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Crop density and fertilization effects on weed suppression in spring oilseed rape

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Abstract

Field experiments were conducted in 2008 and 2009 at the Experimental Station of the Lithuanian University of Agriculture on a *Calc(ar)i-Epihypogleyic Luvisol* (*LVg-n-w-cc*). The objective of the current study was to determine the effect of crop density and fertilization on photosynthetically active radiation (PAR) interception and weed suppression in spring oilseed rape (*Brassica napus* L.) ‘Sponsor’. Treatments of the investigations: factor A – fertilization: 1) without fertilization, 2) fertilization before rape sowing $N_{68}P_{68}K_{68}$ and at the budding stage N_{70}; factor B – crop density: 1) 2 kg ha^{-1} (50.1–100 plants m^{-2}), 2) 4 kg ha^{-1} (100.1–150 plants m^{-2}), 3) 6 kg ha^{-1} (150.1–200 plants m^{-2}), 4) 8 kg ha^{-1} (200.1–250 plants m^{-2}), 5) 10 kg ha^{-1} (250.1–300 plants m^{-2}), 6) 12 kg ha^{-1} (300.1–350 plants m^{-2}), 7) 14 kg ha^{-1} (350.1–400 plants m^{-2}), 8) 16 kg ha^{-1} (400.1–450 plants m^{-2}).

With the increasing spring rape crop density the PAR reaching the soil surface, ¼ and ½ height of the crop stand decreased in the crops without and with fertilization. Intensive fertilization of rape crop, in comparison with that without fertilization, significantly reduced the PAR reaching the soil surface, ¼ height of the crop stand and ½ height of the crop stand in 2008. In the spring rape crop without fertilization dry matter weight of weeds was influenced by crop density and PAR reaching the soil surface and ¼ height of the crop stand, whereas in the spring rape crop with fertilization it depended on crop density, PAR reaching the soil surface, ¼ and ½ height of the crop stand.

Key words: spring rape, fertilization, crop density, photosynthetically active radiation, weed.

Introduction

Agricultural plants have different capability to suppress weeds. It depends on the biological features of plants (Börner, 1995; Зайкова, 2005), soil tillage, fertilization, seed rate and sowing time (Bullied et al., 2006). Spring oilseed rape is sown in April and May and this coincides with the peak of spring weed germination. At this time of the year, broad-leaved weeds dominate (Davies, 2005). Our research evidence shows that spring rape suppresses weeds worse than spring barley and winter wheat do, because it takes a long time for spring rape plants to reach rosette stage (Шпаар, 1999; Velička, Trečiokas, 2002). Therefore the seed rate or density of agricultural plants is a very important factor, which raises domination of agricultural plants and suppresses weeds in the crop stand (Lazauskas, 1990; Auler, 1998; Захаренко, 2000). The essence of weed suppression is that all plants (crops and weeds) become smaller with increasing crop stand density (Lazauskas, 1990). However, an increasing seed rate only raises the number of agricultural plants while the number of weeds does not increase and often even decreases.

The results of Marcinkevičienė et al. (2006) show that light intensity on the soil surface decreases when the assimilation area of spring rape leaves and total crop biomass increases. A significant positive correlation appears between weed abundance and light intensity on soil surface. According to Romaneckienė et al. (2008) lower amounts of PAR influenced the highest percentage of scrag weeds. The emergence, growth of weeds weakens, their leaves become yellow and atrophic if there is not enough sunshine.

The aim of our investigations was to determine the effect of crop density and fertilization on photosynthetically active radiation interception and weed suppression in spring oilseed rape ‘Sponsor’.

Materials and methods

Field experiments were conducted in 2008 and 2009 at the Experimental Station of the Lithuanian University of Agriculture (54°53′N, 23°50′E). The soil of the experimental site was *Calc(ar)i-Epihypogleyic Luvisol*, *LVg-n-w-cc*) and its texture – medium clay loam on heavy clay loam. Soil exchange acidity was 6.97 pH, humus content – 2.51%, available P_2O_5 and K_2O – 242 mg kg^{-1} and 124 mg kg^{-1}, respectively.

Experimental treatments: factor A – fertilization: 1) without fertilization, 2) fertilization before crop sowing $N_{68}P_{68}K_{68}$ (NPK 16:16:16 400 kg ha^{-1}) and at the budding stage N_{70} (ammonium nitrate 200 kg ha^{-1}); factor B – crop density: 1) 2 kg ha^{-1} (50.1–100 plants m^{-2}), 2) 4 kg ha^{-1} (100.1–150 plants m^{-2}), 3) 6 kg ha^{-1} (150.1–200 plants m^{-2}), 4) 8 kg ha^{-1} (200.1–250 plants m^{-2}), 5) 10 kg ha^{-1} (250.1–300 plants m^{-2}), 6) 12 kg ha^{-1} (300.1– 350 plants m^{-2}), 7) 14 kg ha^{-1} (350.1–400 plants m^{-2}), 8) 16 kg ha^{-1} (400.1–450 plants m^{-2}).

Different crop density of spring oilseed rape (*Brassica napus* L. ssp. *oleifera annua* Metzg) was formed by a precision seed-drill with respect to rape 'Sponsor' seed germination rate and 1000 seed weight. The size of a sampling plot was 27.0 m^2, the number of replications 4.

Soil tillage: in the autumn conventional ploughing at the depth of 23–25 cm, in spring – cultivation (twice) and harrowing. In 2008, the forecrop was fodder beets (*Beta vulgaris* L.), in 2009 vetch (*Vicia sativa* L.) and oats (*Avena sativa* L.) mixture. Rape was sprayed twice against pests with lambdacihalotrin (0.0075 kg ha^{-1}).

The agrochemical characteristics of the soil were determined as follows: pH_{KCl} was measured potentiometrically, content of humus according to Tyurin, mobile nutrients with a PSCO/ISI IBM-PC 4250 infrared spectrometer (United States) and a calibration curve (Rimkevičienė, 2000).

Photosynthetically active radiation was measured at the rape flowering stage using a HD 9021 RAD/PAR: PAR E m^{-2}, wavelength range 400÷700 nm, on the soil surface, at the level of ¼, ½ and ¾ heights of the crop stand and on the plant tops at midday (from 12:00 to 13:00). PAR reaching plant tops was taken for 100%.

Dry matter weight of weeds (g m^{-2}) was assessed before rape harvesting on one sampling area in each plot. The frame size used was 1 m^2.

The experimental data were statistically estimated by using Fisher protected LSD test, correlation and regression analyses (*Anova*, *Stat Eng*). The weed incidence data that did not meet the normal distribution were transformed by using the function $y = arctgx + 1$ before statistical evaluation (Tarakanovas, Raudonius, 2003).

In 2008, the sum of active temperatures (≥10°C) within the period of plant growth was 1808.5°C, the level of rainfall was 231.0 mm and the hydrothermal coefficient (HTC) was 1.28. In 2009, the sum of active temperatures within the period of plant growth was 1630.5°C, the level of rainfall was 240.9 mm and the HTC was 1.48.

HTC was calculated using the formula of G. Selianinov (Хомяков, 1989):

$$HTC = \Sigma p \times (0.1 \times \Sigma t)^{-1},$$

where Σp – total rainfall mm during the rape vegetation period, Σt – sum of air temperatures ≥ 10ºC during the same period.

Results and discussion

Experimental results suggest that interception of photosynthetically active radiation was in close relationship with the crop density. The highest PAR reaching the soil surface was observed in the thinnest spring rape crop (50.1–100 plants m^{-2}) without fertilization. In 2008 at rape crop density increase, in comparison with the thinnest crop, the PAR reaching the soil surface decreased from 68.6 to 90.2% (Table 1). In 2009 in the spring rape crop without fertilization with the increasing number of plants to 450 per m^{-2}, the PAR reaching the soil surface decreased, but not significant differences were established (Table 2).

Significant negative correlation was established between rape crop density and PAR reaching the soil surface (in 2008 – $r = -0.72$, $y = 21.96 - 0.05x$, $P < 0.05$; in 2009 – $r = -0.89$, $y = 46.75 - 0.09x$, $P < 0.01$).

In 2008 in spring rape with fertilization crop density had no significant effect on PAR reaching the soil surface. In 2009 in spring rape with fertilization with the increasing rape crop density the PAR reaching the soil surface significantly decreased from 64.4 to 79.4%. Significant negative relationship existed between rape crop density and PAR reaching the soil surface (in 2008 – $r = -0.91$, $y = 1.52 - 0.01x$, $P < 0.01$; in 2009 – $r = -0.74$, $y = 14.53 - 0.06x$, $P < 0.05$). Velička et al. (2007) also reported similar results.

Intensive fertilization of rape crop, in comparison with that without fertilization, significantly reduced the PAR reaching the soil surface: in 2008 – from 64.7 to 95.8%, in 2009 – from 38.1 to 90.8%.

In 2008 in the spring rape crop without fertilization a trend of decreasing PAR reaching the ¼ height of the crop stand at the increasing rape crop density up to 400 plants m^{-2} was established. At the rape crop density of 400.1–450 plants m^{-2}, in comparison with the thinnest crop, a significant decrease (80.2%) of the PAR reaching the ¼ height of the crop stand was observed. In 2009 with the increasing rape crop density the PAR reaching the ¼ height of the crop stand decreased, but not significant differences were established. Significant negative correlation was established between rape crop density and PAR reaching the ¼ height of the crop stand (in 2008 – $r = -0.82$, $y = 43.63 - 0.09x$, $P < 0.05$; in 2009 – $r = -0.92$, $y = 63.69 - 0.12x$, $P < 0.01$).

Table 1. PAR reaching the soil surface and the different heights of the spring rape crop stand 2008

Crop density plants m^{-2} (factor B)	Fertilization (factor A)	Reaching PAR ($E\ m^{-2}$) %			
		soil surface	¼ height of the crop stand	½ height of the crop stand	¾ height of the crop stand
50.1–100	without fertilization	30.6a*	45.1a*	70.4a*	79.2a
	with fertilization	1.30a*	7.10ab*	18.7ab*	75.2a
100.1–150	without fertilization	9.60b*	39.8ab*	65.8a*	64.4a
	with fertilization	1.00a*	20.8a*	21.2a*	66.0a
150.1–200	without fertilization	3.40c*	12.8ab*	43.6a*	53.4a
	with fertilization	1.20a*	4.20ab*	17.0ab*	31.1b
200.1–250	without fertilization	4.10c*	16.3ab*	36.5a*	61.1a
	with fertilization	0.80a*	1.00b*	17.9ab*	41.9ab
250.1–300	without fertilization	3.00c*	16.7ab*	44.9a*	51.6a
	with fertilization	0.70a*	2.50ab*	8.40b*	45.3ab
300.1–350	without fertilization	4.60bc*	16.9ab*	38.0a*	83.7a
	with fertilization	0.50a*	1.30ab*	17.6ab*	40.9ab
350.1–400	without fertilization	7.90b*	15.0ab*	41.7a*	66.6a
	with fertilization	0.50a*	1.20b*	8.10b*	55.5a
400.1–450	without fertilization	3.70c*	8.10b*	33.8a*	52.4a
	with fertilization	0.40a*	0.80b*	11.4ab*	47.3ab

Note. Means not sharing a common letter (a, b, c) and asterisks are significantly different ($P < 0.05$).

Table 2. PAR reaching the soil surface and the different heights of the spring rape crop stand 2009

Crop density plants m^{-2} (factor B)	Fertilization (factor A)	Reaching PAR ($E\ m^{-2}$) %			
		soil surface	¼ height of the crop stand	½ height of the crop stand	¾ height of the crop stand
50.1–100	without fertilization	38.1a*	62.4a*	70.8a	79.1a
	with fertilization	23.6a*	27.8a*	63.2a	88.5a
100.1–150	without fertilization	40.8a*	56.5a*	74.4a	76.0a
	with fertilization	8.40b*	30.1a*	56.2a	72.4a
150.1–200	without fertilization	37.1a*	43.4a*	79.3a	81.7a
	with fertilization	3.30b*	9.80b*	53.6a	68.0a
200.1–250	without fertilization	34.4a*	43.0a*	61.1a	81.9a
	with fertilization	3.20c*	3.60bc*	38.6a	81.6a
250.1–300	without fertilization	32.2a*	40.9a*	73.6a	88.4a
	with fertilization	3.20c*	2.30c*	39.8a	80.5a
300.1–350	without fertilization	33.6a*	39.8a*	69.3a	83.3a
	with fertilization	3.10c*	3.00bc*	41.0a	85.0a
350.1–400	without fertilization	23.2a*	35.3a*	71.8a	85.9a
	with fertilization	2.80c*	4.90bc*	37.3a	79.5a
400.1–450	without fertilization	18.6a*	37.0a*	68.7a*	74.4a
	with fertilization	2.90c*	4.40bc*	31.7a*	82.1a

Note. Explanation under Table 1.

In 2008 in spring rape with fertilization rape crop density had no significant effect on the PAR reaching the ¼ height of the crop stand. In 2009 at the rape crop density increase the PAR reaching the ¼ height of the crop stand, in comparison with the thinnest crop, significantly decreased from 67.4 to 92.4%. Significant negative relationship existed between rape crop density and PAR reaching the ¼ height of the crop stand ($r = -0.83$, $y = 30.80 - 0.11x$, $P < 0.05$).

Intensive fertilization of rape crop, in comparison with that without fertilization, significantly reduced the PAR reaching the ¼ height of the crop stand: in 2008 – from 47.7 to 93.9%, in 2009 – from 53.5 to 94.4%.

In both experimental years in the spring rape without and with fertilization crop density had a little influence on the PAR reaching the ½ height of the crop stand. In 2008 in spring rape without fertilization and in 2009 in spring rape with fertilization the results of the correlation and regression analyses show significant negative dependency of PAR reaching the ½ height of the crop stand on crop density (accordingly $r = -0.89$, $y = 71.71 - 0.09x$, $P < 0.01$ and $r = -0.93$, $y = 66.54 - 0.12x$, $P < 0.01$).

In 2008 intensive fertilization of rape crop, in comparison with that without fertilization, significantly from 51.0 to 81.3% reduced the PAR reaching the ½ height of the crop stand. In 2009, significant decrease (53.9%) of the PAR reaching the ½ height of the crop stand was observed only in the thinnest rape crop.

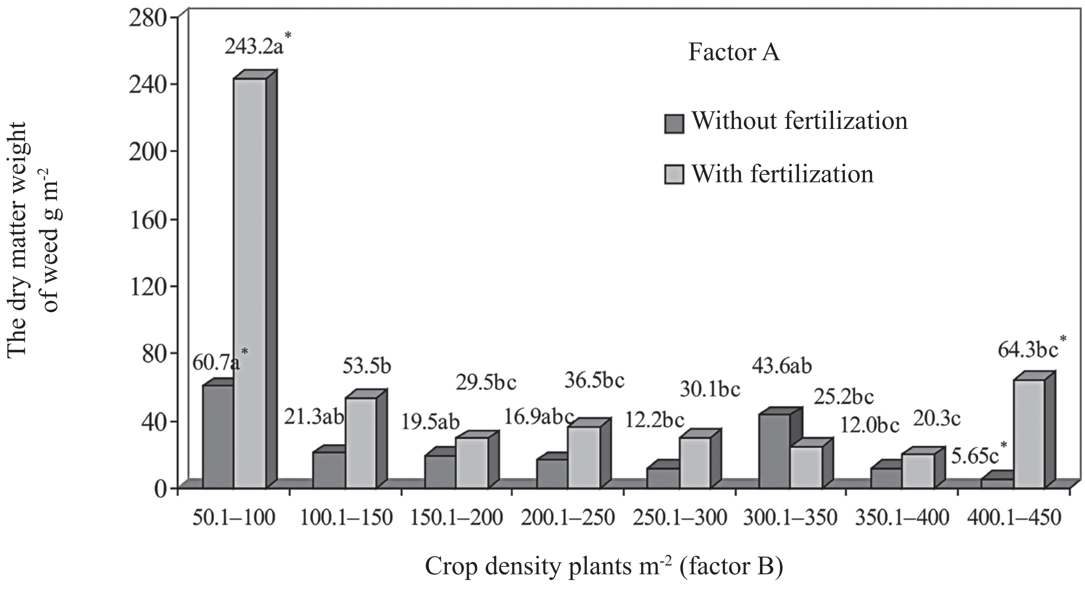
In 2008 and 2009, fertilization and rape crop density had no significant effect on the PAR reaching the ¾ height of the crop stand.

In both experimental years, from 16 to 20 weed species were found in spring rape plots: from 11 to 15 annual and 5 perennial. These species belong to 14 families: *Asteraceae*, *Boraginaceae*, *Brassicaceae*, *Caryophyllaceae*, *Chenopodiaceae*, *Equisetaceae*, *Euphorbiaceae*, *Fabaceae*, *Plantaginaceae*, *Poaceae*, *Polygonaceae*, *Rubiaceae*, *Scrophulariaceae* and *Violaceae*. There were found more annual than perennial weeds. Common lambsquater (*Chenopodium album* L.) was the most abundant one. Results from Nikonova (Никонова, 2009) showed that therophytes (54.54%) and cryptophytes (31.82%) dominated in the spring oilseed rape crop.

Based on the obtained data, in both experimental years it is evident that the highest dry matter weight of weeds was in the thinnest spring rape crop (50.1–100 plants m^{-2}). In 2008 in spring rape without fertilization a trend of decreasing dry matter weight of weeds at the increasing crop density up to 350 plants m^{-2} was established (Figure 1). At the crop density of 350.1–450 plants m^{-2} the dry matter weight of weeds was significantly lower by 80.2–90.7% than that at the lowest plant density. In 2009, with the increasing number of plants to 250 per m^{-2}, the dry matter weight of weeds decreased but not significant differences were established (Figure 2). At a rape crop density of 250.1–450 plants m^{-2}, in comparison with the thinnest crop, a significant decrease of dry matter weight of weeds from 68.1 to 80.5% was observed.

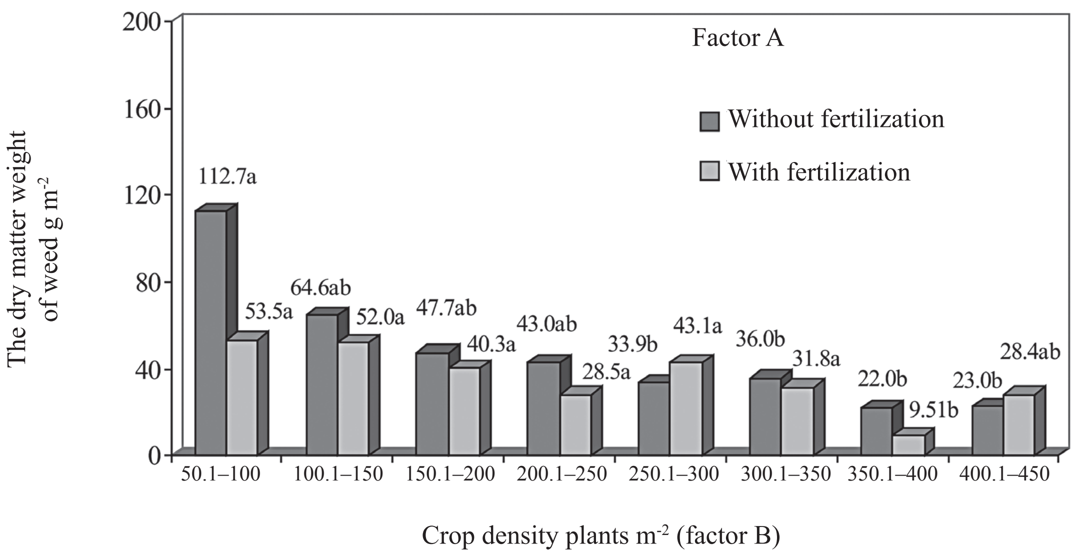
In 2008 in spring rape with fertilization with the increasing crop density the dry matter mass of weeds significantly decreased from 3.8 to 12.0 times. In 2009, rape crop density had no significant effect on dry matter mass of weeds.

Correlation and regression data analysis shows the existence of significant relationships between dry matter weight of weeds and rape crop density: in spring rape without fertilization in 2009 – $r = -0.89$, $y = 104.11 - 0.35x$, $P < 0.01$, in spring rape with fertilization in 2008 – $r = -0.75$, $y = 193.81 - 0.86x$, $P < 0.05$ and in 2009 – $r = -0.80$, $y = 60.06 - 0.13x$, $P < 0.05$.



Note. Explanation under Table 1.

Figure 1. The dry matter weight of weeds as affected by different fertilization and crop density of spring rape, 2008



Note. Explanation under Table 1.

Figure 2. The dry matter weight of weeds as affected by different fertilization and crop density of spring rape, 2009

In 2008, intensive fertilization of rape crop, in comparison with that without fertilization, significantly increased from 4.0 to 11.3 times the dry matter weight of weeds in the thinnest and thickest spring rape crop. In 2009, intensive fertilization had no significant effect on dry matter mass of weeds. The results of Čiuberkis and Končius (2006) show that different nutrient content in the soil did not have any significant effect on spring rape weed infestation. Andersson and Milberg (1996) established that nitrogen fertilization had no significant effect on the total weed biomass in the rape crop. According to Kosorichin (Косорихин, 2009) intensive fertilization increased the emergence and biomass of weed sprouts at the early growing stages of spring oilseed rape. Till rape harvesting the abundance of weeds decreased from 4.7 to 45.8%.

Dry matter weight of weeds depended on PAR conditions. In the spring rape crop without fertilization dry matter weight of weeds was influenced by the PAR reaching the soil surface (in 2008 – $r = 0.78$, $y = 10.89 + 1.57x$, $P < 0.05$) and ¼ height of the crop stand (in 2008 – $r = 0.85$, $y = -58.86 + 1.29x$, $P < 0.01$ and in 2009 – $r = 0.96$, $y = -84.40 + 2.95x$, $P < 0.01$). In the spring rape crop with fertilization the dry matter mass of weeds depended on the PAR reaching the ¼ and ½ height of the crop stand in 2009 (accordingly $r = 0.72$, $y = 26.20 + 0.90x$, $P < 0.05$ and $r = 0.78$, $y = -10.20 + 1.02x$, $P < 0.05$).

Conclusions

1. With the increasing spring rape crop density the PAR reaching the soil surface, ¼ and ½ height of the crop stand decreased in the crops without and with fertilization.

2. Intensive fertilization of rape crop, in comparison with that without fertilization, significantly reduced the PAR reaching the soil surface, ¼ height of the crop stand and ½ height of the crop stand in 2008.

3. In the spring rape crop without fertilization dry matter weight of weeds was influenced by crop density and PAR reaching the soil surface and ¼ height of the crop stand, whereas in the spring rape crop with fertilization it depended on crop density, PAR reaching the soil surface, at ¼ and ½ height of the crop stand.

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Pasėlio tankumo ir tręšimo poveikis piktžolių stelbimui vasarinio rapso pasėliuose

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Santrauka

Tyrimai atlikti 2008–2009 m. Lietuvos žemės ūkio universiteto bandymų stotyje, karbonatingame giliau glėjiškame išplautžemyje (IDg4-k), *Calc(ar)i-Epihypogleyic Luvisol* (*LVg-n-w-cc*). Tyrimų tikslas – nustatyti pasėlio tankumo ir tręšimo įtaką fotosintetiškai aktyvios spinduliuotės prasiskverbimui ir piktžolių stelbimo gebai vasarinio rapso (*Brassica napus* L.) veislės ʽSponsor’ pasėliuose. Bandymo variantai: A veiksnys – tręšimas: 1) netręšta, 2) tręšta prieš rapsų sėją $N_{68}P_{68}K_{68}$ ir butonizacijos tarpsniu N_{70}; B veiksnys – pasėlio tankumas: 1) 2 kg ha^{-1} (50,1–100 augalų m^{-2}), 2) 4 kg ha^{-1} (100,1–150 augalų m^{-2}), 3) 6 kg ha^{-1} (150,1–200 augalų m^{-2}), 4) 8 kg ha^{-1} (200,1–250 augalų m^{-2}), 5) 10 kg ha^{-1} (250,1–300 augalų m^{-2}), 6) 12 kg ha^{-1} (300,1–350 augalų m^{-2}), 7) 14 kg ha^{-1} (350,1–400 augalų m^{-2}), 8) 16 kg ha^{-1} (400,1–450 augalų m^{-2}).

Tankėjant rapsų pasėliui, ir netręštuose, ir tręštuose rapsuose fotosintetiškai aktyvios spinduliuotės, pasiekiančios dirvos paviršių ir ¼ bei ½ pasėlio aukščio, kiekis mažėjo. Palyginti su visai netręštu pasėliu, intensyvus tręšimas iš esmės sumažino fotosintetiškai aktyvios spinduliuotės, pasiekiančios dirvos paviršių ir ¼ pasėlio aukščio, o 2008 m. – ir ½ pasėlio aukščio, kiekį. Piktžolių sausųjų medžiagų masei netręštame pasėlyje turėjo įtakos rapsų tankumas ir fotosintetiškai aktyvios spinduliuotės, pasiekiančios dirvos paviršių ir ¼ pasėlio aukščio, o tręštame – rapsų tankumas ir fotosintetiškai aktyvios spinduliuotės, pasiekiančios ¼ bei ½ pasėlio aukščio, kiekis.

Reikšminiai žodžiai: vasariniai rapsai, pasėlio tankumas, tręšimas, fotosintetiškai aktyvi spinduliuotė, piktžolės.