Chapter

Nonchemical Weed Control in Winter Oilseed Rape Crop in the Organic Farming System

Aušra Marcinkevičienė, Marina Keidan, Rita Pupalienė, Rimantas Velička, Zita Kriaučiūnienė, Lina Marija Butkevičienė and Robertas Kosteckas

Abstract

A field experiment was conducted during the 2014–2017 period at Aleksandras Stulginskis University (now—Vytautas Magnus University Agriculture Academy) on a *Endocalcaric Endogleyic Luvisol* (*LV-can.gln*) according to the WRB 2014. The three nonchemical weed control methods were explored: (1) thermal (using wet water steam), (2) mechanical (interrow loosening), and (3) self-regulation (smothering). In the thermal and mechanical weed control treatments, winter oilseed rape was grown with an interrow spacing of 48.0 cm and in weed smothering (self-regulation) treatment with an interrow spacing of 12.0 cm. Winter oilseed rape was grown in the soil with a regular humus layer (23–25 cm) and with a thickened humus layer (45–50 cm). Annual weeds predominated in the winter oilseed rape crop. In the soil with both humus layers, regular and thickened, the most efficient weed control method was mechanical weed management both during the autumn (efficacy 26.7–75.1%) and spring (efficacy 37.1–76.7%) growing seasons. Thermal and mechanical weed control in combination with the bio-preparations in droughty years significantly reduced the number of weed seedlings. Dry matter mass of weeds most markedly decreased through the application of the mechanical weed management method.

Keywords: winter oilseed rape, weed control methods, organic farming system, bio-preparations, soil humus layer

1. Introduction

The development of organic farming was prompted by the environmental concerns, health-related issues, and the search for solutions to social problems.

In Lithuania, organic farms account for more than 5% of the area under cultivation and are in line with the EU average. According to the popularity of organic farming, Lithuania surpasses the neighboring Poland but is far behind the other Baltic States. Although organic farms represent a small proportion of the total number of farms, their number has increased rapidly over the past decade. In 2017, 2448 organic farms were certified in Lithuania; they cover about 244,000 hectares of the agricultural land [1]. Most of the organic production farms are 10–30 ha in size.

Oilseed rape is one of the world's most important oil crops [2, 3]. The cultivation of oilseed rape on organically managed farms was encouraged by a search for healthy, high-quality, and safe food. According to the data from the public organization "Ekoagros," in 2017, the total area devoted to oilseed rape production on organically managed farms in Lithuania amounted to 3962.2 ha, including 3250.98 ha of winter oilseed rape and 711.22 ha of spring oilseed rape. The main reasons why winter oilseed rape production area on organically managed farms is not increasing are the problems associated with plant nutrition [4, 5], weed, disease and pest control, and unstable plant overwinter survival, and all these factors result in low rapeseed yields [6, 7]. Many organic farms in Lithuania are located on infertile soils, and the erosion and productivity problems are relevant there. Organic crop production farms are prevalent in this region; therefore the problem of crop rotation, nutrient, and humus balance is highly relevant. In the organic production farms, the inclusion of oilseed rape in the crop rotation is very important because it is characterized by phytosanitary properties, is a good pre-crop for other crops, and improves soil properties [8].

In the organic production farms, in the absence of the possibility of controlling weeds with herbicides, a great deal of attention is paid to nonchemical methods of weed control—mechanical, thermal, and natural crop-weed competition/self-regulation. Weed control by using wet water steam has not been extensively studied in the world. More comprehensive studies on the thermal weed control by water steam have been carried out by Lithuanian scientists [9–13].

2. Material and methods

Field experiments were conducted in 2014–2017 at the Experimental Station (54°53′ N, 23°50′ E) of Aleksandras Stulginskis University on an *Endocalcaric Endogleyic Luvisol* (*LV-can.gln*) according to the WRB 2014. Agrochemical properties of the experimental soil with a regular humus layer (averaged data of 2014, 2015, and 2016) were as follows: pH, 7.30; humus, 1.79%; contents of available nutrients in the soil: P_2O_5, 199.0 mg kg^{-1}; K_2O, 97.7 mg kg^{-1}; total nitrogen, 0.079%. Agrochemical properties of the experimental soil with a thickened humus layer were as follows: pH, 7.20; humus, 2.19%; contents of available nutrients in the soil: P_2O_5, 277.7 mg kg^{-1}; K_2O, 123.0 mg kg^{-1}; total nitrogen, 0.115%.

Two-factor field experiments were established using a split-plot design. Winter oilseed rape was grown in the soil with a regular humus layer (23–25 cm) (experiment I) and in the soil with a thickened humus layer (45–50 cm) (in 1988, a thickened humus-rich layer was artificially formed using fertile soil delivered from elsewhere) (experiment II). The length of initial plots was 14 m, width 6 m, and the area 84 m^2. The length of the harvested plots was 10 m, width 2 m, and the area 20 m^2. The experiments included four replications. The winter oilseed rape crop was preceded by black fallow.

The study object was winter oilseed rape (*Brassica napus* L. spp. *oleifera biennis* Metzg.) agrocenosis.

Experimental treatments:

Factor A: nonchemical weed control methods:

1. Thermal (water steam)

2. Mechanical (interrow cultivation)

3. Self-regulation/smothering (natural weed-crop competition, sowing with narrow interrows)

Factor B: biological preparations (bio-preparations):

1. Without bio-preparations

2. With bio-preparations

A winter rape cultivar "Cult" (Sweden, SW Seed) was grown in the experiment. The crop was sown at a seed rate of 3 kg ha^{-1} with a Multidrill M300 sowing machine. In 2014, winter rape was sown on September 1, in 2015 on August 27, and in 2016 on August 29. In the thermal weed control treatment, the oilseed rape crop was grown with interrow spacing of 48 cm, and weeds were killed using a tractor-mounted wet water steam unit at a 3–4 leaf growth stage (BBCH 13–14) of winter rape. The thermal power of the device is 90 kW, with a capacity of 120 kg h^{-1} steam; the device is run on liquefied gas. The temperature of steam is 99°C, with thermal treatment time of 2 s (Sirvydas, Kerpauskas, 2012).

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

2.1 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 present in the steam boiler 8. The wet water steam which has formed in steam boiler 8 gets into the steam separator, in which steam dampness is reduced. Then the wet 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 12 with a mounting device 11.

In the mechanical weed control treatment, the interrows were loosened with an interrow cultivator (KOR-4.2-01, Ukraine) using two passes. In the weed control treatment involving weed smothering (self-regulation), the winter oilseed rape was

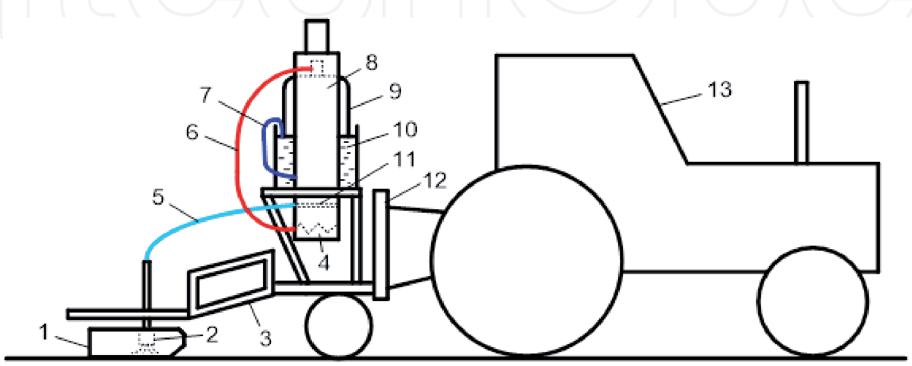

Figure 1.
The principal technological scheme of the tractor-mounted thermal weed control unit: (1) protectors of steam diffusers, (2) steam diffusers, (3) diffusers' height adjustment mechanism, (4) combustion chamber, (5) tube by which wet water steam is fed to steam diffusers and discharges, (6) tube 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, and (13) tractor.

grown with 12.0 cm interrow spacing. Winter rape was not fertilized, and no chemical plant protection products were applied.

In the treatments with the use of the bio-preparations, pre-sowing, the seeds of winter rape were coated with the bio-organic fertilizer Nagro (BioPlant) (0.5 l per ton of seeds and 10 l of water), and during the growing season, the winter rape crop was sprayed twice with the bio-preparations (in the autumn with Terra Sorb Foliar (BioIberica) (2 l ha^{-1}), in the spring with Terra Sorb Foliar (1 l ha^{-1}) and 0.3% Conflic (Atlantica Agricola)).

2.2 Assessment of weed incidence in the crop

The analysis of weed seedlings was carried out at winter rape 3–4 leaf growth stage (BBCH 13–14) in the autumn and after resumption of vegetation in the spring (BBCH 50) before the application of thermal and mechanical weed management methods. In each experimental plot, in four randomly selected 0.10 m^2 record plots, the number of weed seedlings and weed species composition were established. This analysis was done for the second time 5–7 days after application of the weed control methods in the marked record plots. The number of weed seedlings was recalculated as per m^2. The efficacy (E) of the weed management methods for the change in the number of weed seedlings was calculated according to the formula:

$$E = (S1–S2)/S1 \times 100\,\%, \tag{1}$$

where S1 is the number of weed seedlings per m^2 before application of the weed control methods and S2 is the number of weed seedlings per m^2 after application of the weed control methods.

At winter rape green silique stage (BBCH 79), the number of weeds and weed species composition were determined in each plot in four 0.25 m^2 record plots; he weeds were dried in a drying chamber at 60°C temperature and weighed [14].

2.3 Statistical analysis

The significance of the differences between the means was estimated using the *t* criterion; the interplay between the traits was determined by the correlation regression methods. The statistical analysis of the experimental data was performed using software STAT from the software package SELEKCIJA [15]. The experimental data that did not fit the normal distribution law, prior to the statistical evaluation, were transformed using the function y = lnx + 1.

2.4 Meteorological conditions

In 2014 autumn was warm and long, so conditions for rape growing were favorable. In winter, meteorological conditions were favorable for rape over-wintering. In 2015, autumn was warm and humid. During the first decade of January 2016 of very cold weather and the absence of snow, over-wintering of rape was not successful. In 2016, the conditions for rape preparation for wintering and for over-wintering were favorable. In 2017, rape vegetation renewed on March 31. April was cold and humid with 35.3 mm more rainfall than usual. As a result, some winter rape has not over-wintered.

3. Experimental results

3.1 Weed incidence in the winter rape crop in the autumn and spring growing seasons

The following annual weed species predominated in the winter rape crop: *Chenopodium album* L., *Tripleurospermum perforatum* (Merat) M. Lainz, *Stellaria media* (L.) Vill., *Viola arvensis* Murray, *Veronica arvensis* L., *Sinapis arvensis* L., *Capsella bursa-pastoris* (L.) Medik, and *Poa annua* L.

In the soil with both regular and thickened humus layers, in the treatments where winter rape was grown with wide interrow spacings (48 cm), when the light and moisture conditions were favorable, the number of emerged weeds was higher than in the treatments with narrow interrows (12 cm), except for the spring growing season of 2017. The application of the bio-preparations in most cases reduced the number of weed seedlings in the winter rape crop both during the autumn and spring growing seasons.

Experiment I: in the soil with a regular humus layer. The most effective weed control method in organic winter rape crop was mechanical: efficiency 26.7–71.5% without biological preparations and 54.2–71.7% with biological preparations (**Figure 2**). The efficiency of the thermal weed control method was lower than the mechanical one. In Ref. [16], it was stated that the efficiency of mechanical and thermal weed control was 50–100%. Biological preparations enhanced the effectiveness of thermal and mechanical weed control techniques only in 2014. The effectiveness of the self-regulation method for the change of weed sprouts was negative throughout the study years.

Experiment II: in the soil with a thickened humus layer. The most effective weed control method in rapeseed crop was mechanical: efficiency was 39.8–75.1% without biological preparations and 53.0–68.9% with biological preparations (**Figure 3**). The efficiency of the thermal weed control method was lower than the mechanical one. Bio-preparations enhanced the effectiveness of mechanical weed control only in 2014. The method of self-regulation did not reduce the number of weed sprouts.

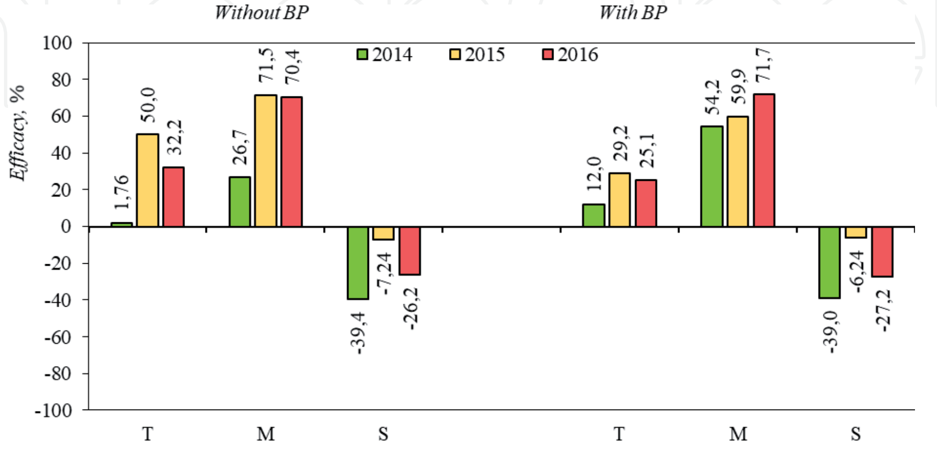

Figure 2.
The efficacy of the nonchemical weed control methods for the change in the number of weed seedlings in the winter oilseed rape crop, grown in the soil with a regular humus layer in the autumn (2014–2016). Note. T, thermal; M, mechanical; S, self-regulation; BP, bio-preparations.

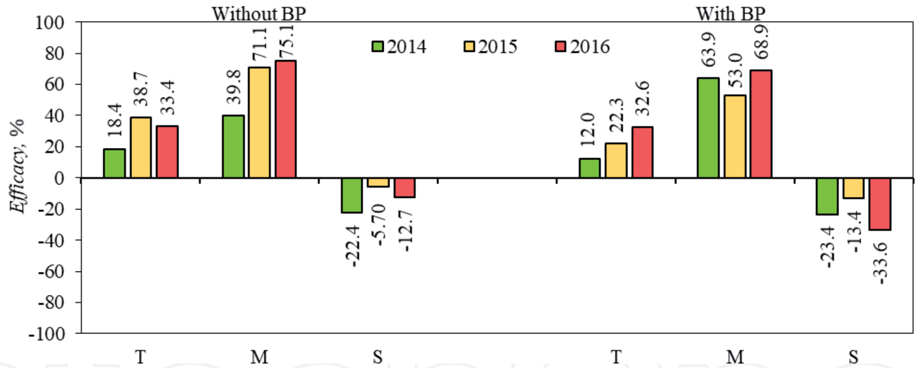

Figure 3.
The efficacy of the nonchemical weed control methods for the change in the number of weed seedlings in the winter oilseed rape crop, grown in the soil with a thickened humus layer in the autumn (2014–2016). Note. T, thermal; M, mechanical; S, self-regulation; BP, bio-preparations.

3.2 Weed incidence in the winter rape crop before harvesting

Experiment I: in the soil with a regular humus layer, the nonchemical weed management methods did not exert any pronounced effect on the weed number in the winter rape crop before harvesting throughout study years (**Figure 4**). Using bio-preparations in 2015 in experimental plots with mechanical weed control method, weed number was significantly 42.9% lower than in experimental plots with self-regulation. In 2016 and 2017, there were no significant differences in weed number between the different weed control methods.

The use of bio-preparations did not significantly affect the number of weeds in the oilseed rape crop during all study years compared to the treatment where they were not used.

There was no significant difference in weed dry matter mass between different weed control methods in plots with bio-preparations or without bio-preparations in 2015 (**Figure 5**). In 2016 and 2017, weed killing with interrow loosening and without biological preparations resulted in significantly lower weed dry mass than this in plots where thermal weed control and self-regulation methods were used, respectively, 2.0 and 2.5 times and 3.0 and 4.5 times. In 2017, the weed dry matter mass in plots with thermal weed control was significantly 32.3% lower than that of the self-regulation plots. In 2016 in plots with bio-preparations and mechanical

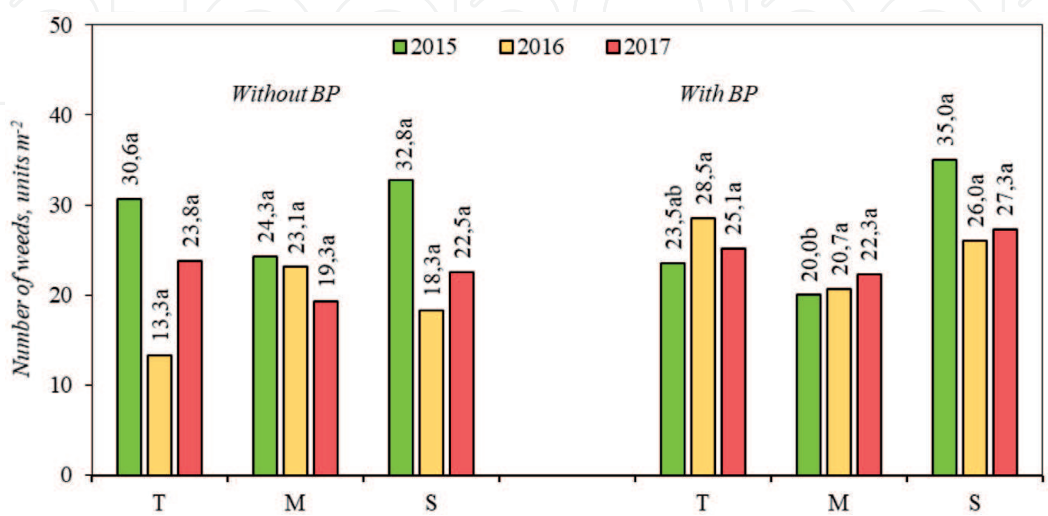

Figure 4.
The number of weeds in the winter oilseed crop, grown in the soil with a regular humus layer, before harvesting (2015–2017). Note. The differences between the averages of treatments of factor a, marked by not the same letter (a, b), are significant (P < 0.05). T, thermal; M, mechanical; S, self-regulation; BP, bio-preparations.

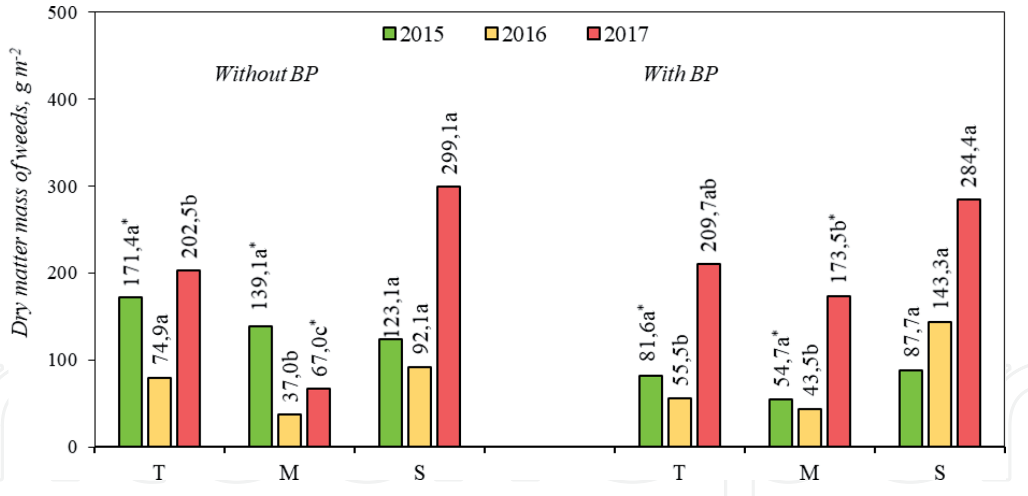

Figure 5.
The dry matter mass of weeds in the winter oilseed crop, grown in the soil with a regular humus layer, before harvesting (2015–2017). Note. The differences between the averages of treatments of factor a, marked by not the same letter (a, b, c), and between the averages of treatments of factor B, marked by an asterisk, are significant (P < 0.05). T, thermal; M, mechanical; S, self-regulation; BP, bio-preparations.

weed control method, the weed dry matter mass was significantly 2.6 and 3.3 times lower than that in the self-regulation weed control method plots. In 2017, mechanical weed control resulted in a significantly 39.0% lower dry mass of weeds than self-regulation method. It was found that thermal weed control resulted in a 44.0% reduction in dry mass of weeds using thermal weed control with water steam [16]. The similar results were obtained in the experiments in Lithuania—weed numbers were 3.2–4.4 times lower in plots with mechanical weed control method than this in plots with self-regulation weed control method and respectively weed dry mass by 2.2–3 times [17, 18].

With the use of biological preparations, the dry matter mass of weeds decreased significantly by 2.1 and 2.5 times in the fields of thermal and mechanical weed control methods only in the droughty 2015, as the more fertile rapeseed crop using biological preparations better suppressed weeds. K. Różyło and E. Pałys [19] found that as the assimilation leaf area of rape increased, the dry matter mass of weeds decreased. In 2017 with the use of biological agents, the dry weight of weeds increased significantly 2.6 times in the fields of mechanical weed control.

Experiment II: in 2015 in the soil with a thickened humus layer, interrow loosening without biological preparations significantly decreased weed number by 38.8 and 36.8% compared to thermal weed control and self-regulation (**Figure 6**). In 2016 and 2017, there were no significant differences in the number of weeds 0in the plots with various weed control methods without biological preparations. Using bio-preparations in 2015 in plots with mechanical weed control method, and in 2017 in plots with thermal weed control method, the weed numbers were significantly lower than in the plots of self-regulation weed control method by 42.9 and 34.7%, respectively. In 2016, there was no significant difference in the number of weeds in the plots with different weed control methods and with biological preparations.

Without biological preparations in 2015 and 2016, there were no significant differences in weed dry mass between the different weed control methods (**Figure 7**). Different weed control techniques used in plots with biological preparations in 2015 had no significant effect on the dry matter mass of the weeds. In 2016 in plots with mechanical weed control and with biological preparations, weed dry matter mass was significantly 4.1 and 5.1 times lower than that in plots with thermal weed control and self-regulation. In 2017 the dry matter mass of weeds was 6.7 and 5.7

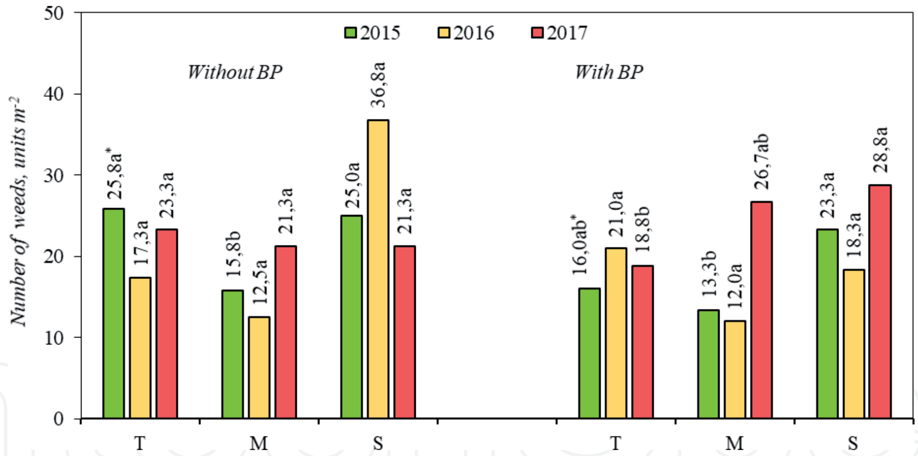

Figure 6.
The number of weeds in the winter oilseed crop, grown in the soil with a thickened humus layer, before harvesting (2015–2017). Note. The differences between the averages of treatments of factor a, marked by not the same letter (a, b), and between the averages of treatments of factor B, marked by an asterisk, are significant (P < 0.05). T, thermal; M, mechanical; S, self-regulation; BP, bio-preparations.

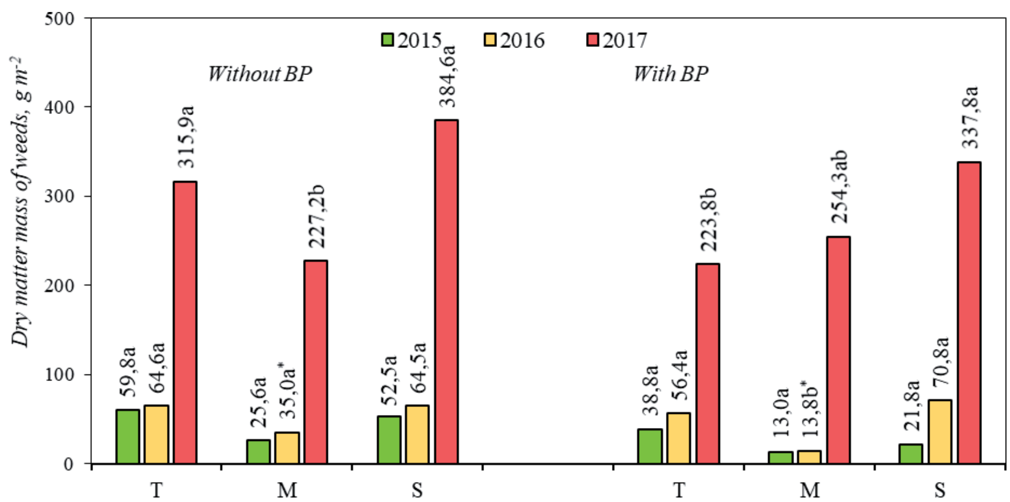

Figure 7.
The dry matter mass of weeds in the winter oilseed crop, grown in the soil with a thickened humus layer, before harvesting (2015–2017). Note. The differences between the averages of treatments of factor a, marked by not the same letter (a, b), and between the averages of treatments of factor B, marked by an asterisk, are significant (P < 0.05). T, thermal; M, mechanical; S, self-regulation; BP, bio-preparations.

times higher, respectively, without the use of biological preparations and 11.1 and 5.8 times higher with the use of biological preparations than in 2015 and 2016. Apparently, the higher weed dry matter content was caused by the lower rape crop and the humid and cold weather during rape vegetation. The mechanical weed control without biological preparations were found to have a significantly lower mass of weed dry mass than the thermal weed control and self-regulation, by 28.1 and 40.9% lower. The use of biological preparations and thermal weeds to control using wet water vapor resulted in a significantly by 33.7% lower dry mass of weeds than that in the self-regulation plots.

The use of biological agents significantly reduced weed dry matter in mechanical weed control fields only by 2016.

In 2017, negative, very strong, significant correlations were determined between the winter rape plant population density and weed dry matter mass: in the soil with a regular humus layer $r = -0.95$, $P < 0.01$; in the soil with a thickened humus layer $r = -0.91$, $P < 0.05$. [20]. R. Kosteckas (2011) [20] also found that the dry matter mass of weeds correlates with the density of rape crop.

4. Conclusions

Annual weeds predominated in the winter oilseed rape crop: *Chenopodium album* L., *Tripleurospermum perforatum* (Merat) M. Lainz, *Stellaria media* (L.) Vill., *Viola arvensis* Murray, *Veronica arvensis* L., *Sinapis arvensis* L., *Capsella bursa-pastoris* (L.) Medik., and *Poa annua* L.

In the soil with both humus layers, regular and thickened, the most efficient weed control method was mechanical weed management both during the autumn (efficacy 26.7–75.1%) and spring (efficacy 37.1–76.7%) growing seasons.

Thermal and mechanical weed control in combination with the bio-preparations in droughty years significantly reduced the number of weed seedlings. Dry matter mass of weeds most markedly decreased through the application of the mechanical weed management method.

Author details

Aušra Marcinkevičienė[1], Marina Keidan[2], Rita Pupalienė[1]*, Rimantas Velička[1], Zita Kriaučiūnienė[1], Lina Marija Butkevičienė[1] and Robertas Kosteckas[1]

1 Vytautas Magnus University, Kaunas, Lithuania

2 Public Institution "Ekoagros"

*Address all correspondence to: rita.pupaliene@vdu.lt

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