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Research Article

THE EFFECT OF DIFFERENT TYPES OF STRAW MULCHES ON WEED-CONTROL IN VEGETABLES CULTIVATION

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ABSTRACT

The experiment was carried out in 2010–2012. The effect of different kinds of straw and its dose applied to soil mulching on the amount and fresh mass of weeds and yield level of broccoli and tomato was investigated. The type of straw mulch applied to the soil mulching influenced number and fresh mass of weeds. This effect could be the result of the properties of the mulch (colour, structure, etc.) or the allelopathic effect on the germination and growth of individual weed species. The most efficient for limiting infestation was mulch from buckwheat and rye straw. Soil mulching, regardless of its kind, causes a decrease in the number and mass of weeds at the beginning of growing period of vegetables. The application of straw at a dose of 20 $t \cdot ha^{-1}$ had higher weed-suppressing effect than at a dose of 10 $t \cdot ha^{-1}$. When assessing the infestation before harvest the influence of straw mulch was lower but still significant. The application in higher dose of rye and buckwheat straw in broccoli, corn and rape in tomato cultivation reduced a number of weeds compared to dose of 10 $t \cdot ha^{-1}$. The better yielding effect in both vegetable species had soil mulching with straw at a dose of 10 $t \cdot ha^{-1}$.

Keywords: straw mulch, infestation, yield, broccoli, tomato.

INTRODUCTION

Soil coverage with organic mulches is one of the natural methods of preventing weed infestation. It can be achieved by using plant mulches and mulches from straw left after cereal grain harvest [Liebman and Davis 2000, Bàrberi 2002]. A number of studies have documented that straw mulch is a good means of decreasing weed emergence and growth, reduce erosion and increase the biological activity of soil [Teasdale and Mohler 2000, Grassbaugh et al. 2004, Ramakrishna et al. 2006]. This allows farmers to reduce an application of herbicides and tillage operations which disturb soil structure [Abdul-Baki et al. 1996]. According to Jodaugienė et al. [2006], a positive effect of mulch is particularly visible in the period of intensive weed germination. In the study by Zagaroza [2003], how efficient the mulch was depended on the thickness of mulch layer on the soil surface. However, in the study by Döring et al. [2005] moderate amounts of straw (1.25, 2.5 and 5 $t \cdot ha^{-1}$) neither reduced nor enhanced the amount of weed significantly. Yordanova and Shaban [2007] claim that, organic mulch, irrespective of the mulch layer on the soil surface, did not provide good weed control, especially against the perennial weeds.

The study aimed to determine the effect of soil mulching with different types of straw mulch on the number and fresh mass of weeds and yield level of broccoli and tomato.

MATERIALS AND METHODS

The experiment was carried out in years 2010–2012 at the Experimental Station of Siedlce University of Natural Sciences and Humanities, which is located in central-eastern Poland (52º03'N, 22º33'E). According to the international system of FAO classification, the soil was classified as a Luvisol (LV) [WRB FAO 1998]. The soil organic matter content averaged 1.5% and

its humus horizon reached a depth of 30–40 cm, the value of pH determined in H_2O was 5.4. The total contents of macroelements in mg·dm^{-3} air dried matter amounted to 34 for phosphorus, 83 for potassium, 36 for magnesium, 14 for N-NO_3, 7 for N-NH_4 7 and 260 for calcium. The content of plant-available nutrients was lower than that specified by Sady [2000].

The experiment was established in a split-block design with three replicates. The effect of the kind of straw (rye, corn, rape, buckwheat) and its dose (10 and 20 t·ha^{-1}) applied as a mulch on the number and fresh mass of weeds and yield level in 'Milady F_1' broccoli and 'Polfast F_1' tomato was investigated. The effect of straw was compared to non-mulched control.

The forecrop for the vegetables was triticale. In the autumn preceding broccoli and tomato cultivation, ploughing was performed. At the same time, farmyard manure was incorporated at a rate of 30 t·ha^{-1}. In the spring, two weeks before the seedlings were planted, disc harrowing was applied to loosen the upper soil layer and prepare it for planting. After that, mineral fertilisers were applied in the amount of supplementary content to the optimal level for broccoli: 110 kg N, 98 kg P_2O_5, 220 kg K_2O per 1 ha and for tomato: 85 kg N, 104 P_2O_5, 234 K_2O per 1 ha. Mineral fertilisers were applied in a form of ammonium nitrate, triple superphosphate and 60% potassium salt.

Directly before the seedlings were planted, a particular type of organic mulch in appropriate dose was applied. Mulch with rye, rape, and buckwheat straw was in rather long (30-40 cm) pieces. These pieces were crumbled up, so it would be easy to spread them on the field. However, mulch with corn straw was chopped up into short pieces (20-30 cm). The thickness of the mulch layer depended on the type of mulch. In the case of rye and rape straw, application at a dose of 10 t·ha^{-1} mulch thickness amounted to 7-8 cm on average; in the case of corn straw, the mulch layer amounted to about 5 cm; however, for buckwheat straw the average was 8-10 cm. At a dose of 20 t·ha^{-1} the mulch layer was two times higher.

Broccoli seedlings were grown in a non-heated greenhouse. Seeds (10 g) were sown in successive study years on the 19th, 18th and 20th of March in multi-trays. The seedlings were produced using peat substrate. Prior to planting, seedlings were moved outdoors. The plants were planted on the 19th, 18th and 23rd of April, at a spacing of 50×50 cm.

Tomato seedlings were grown in a heated greenhouse. The seeds were sown at the a rate of 10 g to seedling containers with peat substrate on 18th of March in 2010 and 2011 and 28th of March in 2012. After cotyledon formed and at the beginning of first leaf emergence, the seedlings were bedded into pots with a diameter of 8–10 cm (1st April in 2010 and 2011 and 11th April in 2012). Prior to transplanting the seedlings were hardened off and then moved permanently outdoors. The plants were planted in the successive study years on 20th, 16th and 14th May, at a spacing of 60×40 cm.

The effect of the examined factors on weed infestation was estimated twice each year. The primary infestation was performed in the initial period of vegetable growth, which meant the third 10 days of May in broccoli cultivation, and the second 10 days of June in tomato cultivation. After that, manual weeding was performed. The secondary infestation in broccoli cultivation was performed before harvesting, which meant the third 10 days of June, and in tomato cultivation at the beginning of the fruit harvest, which meant the third 10 days of July. Weed infestation was determined by the quantitative-weighing method. This method entailed determining the number of individual weeds species and their fresh mass in each plot. Samples were taken from the area of 0.5 m square in two randomly selected places in each plot. The weight of the weeds was expressed per 1 m^2. The dominant species among the annuals were *Chenopodium album* L., *Echinochloa crus-galli* (L.) P. Beauv., *Viola arvensis* L., however, among the perennials, the most common weed was *Elymus repens* (L.) Gould.

Broccoli was harvested by hand on 30 June in 2010, and 28 June in 2011 and 2012. Tomato fruit harvesting was performed several times as the fruit ripened. The beginning of harvest occurred in the last 10- days of July and ended in the first 10- days of September. During the harvest the marketable yield of broccoli and tomato was determined.

The results were statistically analysed by means of the analysis of variance (ANOVA) following a mathematical model for the split-block design. Significance of differences were determined by the Tukey test at the significance level of $p = 0.05$.

Weather conditions in the years of the study are presented in Figure 1. A big difference was observed in rainfall distribution between succes-

sive growing seasons. The more favourable for broccoli cultivation was the wet year 2010. However, in this year was also observed higher crop infestation compared to remaining years of the study. In turn, more favourble weather conditions for tomato cultivation was in moderate moisture 2011 and 2012. In that years were also noted fewer crop infestation.

RESULTS AND DISCUSSION

In the first date of estimation higher number of weeds, both in broccoli and tomato, was found in wet 2010, 215.2 and 90.7 no·m^{-2}, respectively (Figure 1–3). In 2010 and 2012 soil mulching with straw in broccoli cultivation, regardless of dose, contributed to significant decrease number of weeds compared to non-mulched control. In 2011 a significantly lowest number of weeds characterized plots mulched with straw at a dose of 20 t·ha^{-1}, more weeds were observed in the plots with straw at a dose of 10 t·ha^{-1} and significantly the most in control plot (Figure 2). In tomato cultivation similar dependence was found in years 2011 and 2012. In 2010 soil mulching with straw at a dose of 20 t·ha^{-1} caused significant decrease in the number of weeds compared to non-mulched control and plots with a straw dose of 10 t·ha^{-1} (Figure 3). According to Döring et al. [2005] the reason why weed growth on the straw mulch was comparatively small application rates. This is confirmed in the study by Bushnell and Welton [1931], where they noted that annual weeds penetrated the straw when less than 8 ton per acre (19.75 t·ha^{-1}) were used. Similarly, Hembry and

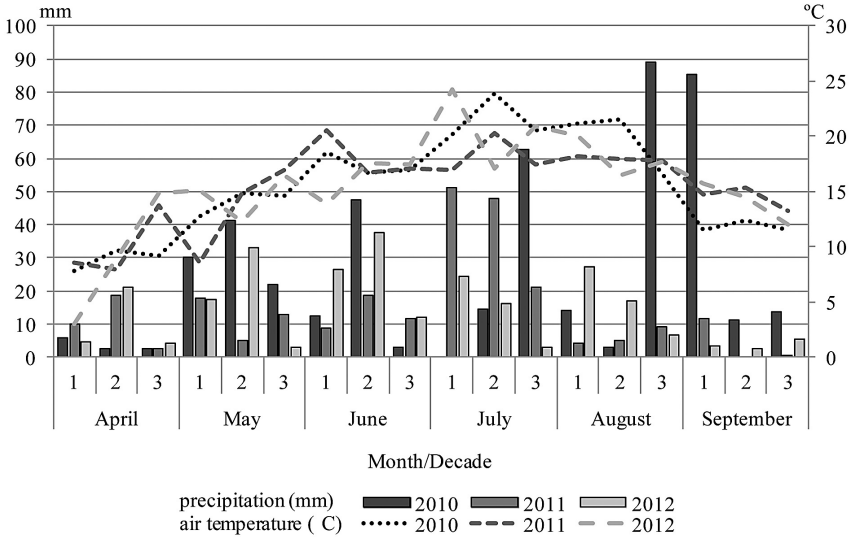
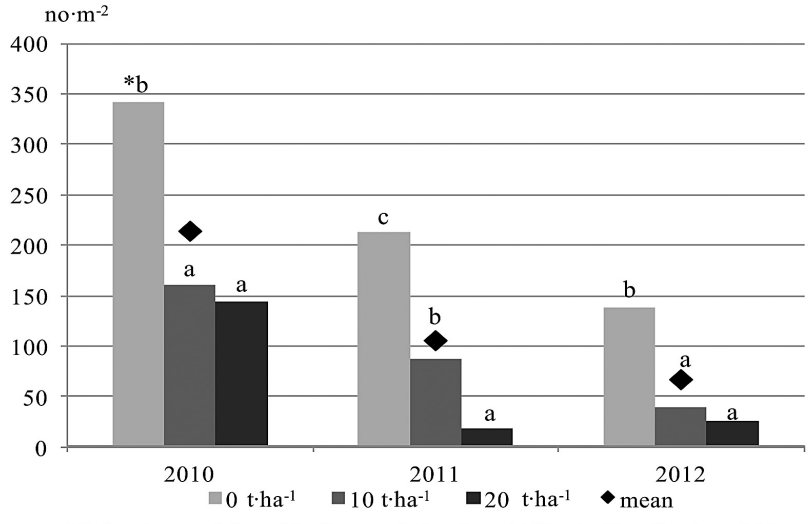


Figure 1. Weather conditions in the vegetation period of vegetables



* Values in rows followed by the same letters do not differ significantly at p = 0.05

Figure 2. Number of weed in the initial period of broccoli growth depending on the dose of straw

Davies [1994] found that weed growth still occurred at 20 t·ha^{-1} of straw mulch, although there were fewer weeds. In turn, in the study by Yordanova and Shaban [2007] the weed on mulching plots were growing where the straw was not spread closely to the stalk of the plants, nor was it thick enough because of the wind.

A significant influence of the interaction between the kind and dose of straw on the number of weeds in both vegetables species in early period of growth was found (Table 1). All straws, irrespective of dose, reduced infestation in broccoli. It was also found fewer weeds in objects with straw at a dose of 20 t·ha^{-1} compared to 10 t·ha^{-1}, however only in the case of corn and buckwheat straw differences were statistically confirmed. In tomato cultivation mulch decreased the number of weeds compared to the control. All straws applied at a dose of 20 t·ha^{-1} decreased the number of weeds compared to a dose of 10 t·ha^{-1}. The weed-suppressing effect of mulch can also result from a limited amount of light reaching the soil surface and as a result reducing the germination and growth of weeds [Mohler and Teasdale 1993]. According to Creamer et al. [1996] infestation is also limited by the allopathic effect of chemical compounds contained in the tissue of plant mulches. In the study by Jodaugienė et al. [2006] the mulch that limited weed germination the most at the beginning of summer (3.5–14.1 times) was straw. The authors pointed that straw should not to contain weed or crop seeds, which could cause secondary infestation. In a study by Mohtisham et al. [2013], straw mulch reduced the number of germinating weeds by half, compared to the non-mulched control. Similarly, in a study by Radics and Bognar [2004], mulching with straw and grass significantly limited weed germination, compared

Table 1. Number of weeds [no·m^{-2}] in the initial period of growth (mean for years 2010–2012)

Dose of straw t·ha^{-1}	Kind of straw				Mean
	rye	corn	rape	buckwheat	
Broccoli					
No straw	233.6	217.8	231.7	241.7	231.2
10	69.3	133.3	124.4	56.9	96.0
20	39.1	87.1	101.3	23.1	62.7
Mean	114.0	146.1	152.5	107.2	130.0
$LSD_{0.05}$ for: kind of straw – n.s.; dose of straw – 31.1; interaction kind of straw × dose of straw – 32.8					
Tomato					
No straw	129.4	140.3	134.6	139.9	136.1
10	60.4	87.1	104.0	110.2	90.4
20	27.6	55.1	28.4	17.8	32.2
Mean	72.5	94.2	89.0	89.3	86.2
$LSD_{0.05}$ for: kind of straw – n.s.; dose of straw – 15.6; interaction kind of straw × dose of straw – 25.3					

Table 2. Fresh mass of weeds [g·m^{-2}] in the initial period of growth (mean for years 2010–2012)

Dose of straw t·ha^{-1}	Kind of straw				Mean
	rye	corn	rape	buckwheat	
Broccoli					
No straw	219.4	226.0	239.8	219.3	226.1
10	53.3	87.0	136.2	32.9	77.4
20	17.8	52.2	83.6	35.6	47.3
Mean	96.9	121.7	153.2	95.9	116.9
$LSD_{0.05}$ for : kind of straw – n.s.; dose of straw – 10.3; interaction kind of straw × dose of straw – n.s.					
Tomato					
No straw	595.6	556.9	602.6	684.0	609.8
10	96.9	460.1	380.4	151.7	272.3
20	95.1	197.3	152.9	24.9	117.6
Mean	262.5	404.8	378.6	286.9	333.2
$LSD_{0.05}$ for: kind of straw – 137.8; dose of straw – 129.8; interaction kind of straw × dose of straw – 121.8					

to the plots without mulch. Mulching decreased the number of weeds in a study by Sinkevičienė et al. [2009]. According to the authors among few organic mulches applied to soil mulching, straw mulch was the best for weed control. In plots with straw mulch weed density was established at 2.8–6.4 times lower compared with weed density in plots without mulch.

The effect of the dose of straw on the mass of weeds depended on weather conditions in years of the study (Figure 1, 4 and 5). Soil mulching in the cultivation both species in 2010 decreased mass of weeds compared to a control plot. In 2011 significantly lowest mass of weeds was noted in plots mulched with straw at a dose of 20 $t \cdot ha^{-1}$, higher in plots with dose of 10 $t \cdot ha^{-1}$ and the highest in the control object. In 2012 soil mulching with straw at a dose of 20 $t \cdot ha^{-1}$ decreased the mass of weeds in tomato cultivation compared to a control plot.

A significant influence of the dose of straw on the mass of weeds in the initial period of broccoli growth was found (Table 2). Soil mulching reduced the mass of weeds compared to a control plot. It was also smaller mass of weeds that was found in the plots with straw at a dose of 20 $t \cdot ha^{-1}$ than 10 $t \cdot ha^{-1}$.

The interaction between the kind and dose of straw on the fresh mass of weeds in tomato cultivation was found (Table 2). The highest mass had the weeds from the control plot. Soil mulching with corn, rape and buckwheat straw at a dose of 20 $t \cdot ha^{-1}$ significantly decreased the mass of weeds compared to plots with straw at a dose of 10 $t \cdot ha^{-1}$. Ahmed et al. [2007] observed that mulch with wheat straw contributed to a significant decrease in the mass of weeds compared to the control. The application of mulch at a dose of 4 $t \cdot ha^{-1}$ produced a minimum total weed biomass, however, maximum biomass was

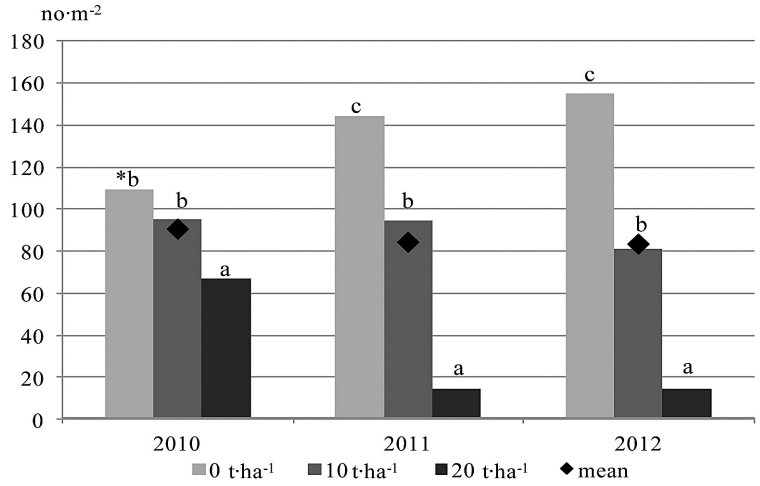


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Figure 3. Number of weed in the initial period of tomato growth depending on the dose of straw

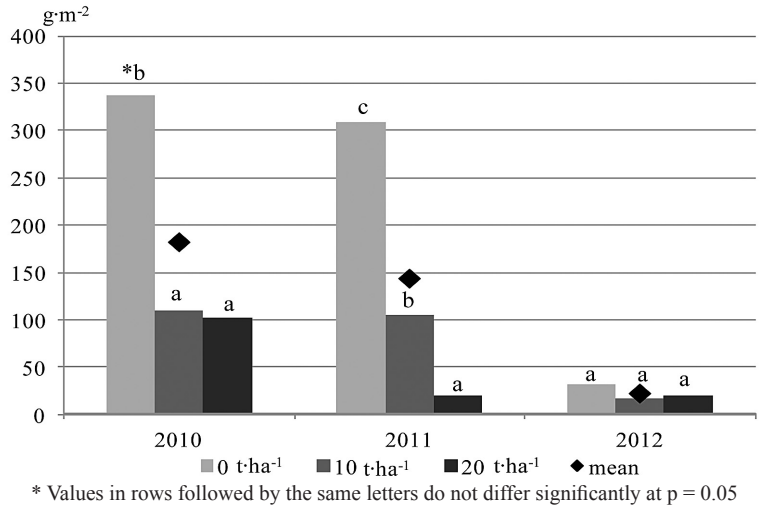

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Figure 4. Fresh mass of weed in the initial period of broccoli growth depending on the dose of straw

noted in control, which was followed by 3, 2 and 1 t·ha^{-1} mulch application, respectively. A trend showing a gradual decrease in weed biomass (3-17%) when there was an increase in the mulch rate. This is confirmed in the study by Uwah and Iwo [2011], in which there was a decrease in the mass of weed when there was an increase in the grass dose applied to mulching. According to authors, the weed dry matter yield obtained in the control was over eleven times higher than the 8 t·ha^{-1} mulch rate and more than six times above the 6 t·ha^{-1} mulch rate. In the study by Din et al. [2013], soil mulching with wheat straw in corn cultivation contributed to decreased mass of weeds, on average, by 27.1%, compared to the plot without straw.

The study results indicated an influence of the interaction between the kind and dose of straw on the number of weeds before vegetables harvest (Table 3). Soil mulching with rye and buckwheat straw at a dose of 20 t·ha^{-1} decreased the number of weeds in broccoli cultivation compared to the dose of 10 t·ha^{-1} and the control plot. All straws decreased the number of weeds in tomato. However, significant differences between the doses of straw (10 and 20 t·ha^{-1}) were noted for mulch with corn and rape straw. According to Jodaugienė et al. [2006] in the second part of summer and in early autumn, weed emergence is weaker in comparison with that in spring and early summer, therefore, mulch has smaller influence. The number of weeds that germinated in the beginning of summer in mulched soil was by 30.9–50.6 times lower than in the soil without mulch. Later this positive influence weakened, but remained for the entire growing period.

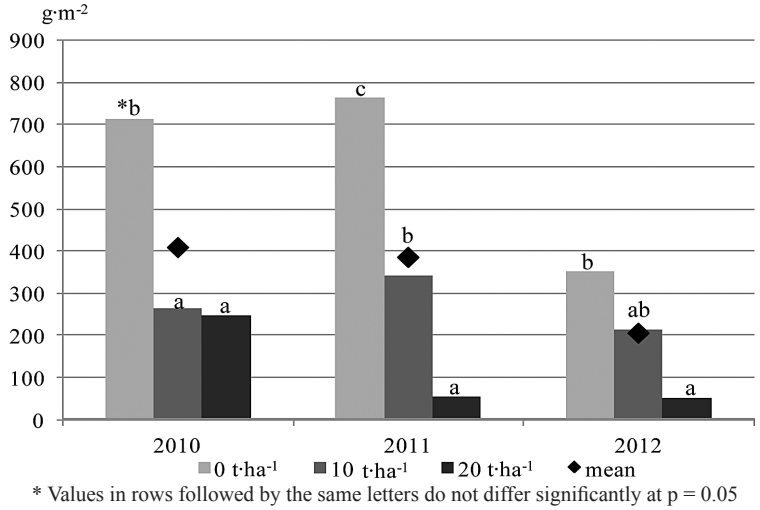

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Figure 5. Fresh mass of weed in the initial period of tomato growth depending on the dose of straw

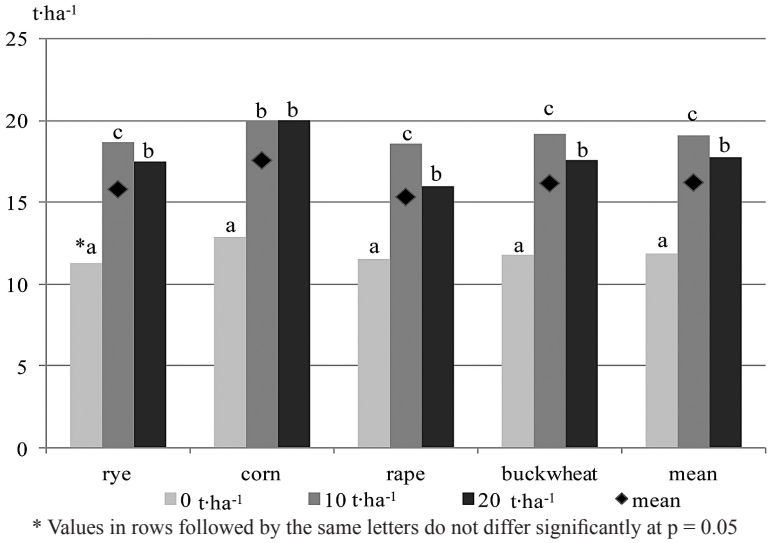

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Figure 6. Marketable yield of broccoli depending on the kind and dose of straw (mean for years 2010–2012)

Table 3. Number of weeds [no·m^{-2}] before harvest (mean for years 2010–2012)

Dose of straw t·ha^{-1}	Kind of straw				Mean
	rye	corn	rape	buckwheat	
Broccoli					
No straw	92.3	106.2	102.6	96.9	99.5
10	93.3	94.2	92.4	78.2	89.6
20	69.3	74.7	100.4	56.9	75.3
Mean	85.0	91.7	98.5	77.3	88.1
$LSD_{0.05}$ for: kind of straw – n.s.; dose of straw – n.s.; interaction kind of straw × dose of straw – 20.3					
Tomato					
No straw	134.7	127.9	120.0	143.7	131.6
10	73.8	88.0	110.2	76.4	87.1
20	60.4	60.4	72.9	63.1	64.2
Mean	89.6	92.1	101.0	94.4	94.3
$LSD_{0.05}$ for: kind of straw – n.s.; dose of straw – 28.2; interaction kind of straw × dose of straw – 15.9					

Table 4. Fresh mass of weeds [g·m^{-2}] before harvest (mean for years 2010–2012)

Dose of straw t·ha^{-1}	Kind of straw				Mean
	rye	corn	rape	buckwheat	
Broccoli					
No straw	1240.2	1187.2	1129.4	1123.9	1170.2
10	976.0	1091.6	835.8	714.7	904.5
20	652.4	1187.6	965.3	668.4	868.4
Mean	956.2	1155.4	976.9	835.7	981.0
$LSD_{0.05}$ for: kind of straw – n.s.; dose of straw – n.s.; interaction kind of straw × dose of straw – 252.0					
Tomato					
No straw	1542.1	1595.4	1465.7	1613.4	1554.2
10	782.3	935.7	1149.4	675.6	885.8
20	741.3	926.2	725.3	707.6	775.1
Mean	1021.9	1152.4	1113.5	998.9	1071.7
$LSD_{0.05}$ for: kind of straw – n.s.; dose of straw – 625.1; interaction kind of straw × dose of straw – 234.3					

The weeds from plots mulched with rye, rape and buckwheat straw before broccoli harvest were characterised by lower mass than in control plot (Table 4). Soil mulching, regardless of kind of straw decreased the mass of weeds compared to a control plot before tomato harvest. Application of rye straw at a dose of 20 t·ha^{-1} in broccoli and rape in tomato significantly decreased the mass of weeds compared to a dose of 10 t·ha^{-1}.

The influence of kind and dose of straw on the broccoli yield was statistically confirmed (Figure 6). The application of straw at a dose of 10 t·ha^{-1} had a more favourable effect on the broccoli yield. The increased of yield amounted to 7.3% compared to straw at a dose of 20 t·ha^{-1} and 60.5% compared to control object. Soil mulching with rye and buckwheat straw at a dose of 10 t·ha^{-1} also increased yield of tomato, but the differences were not statistically confirmed (Figure 7). Parmar et al. [2013] found that soil mulching with wheat straw and dry leaves mulch contributed to increase melon yield compared to the control plot without mulch. However, the authors did not find a difference in yield level between organic mulches. In the study by Wicks et al. [1994] with increasing straw dose applied to soil mulching, there was increased weight and number of corn cobs per plant. However, the highest yield of grain was obtained at a straw dose of 5.1 t·ha^{-1} compared to the control and mulching with straw at a dose of 1.7; 3.4 and 6.8 t·ha^{-1}. Similarly, the study by Uwah and Iwo [2011] showed that increasing mulch dose from 2 to 8 t·ha^{-1} increased the yield of corn grain, but an increase of yield between mulch dose of 6 and 8 t·ha^{-1} amounted to only 3.1%.

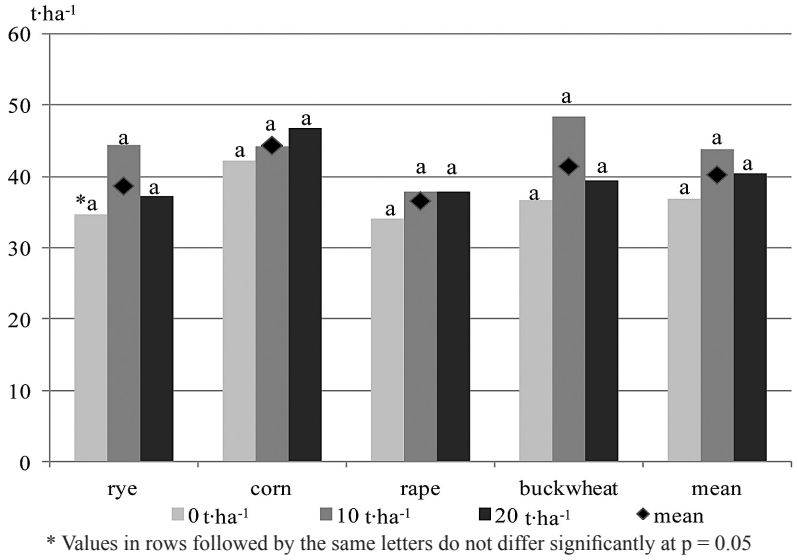

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Figure 7. Marketable yield of tomato depending on the kind and dose of straw (mean for years 2010–2012)

CONCLUSIONS

1. Weather conditions in years of the study in higher degree influenced the number and fresh mass of weeds. The most weeds were observed in 2010, which characterized higher rainfall compared to remaining years.
2. Soil mulching in both estimation dates (in the initial period of growth and before vegetables harvest) significantly limited crop infestation. Soil mulching with rye and buckwheat straw had the largest effect on the reduction of weeds.
3. The application of straw at a dose of 20 t·ha^{-1} had higher weed-suppressing effect than at a dose of 10 t·ha^{-1}.
4. A higher yielding effect on the cultivation of both species had mulching with straw at a dose of 10 t·ha^{-1}.

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