorologinių sąlygų ir dirvožemio agrocheminių savybių. Sliekų gausumas dirvožemyje koreliavo su fermentų aktyvumu. Nustatyti teigiami, stiprūs ir labai stiprūs esminiai koreliaciniai ryšiai tarp sacharazės aktyvumo ir sliekų skaičiaus ($r = 0,89$, $P < 0,05$), tarp ureazės aktyvumo ir sliekų skaičiaus ($r = 0,99$, $P < 0,01$) bei tarp ureazės aktyvumo ir sliekų biomasės ($r = 0,94$, $P < 0,01$).

Reikšminiai žodžiai: *Brassica napus*, dirvožemio fermentai, ekologinė žemdirbystė, sliekai, stelbimas, šaknys, terminė ir mechaninė piktžolių kontrolė.