The yield and quality of broccoli grown under flat covers with soil mulching

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ABSTRACT

The experiment was carried out between 2010 and 2012. Effect of plants covering and the kind of organic mulch applied to soil mulching on the yield and selected component of nutritive value in Milady F_1 broccoli cultivated for early harvest was investigated. The application of polypropylene fibre contributed to a significant increase in the marketable yield of broccoli on average by 5.25 t/ha, weight of head by 0.10 kg and length of arc by 1.44 cm. Increase of the content of chemical components as a result of plants covering amounted to 1.76% for dry matter, 2.50 mg/100 g fresh matter (FM) for ascorbic acid, 0.65% FM for total sugar and 0.15% FM for monosaccharides. All kinds of straw contributed to an increase in the broccoli yield and improvement its parameters. The highest marketable yield and weight of head was obtained in the plots mulched with buckwheat straw. Irrespective of covering, cultivation on the mulch with buckwheat straw contributed to a slight decrease in dry matter, total sugars content, whereas cultivation on the rye straw decreased ascorbic acid content.

Keywords: polypropylene fibre; organic mulch; *Brassica oleracea* L. var. *italica* Plenck; *Lycopersicon esculentum* Mill.; chemical composition; vegetable

The main role of organic mulches in vegetable crops cultivation is to protect the soil surface from the influence of unfavorable factors and to improve the growing conditions for the crop plants (Derek et al. 2006, Olfati et al. 2008). They reduce soil wind and water erosion (Feldman et al. 2000), conserve soil moisture (Sinkevičienė et al. 2009) and help maintain stable soil temperature (Kar and Kumar 2007). Mulch increases soil porosity and suppresses weed growth (Uwah and Iwo 2011). Björkman and Pearson (1998) and Tan et al. (2000) claim that plant's growth conditions are the main determinant of the quality of their yield.

The application of plastic covers can have a significant influence on the vegetables yield. Covers are used to modify plants environment in order to optimize plants growth, increase yields and improve their quality. The profitable conditions under the covers resulted in higher yield for sweet pepper (Ibarra-Jimenez and Rosa-Ibarra 2004), Chinese cabbage (Moreno et al. 2002), early potato (Hamouz et al. 2007). According to Gordon et al. (2010) an increase in soil temperature and moisture under covers will not always cause an increase in the yield of plants.

The study aimed to determine the effect of plant covering with polypropylene fibre and soil mulching with organic mulch on the yield and quality of broccoli cultivated for early harvest.

MATERIAL AND METHODS

Experimental site. The experiment was carried out between 2010–2012 at the Experimental Station of the Siedlce University of Natural Sciences and Humanities, which is located in central-eastern Poland (52°03'N, 22°33'E). According to the international system of FAO classification, the soil was classified as Luvisol (WRB FAO 1998). The total contents of macroelements in mg/L air dried matter amounted to 34 for phosphorus,

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83 for potassium, 36 for magnesium, 14 for NO_3-N, 7 for NH_4-N and 260 for calcium.

Experimental design. The experiment was established as a split-block design with three replicates. Effect of plants covering (without cover, under polypropylene fibre) and the kind of straw applied to soil mulching (rye, corn, rape, buckwheat) was investigated. The effect of straw mulch was compared to a control plot without mulch. The influence of examined factors on the yield and selected component of nutritive value in Milady F_1 broccoli was investigated.

Field work. The forecrop for broccoli was triticale. In the autumn preceding broccoli cultivation, ploughing was performed and organic manure at a rate of 30 t/ha was incorporated. In the spring, two weeks before seedlings were planted, disc harrowing was applied. After that, mineral fertilizers were applied in the amount of supplementary content to the optimal level for broccoli: 110 kg N, 43 kg P, 183 kg K per 1 ha.

Before the seedlings were planted, a particular type of straw at a dose of 10 t/ha was applied. In the case of rye and rape straw, the thickness of the mulch layer amounted, on average, to 7–8 cm. In the case of corn straw, the mulch layer amounted to about 5 cm, however for buckwheat straw the average was 8–10 cm.

Broccoli seedlings were grown in a non-heated greenhouse. Seeds were sown in the successive study years on the 19th, 18th and 20th of March. Plants were planted on the 19th, 18th and 23rd of April, at a spacing of 50 × 50 cm. After plants where planted suitable combinations were covered with polypropylene fibre Pegas Agro 17UV (Rybnik, Poland). The cover was removed after 4 weeks. After that 50 kg N/ha was applied (top dressing).

Sample collection and laboratory analysis. Broccoli was harvested by hand on 30 June in 2010, and 28 June in 2011 and 2012. During the harvest was determined: marketable yield, weight of marketable head, length of broccoli arc and stalk diameter. From each plot a head sample was taken to perform chemical analyses. The following was determined:

– dry mass – by drying to the constant weight at 105°C;
– L-ascorbic acid – by the Tillmans method (Polish Standard PN-A-04019);
– total sugars and monosaccharides – by the Luff-Schoorl method.

Statistical analysis. The results were statistically analysed by means of the analysis of variance (ANOVA) following the model for the split-block design. The significance of differences was determined by the Tukey's test at the significance level of $\alpha = 0.05$.

Weather and soil conditions. Years 2010 and 2012 were characterized by a similar temperature during the growing period and favorable rainfall distribution for growing and development of broccoli (Figure 1). The least favorable conditions for broccoli growth were in 2011, which was characterized by high mean air temperatures compared with the other study years but insufficient quantity of rainfall.

During the plant's growing period, measurement of the soil temperature was performed at a depth of 10 cm in all objects of experience, at 8^{00} a.m. and 2^{00} p.m. (Figures 2 and 3). Soil temperature

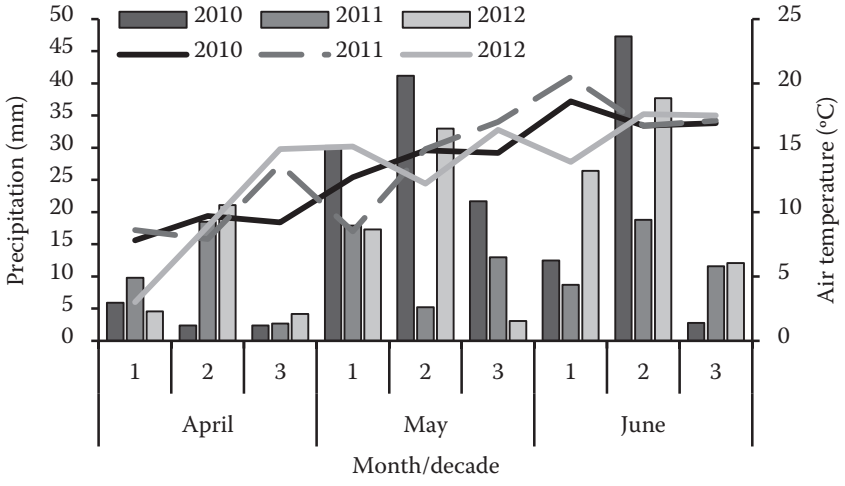

Figure 1. Weather conditions in the vegetation period of broccoli

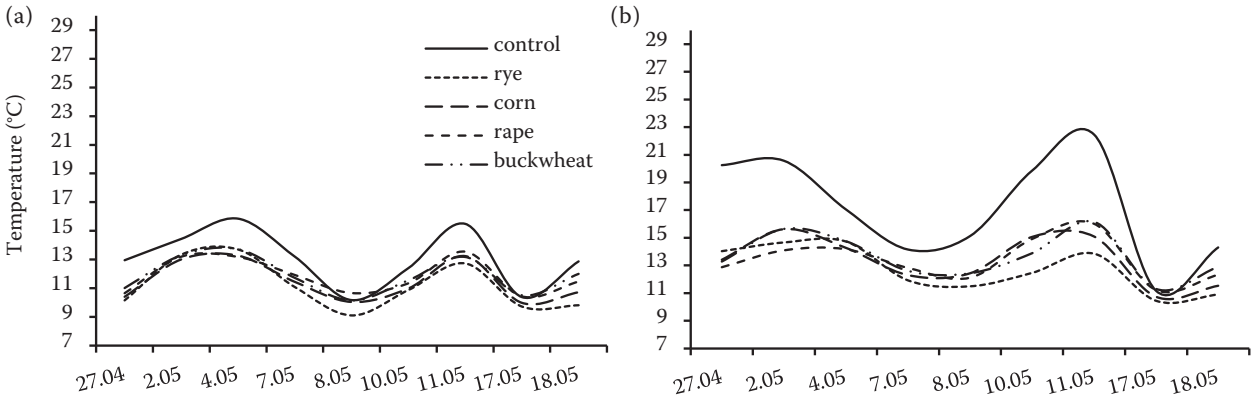

Figure 2. Soil temperature on different kind of straw at (a) 8^{00} a.m. and (b) 2^{00} p.m. in non-covered combination

in the cultivation under polypropylene fibre was higher than in non-covered plot. The increase in soil temperature under cover amounted to 1.2°C in the morning and 1.8°C in the afternoon. The soil temperature in the plots without straw mulch, both at 8^{00} a.m. and 2^{00} p.m. in non-covered plot and under polypropylene fibre was higher than in plots mulched with straw.

RESULTS AND DISCUSSION

The highest yield (23.15 t/ha) and weight of head (0.64 kg) was obtained in 2010, the most favorable for broccoli cultivation (Figures 4 and 5). In 2010 significantly higher yield and weight of head was obtained from the plots mulched with rye, corn and buckwheat straw. The yield and weight of head achieved from objects with buckwheat straw were 1.5 times higher compared to those without straw. In 2012 all kinds of straw contributed to a significant increase in the marketable yield and weight of broccoli head. The yield of broccoli in the plots mulched with buckwheat straw was almost 2.0 times higher and weight of head was above 1.5 times higher. In the study by Awodoyin et al. (2007) mulching increased growth of plants and yield of tomato fruit. According to authors it was possible through modification of the growing environment. In the studies by Samaila et al. (2011a) mulching increased total yield of tomato compared with non-mulched plot. Sinkevičienė et al. (2009) reported that yield of vegetables depended on the kind of mulch application to soil mulching. The authors found that yields of vegetables from plots mulched with grass were the highest, from the objects with straw and peat substrate mulch they were similar – however, sawdust was less useful as mulch.

The study results showed a significant influence of the interaction between the covering and the kind of straw on the yield level and weight of head (Table 1). In the non-covered combination all kinds of straw contributed to a significant increase in the marketable yield and weight of head compared to a control plot. In the covered plots the highest yield and weight of head was obtained from the plots mulched with buckwheat straw. The increase

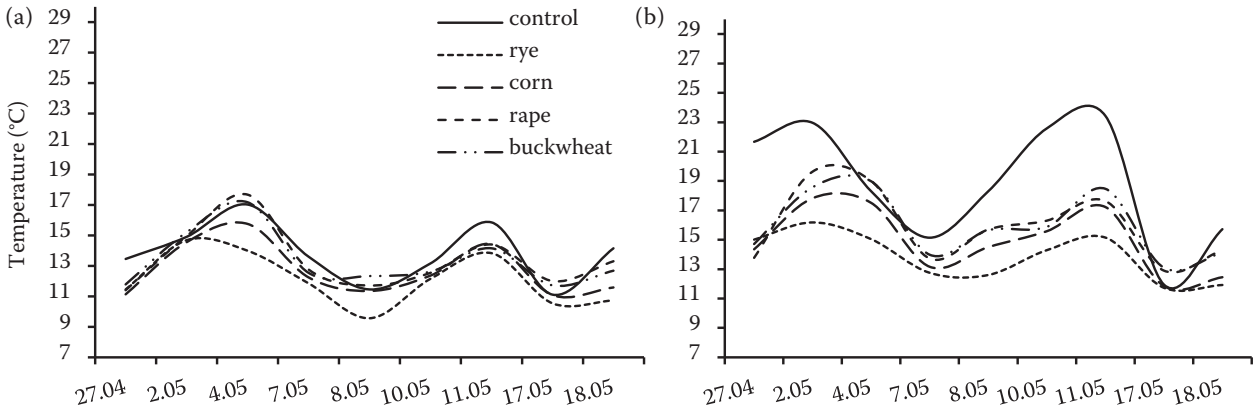

Figure 3. Soil temperature on different kind of straw at (a) 8^{00} a.m. and (b) 2^{00} p.m. in covered combination

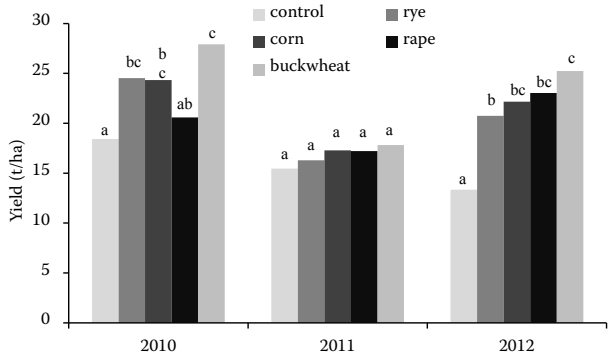

Figure 4. Marketable yield of broccoli depending on the kind of straw in the successive years of study. Values in rows followed by the same letters do not differ significantly at α = 0.05

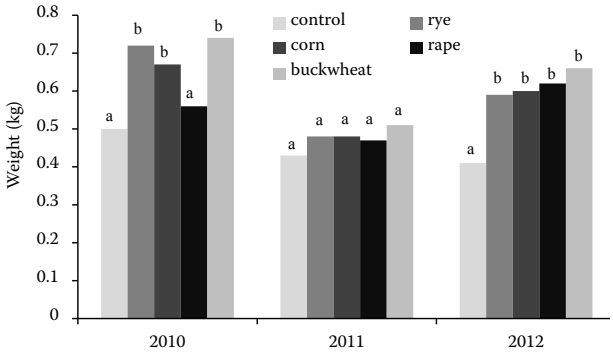

Figure 5. Weight of marketable head depending on the kind of straw in the successive years of study. Values in rows followed by the same letters do not differ significantly at α = 0.05

in the marketable and total yield of Chinese cabbage as a result of plant covering was reported in the study by Moreno et al. (2002). The marketable yield was higher by 486% and total yield by 108%. In the study by Gordon et al. (2008) early marketable yields of squash were lowest from plants grown on bare soil with a row cover followed by bare soil alone. The highest early marketable yield was obtained from combined cultivation of black mulch with a row cover.

A significant influence of the investigated factors on the length of arc and stalk diameter was found (Table 2). In the cultivation without cover the best length of arc was observed at heads from plots mulched with rye straw. However, all kinds of straw contributed to an increase in the stalk diameter compared to non-mulched control. In the cultivation under cover broccoli heads cultivated on the corn and buckwheat straw longer arc had. The heads with higher stalk diameter were obtained from objects mulched with buckwheat straw. Olfati et al. (2008) showed that all organic mulches had a significant influence on the increased length of carrot roots. However, the authors did not find differences in the height of plants or root diameter. The increase of tomato fruits diameter as a result of soil mulching with straw was found by Samaila et al. (2011a). In the study by Gordon et al. (2008) squash plants grown with mulch and row covers were taller and have higher stalk diameter than those grown with plastic mulch alone or on bare soil.

The chemical composition of vegetables is genetically determined as well as it is modified by factors affecting the plant during growth (Lee and Kadar 2000). At conducted research the content of dry matter in broccoli ranged from 7.69% to 10.75% (Table 3). A similar content of this component was found by Grabowska et al. (2009). The content of ascorbic acid amounted to 84.17 mg/100 g fresh matter (FM). In the study by Yildirim et al. (2007), the content of vitamin C ranged from 81 to

Table 1. Marketable yield of broccoli and weight of marketable head (mean for 2010–2012)

Kind of straw	Marketable yield (t/ha)			Weight of head (kg)		
	A	B	mean	A	B	mean
Control	11.88	19.58	15.73	0.37	0.52	0.45
Rye	18.75	22.30	20.53	0.56	0.63	0.59
Corn	19.93	22.59	21.26	0.56	0.61	0.59
Rape	18.59	21.95	20.27	0.53	0.57	0.55
Buckwheat	19.16	28.14	23.65	0.53	0.74	0.64
Mean	17.66	22.91	20.29	0.51	0.61	0.56

$HSD_{0.05}$ for marketable yield: covering – 3.77; kind of straw – 2.54; interaction covering × kind of straw – 3.54; $HSD_{0.05}$ for weight of head: covering – 0.08, kind of straw – 0.06, interaction covering × kind of straw – 0.07.
A – without cover; B – under polypropylene fibre

Table 2. Length of broccoli arc and stalk diameter (mean for 2010–2012)

Kind of straw	Length of arc (cm)			Stalk diameter (cm)		
	A	B	mean	A	B	mean
Control	24.02	24.68	24.35	4.11	3.86	3.98
Rye	26.95	26.42	26.68	4.57	4.12	4.35
Corn	24.43	27.01	25.72	4.67	3.95	4.31
Rape	24.56	26.57	25.56	4.76	3.91	4.34
Buckwheat	24.47	26.97	25.72	4.63	4.51	4.57
Mean	24.89	26.33	25.61	4.55	4.07	4.31

$HSD_{0.05}$ for length of arc: covering – 0.35; kind of straw – 1.54; interaction covering × kind of straw – 0.25; $HSD_{0.05}$ for stalk diameter: covering – 0.28, kind of straw – 0.27, interaction covering × kind of straw – 0.43. A – without cover; B – under polypropylene fibre

115 mg/100 g FM. An average content of total sugars and monosaccharides in broccoli amounted to 3.02% FM and 1.65% FM, respectively. In the study by Grabowska et al. (2009) the content of monosaccharides amounted from 0.54% to 1.53% FM.

A significant influence of the covering and kind of straw on the content of investigated components in broccoli was found (Table 3). In the study by Moreno et al. (2002) an application of polypropylene fibre contributed to increased dry matter content in the Chinese cabbage on average by 18% and ascorbic acids content by 7%, which is confirmed in the present study.

In the cultivation without covering more dry matter was found in heads from plots mulched with rye and corn straw and control plot. In turn, ascorbic acid content decreased at soil mulching with rye straw. The highest content of total sugars was found in heads from the plots mulched with corn straw and monosaccharides with corn, rape and buckwheat straw. Parmar et al. (2013) were found that soil mulching with straw and dry leaves slightly reduced flesh acidity of melon but caused an increased monosaccharides and total sugars contents. In the studies by Samaila et al. (2011b) mulch with straw contributed to increased dry matter, protein and carbohydrate content in tomato.

In the cultivation with polypropylene fibre broccoli from the plots mulched with rye and rape straw and from control plot accumulated more dry matter than cultivated on the corn and buckwheat straw. The higher ascorbic acid content was found in the broccoli from plots mulched with rape straw and non-mulched control. Higher total sugar content was observed in heads from plots mulched with rye than buckwheat straw. In the study by Majkowska-Gadomska (2010) the highest dry matter accumulation was noted in the fruit of melon grown in mulched

Table 3. The content of selected components of nutritive value of broccoli (mean for 2010–2012)

Kind of straw	Dry matter (%)			Ascorbic acid (mg/100 g FM)			Total sugars (% FM)			Monosaccharides (% FM)		
	A	B	mean	A	B	mean	A	B	mean	A	B	mean
Control	8.97	10.53	9.75	83.27	87.33	85.30	2.70	3.39	3.04	1.53	1.70	1.62
Rye	8.69	10.58	9.63	79.30	85.36	82.33	2.65	3.43	3.04	1.54	1.73	1.64
Corn	9.03	9.40	9.22	83.04	83.17	83.11	2.89	3.27	3.08	1.58	1.73	1.66
Rape	7.69	10.75	9.22	83.88	85.99	84.93	2.66	3.39	3.03	1.59	1.72	1.66
Buckwheat	7.81	9.73	8.77	85.11	85.23	85.17	2.57	3.22	2.89	1.61	1.70	1.66
Mean	8.44	10.20	9.32	82.92	85.42	84.17	2.69	3.34	3.02	1.57	1.72	1.65

$HSD_{0.05}$ for dry matter: covering – 0.73; kind of straw – not significant; interaction covering × kind of straw – 0.72; $HSD_{0.05}$ for ascorbic acid: covering – 2.04, kind of straw – 1.23, interaction covering × kind of straw – 2.76; $HSD_{0.05}$ for total sugars: covering – 0.18; kind of straw – 0.15; interaction covering × kind of straw – 0.19; $HSD_{0.05}$ for monosaccharides: covering – 0.03, kind of straw – 0.03, interaction covering × kind of straw – 0.04. A – without cover; B – under polypropylene fibre; FM – fresh matter

soil under non-woven polypropylene cover (7.36%), and the lowest (6.15%) – in plants grown under non-woven PP cover only. Plant and soil covering had no significant influence on the ascorbic acid, sugars and organic acids changes.

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