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QUALITY OF SWEET CORN YIELD DEPENDING ON WINTER CATCH CROPS AND WEED CONTROL METHOD

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Abstract. A special role in improving soil fertility is ascribed to green manures. Organic manuring can also influence on the quantity and quality of vegetable yield. The secondary effect of winter catch crops (VV – hairy vetch, TR – white clover, SC – rye, LM – Italian ryegrass, BRT – turnip rape) and weed control methods on the yielding, biometric parameters of ears and selected components of nutritive value in sweet corn were examined. The effects of an application of green manures were compared to the effect of farmyard manure (FYM) – 30 t·ha^{-1} – and control treatment without organic manure (NOM). Two methods of weed control were used: hand weeding and a mixture of herbicides Mustang 306 SE (florasulam + 2.4 D) + Titus 25 WG (rimsulfuron). Cultivation of sweet corn after FYM and VV most beneficially affected the crop's yield performance, ear weight, kernel weight per ear and sugars content. Ears were the longest when harvested in FYM and VV plots and NOM whereas ear fulfillment was the best in FYM and TR plots. Ear diameter was the greatest for sweet corn cultivated after FYM, LM and BRT. The highest dry matter content was determined in kernels of corn following LM and protein content after LM, VV and TR. Ascorbic acid content increased after all the catch crops compared with FYM and NOM. When weeds had been chemically controlled, corn produced larger ears which, however, had less kernel rows compared with hand weeded plants.

Key words: *Zea mays* L. var *saccharata*, ears, green manure, farmyard manure, chemical composition

INTRODUCTION

Sweet corn is a valuable crop plant with many uses in human nutrition which is popular in Central Europe, including Poland. The sweet corn kernel is rich in nutrients. It contains high amounts of protein, sugars, and most of vitamins and microelements. Weather conditions, in particular air temperature during the growing season, have the

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greatest influence on sweet corn growth, yield and yield quality [Stone et al. 1999]. Successful cultivation is also determined by agrotechnological factors, fertilisation being one of the most significant ones. An application of farmyard manure is recommended in the autumn [Haghighat et al. 2012]. However, it is not always possible to use farmyard manure due to economic, production or technical reasons. As a result, it is necessary to search for alternative sources of organic matter. In both horticulture and agriculture, catch crops used as green manure are a valuable source of organic matter. In the last decades, the evidence of negative environmental impact of agriculture aroused renewed interest in growing catch crops in autumn and winter, the effect of which is to take up nitrogen that would otherwise be lost, resulting in decreased nitrate concentrations in leachate [Thorup-Kristensen 2006, Collins et al. 2007]. During the process of catch crop mineralisation, the nitrogen is gradually released and becomes available for the subsequent plants [Vos and van der Putten 2001]. Catch crops also have a many-sided effect on biological, physical and chemical soil properties. Studies on an application of catch crops used as green manures in corn growing focus primarily on their influence on soil physical and chemical properties [Hanly and Gregg 2004, Clark et al. 2007], weed infestation [Caporali et al. 2004, O'Reilly et al. 2011] and yield increase [Turgut et al. 2005, Teasdale et al. 2008, Lawson et al. 2013]. There is a paucity of literature on the subject of secondary effect of green manures on the yield quality and nutritive value of sweet corn [Jabłońska-Ceglarek and Rosa 2005, Jędrszczyk and Poniedziałek 2007, Zaniewicz-Bajkowska et al. 2010, Zhang et al. 2010, Zaniewicz-Bajkowska et al. 2012].

Sweet corn is a poor competitor with weeds in the initial period of growth. Weed infestation can contribute to decreased yields of ears by up to 85% and also decrease ear quality [Williams 2010]. It is therefore crucial to control weeds from the very beginning of sweet corn cultivation. The most effective method of weed control is to apply herbicides which, however, have an adverse effect on the natural environment and may negatively affect yield quality.

The study aimed to determine the effect of winter catch crops and weed control methods on the yield quality of sweet corn.

MATERIALS AND METHODS

The experiment was carried out in 2008–2011 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). The soil was classified as Luvisol [FAO 2006]. The average organic carbon content amounted to 0.97%, the humus layer reaching the depth of 30–40 cm, and pH_{KCl} was 6.0. The total macronutrient contents in air dried matter amounted to 74 mg of nitrogen (NO_3 + NH_4), 73 P, 85 K, 38 Mg, and 280 Ca per 1 dm^3.

The experiment was established as a split-block design with three replicates. The effect of winter catch crops and the weed control methods on the biometric parameters of ears and selected components of nutritive value in 'Sweet Nugget F_1' (Agri-Saaten) sweet corn was investigated.

The following winter catch crops were grown: VV – hairy vetch (*Vicia villosa* Roth.), TR – white clover (*Trifolium repens* L.), SC – winter rye (*Secale cereale* L.), LM – Italian ryegrass (*Lolium multiflorum* L.), BRT – winter turnip rape (*Brassica rapa* var. *typica* Posp.). Their seeds were sown in early September in the years 2008–2010, at the following rates: VV – 70 kg, TR – 20 kg, SC – 180 kg, LM – 35 kg, BRT – 12 kg per 1 ha. The seedbed was prepared according to the generally established rules of sweet corn agrotechnology.

Nitrogen fertilisation was: 30 kg $N \cdot ha^{-1}$ for VV and TR and 60 kg $N \cdot ha^{-1}$ for SC, LM and BRT. The phosphorus and potassium rates for all of catch crop species were 40 kg $P_2O_5 \cdot ha^{-1}$ and 80 kg $K_2O \cdot ha^{-1}$. The effect of winter catch crops was compared to a control treatment without organic manure (NOM), and farmyard manure (FYM) applied at a rate of 30 $t \cdot ha^{-1}$. Green mass of the catch crops (roots + above ground parts) and FYM were incorporated in early May.

Just before catch crop incorporation, samples of plant material (roots + above ground parts) were taken to assess fresh (FM) and dry matter (DM) yields and perform chemical analyses to determine macronutrient contents. Dry matter contents of the catch crops and farmyard manure were determined using the oven-drying gravimetric method. Total Kjeldahl N of all plants was determined with a Tecator Kjeltec System 1026 analyzer. Phosphorus content was evaluated by colorimetry with a spectrophotometer SPEKOL 221. Potassium and calcium were determined by means of a flame photometer FLAPHO 41. Magnesium was determined with an atomic absorption spectrophotometer SOLAR 929 ATI UNICAM.

Seeds of sweet corn were sown (12 $kg \cdot ha^{-1}$) on the 14^{th}, 24^{th} and 11^{th} of May, in 2009–2011, at the between- and within-row spacing of 60 × 25 cm. Before sowing, mineral fertilisers were applied at the following rates: 60 kg N (urea), 50 kg P_2O_5 (superphosphate), 180 kg K_2O (60% potassium chloride) per 1 ha. When sweet corn plants were 20 cm high, top dressing of 60 kg $N \cdot ha^{-1}$ (ammonium nitrate) was applied. Two weed control methods were used: HW – hand weeding: 28 and 54 days after sowing of sweet corn; M + T – Mustang 306 SE (florasulam + 2.4 D) 0.6 $l \cdot ha^{-1}$ + Titus 25 WG (rimsulfuron) 40 $g \cdot ha^{-1}$ + adjuvant Trend 90 EC (0.1%) per 250 dm^3 H_2O, 28 days after sowing. Other cultivation practices followed the generally established rules of sweet corn agrotechnology.

Ears of sweet corn were harvested at the stage of milk maturity of kernels that is on the 8^{th} of September in 2009, 23^{rd} of August in 2010 and 3^{rd} of September in 2011. The whole plot area for harvest was 16 m^2. During harvest, a sample of 20 ears was taken from each plot in order to determine the weight of marketable ears, kernel weight per ear, ear fulfillment (%), ear length and diameter, number of kernel rows per ear, and to perform chemical analyses. The following components were determined in sweet corn kernels: dry matter (by drying to the constant weight at 105°C), L-ascorbic acid (Tillmans method), total sugars and sucrose (Luff-Schoorl method), total protein (Kjaldahl method, using a factor of 6.25). The results were statistically analysed by ANOVA following the model for the split-block design. The significance of differences was determined by the Tukey test at the significance level of $\alpha = 0.05$. All the calculations were performed in Statistica 10.0.

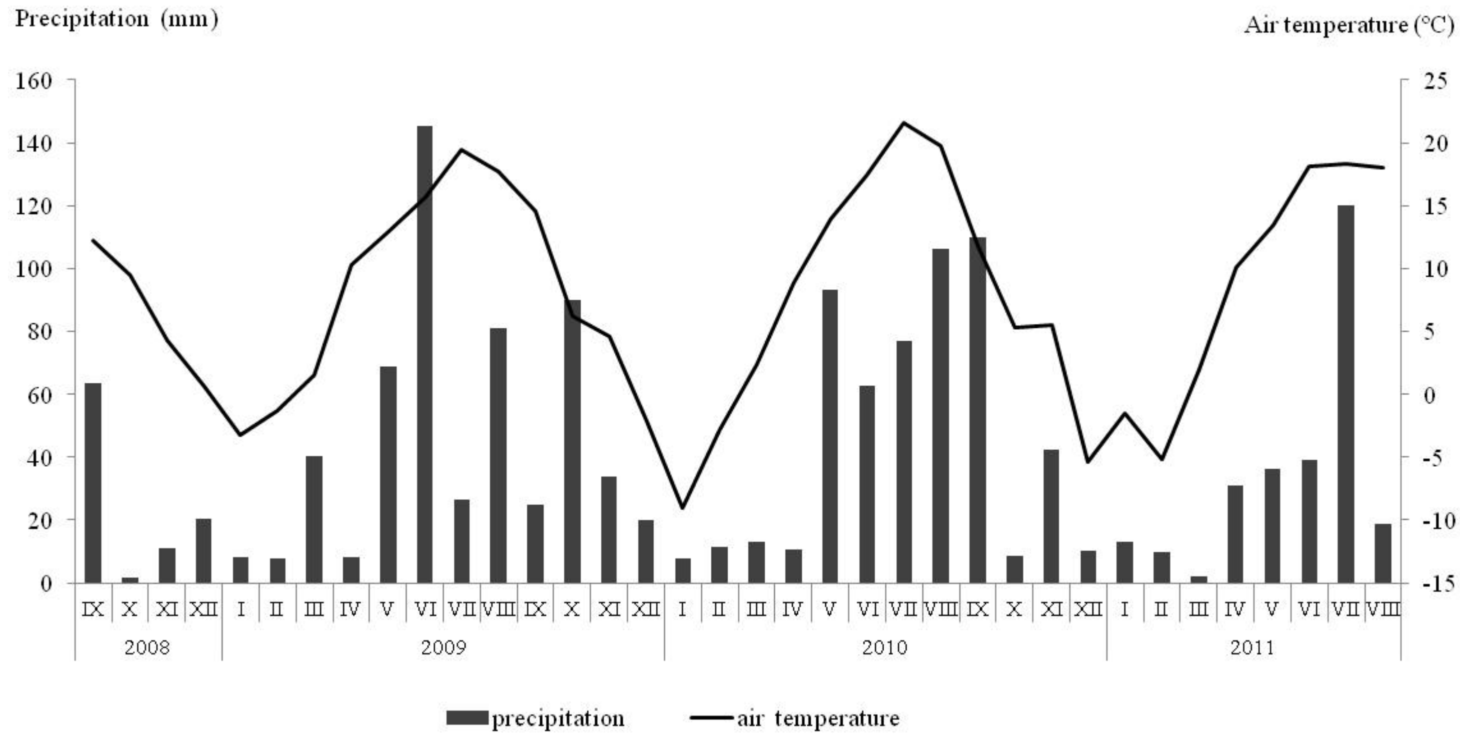


Fig. 1. Total rainfall and average air temperatures in the period of study

Over the study years the weather conditions during the growing season of catch crop plants and sweet corn were favourable. Precipitation was the greatest in the third study year (226.6 mm), and the lowest in the first year (160.9 mm). The period September to May was the warmest (the average 8.5°C) in the growing season 2008/2009 whereas in 2009/2010 and 2010/2011 average air temperatures were lower by 2.8–2.9°C. The period May-August was the warmest in 2010 and the coldest in 2009 (18.2 and 16.4°C, respectively). In 2011, the average air temperature during the growing season of sweet corn was 17.0°C. Precipitation sums in the growing season of sweet corn in 2009 and 2010 were similar (321.4 and 339.1 mm). However, the rainfall was most evenly distributed in the growing season of 2010. The least precipitation was noted in 2011 (214.0 mm). The weather conditions during the study period are shown in figure 1.

RESULTS AND DISCUSSION

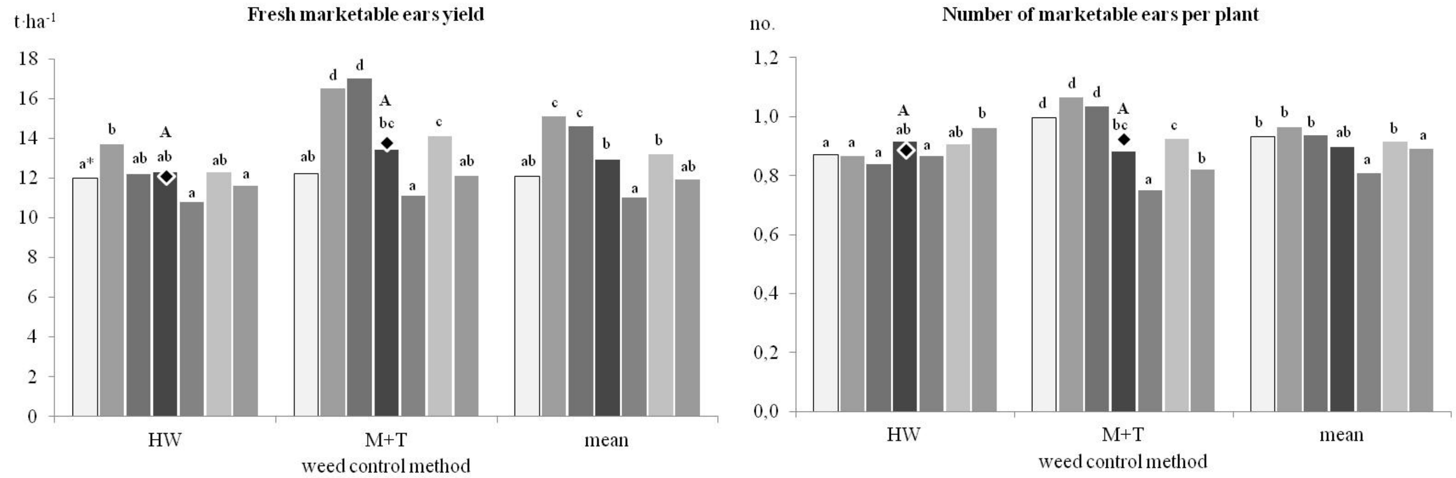
Catch crop biomass yield and macronutrients accumulated are presented in table 1. The greatest biomass yield was harvested for rye (SC) and winter turnip rape (BRT). SC produced over twice as much DM as hairy vetch (VV) and Italian ryegrass (LM) and over three times as much DM as white clover (TR). The most nitrogen and magnesium were incorporated into the soil with SC (134.7 and 26.5 kg·ha^{-1}, respectively) and the most phosphorus and calcium with BRT (81.8 and 87.1 kg·ha^{-1}, respectively). Potassium accumulated in LM, SC, and BRT ranged from 131.2 to 195.7 kg·ha^{-1}, the amount being significantly higher compared with VV and TR. Farmyard manure (FYM) applied at the rate of 30 t supplied 7.6 t DM as well as 106.0 kg mineral N, 49.7 kg P, 133.2 kg K, 64.1 kg Ca and 39.1 kg Mg per 1 ha.

The average marketable ears yield was 13.0 t·ha^{-1} and the number of marketable ears per plant was 0.9 (fig. 2). Regardless of weed control method, the highest yields were obtained from sweet corn following FYM and VV, amounting to 15.1 and 14.6 t·ha^{-1}, respectively, when averaged across years. Hand-weeded corn produced the highest ear yields after FYM (13.7 t·ha^{-1}) whereas corn in which weeds had been chemically controlled with M + T – after VV and FYM (17.0 and 16.5 t·ha^{-1}, respectively). The lowest yields and the lowest number of ears per plant were found for corn following incorporation of SC. The catch crops were planted after spring barley harvest and the cereal had depleted soil reserves of minerals. As a result, to obtain satisfactory biomass yield, it was necessary to pre-plant apply fertilisers so as to supply the soil with nutrients to the level required by individual species. Although higher than in NOM and FYM overall rates of mineral fertilisers had been applied in crop plant plots, ear yields after non-leguminous catch crops (in particular SC and BRT) were found to be significantly lower compared with FYM, and similar to NOM. It was due to nitrogen immobilisation and slow mineralisation of catch crop biomass resulting from a wide C/N ratio. Jensen et al. [2005] have stated that the majority of plant materials whose C/N ratio is higher than 45 tend to immobilise mineral nitrogen in soil. As a result, the crop plants that follow suffer from N deficiency. Other authors have mentioned that the C/N ratio in non-leguminous and leguminous plants is 21.6–54.4 and 8.8–27.8, respectively, depending on the plant species and growth stage [Tejada et al. 2008, DuPont et al. 2009, Janušauskaitė et al. 2013]. Weed control method did not significantly change sweet corn yield performance. The effect of the winter catch crops on yield level, structure and parameters as affected by weed control methods was described in detail in the author's previous work [Rosa 2014]. Studies conducted in different parts of the world have confirmed a positive effect of hairy vetch catch crop on sweet corn yields. Turgut et al. [2005] obtained a significant increase in yields of corn following common vetch green manure, and Caporali et al. [2004] as well as Dolijanovic et al. [2012] after hairy vetch green manure compared to cultivation without catch crop. Also Griffin et al. [2000] demonstrated favourable influence of hairy vetch winter catch crop and hairy vetch + rye winter catch crop on the yield of sweet corn.

Sweet corn ear quality is determined based on the following characteristics: ear weight and size, number of kernels per ear and nutrient content of ears [Kwabiah 2004]. Type of organic manure had a highly significant effect ($P < 0.001$) on all the biometric parameters of ears and nutrient content of kernels. The weed control methods significantly affected number of kernel rows per ear as well as ear length. Moreover, the interaction of both the factors was significant for all the traits excluding protein and ear diameter (tab. 2–5).

Irrespective of the weed control method, the greatest ear weight and kernel weight per ear were determined for sweet corn following VV (245.1 and 178.0 g, respectively) and FYM (241.0 and 172.6 g, respectively). Similar weight of ears was also found for sweet corn after LM (tab. 2), the lightest ears being harvested after BRT. Compared with FYM and control (NOM), incorporation of BRT was followed by a significant decline in the weight of ears in the hand-weeded plots. There was also observed a decline in kernel weight per ear of sweet corn cultivated after BRT in comparison with FYM, NOM and VV. Earns of corn following VV in H+T-treated plots were significantly heavier compared with BRT and NOM; also, their kernels per ear weighed more compared with NOM, BRT and LM.

Share of kernels per ear ranged from 88.3 to 95.8% (tab. 2) being the greatest for sweet corn cultivated after FYM and leguminous catch crops (VV and TR) and the lowest after rye catch crop (SC). Teasdale et al. [2008] found that hairy vetch and rye catch crops significantly increased ear weight of sweet corn cultivated without N fertiliser compared with the control but the effect was insignificant for N-fertilised crop. Previous studies by Rosa et al. [2012] demonstrated that sweet corn after phacelia and amaranth summer catch crops increased ear weight and biological productivity compared with cultivation without incorporation of catch crop. The authors also found that ear weight increased proportionally to the amount of catch crop biomass incorporated. In a study by Jabłońska-Ceglarek and Rosa [2005], the effect of forecrop green manures (common vetch, field pea, oat) on the weight of marketable ears was similar to the influence of farmyard manure ($25\ t \cdot ha^{-1}$). Of the catch crops examined by these authors, common vetch had the most positive influence on ear weight. Jędrszczyk and Poniedziałek [2007], who examined living mulches, found that ear weight of sweet corn after white clover differed insignificantly and after rye declined significantly compared with no-living mulch control. Kernel numbers per ear were similar for all the treatments.



HW – hand weeding, M+T – Mustang 306 SE + Titus 25 WG, NS – not significant
* Values followed by the same uppercase and lowercase letters are not significantly different

□ control (NOM) ■ farmyard manure (FYM) ■ hairy vetch (VV) ■ white clover (TR) ■ rye (SC) ■ italian ryegrass (LM) ■ winter turnip rape (BRT) ◆ mean

ANOVA	*F*-value	*P*	$LSD_{0.05}$	*F*-value	*P*	$LSD_{0.05}$
Weed control method	4.32	>0.05	NS	0.65	>0.05	NS
Kind of organic manure	14.30	<0.001	1.78	6.28	<0.001	0.09
Interaction	11.69	<0.001	1.52	29.00	<0.001	0.08

Fig. 2. Yielding of sweet corn depending on the examined factors (mean for 2009–2011)

Table 1. The quantity of fresh and dry matter and the amount of macronutrients incorporated with catch crops (mean for 2009–2011)

		Fresh matter ($t \cdot ha^{-1}$)	Dry matter ($t \cdot ha^{-1}$)	Macroelements ($kg \cdot ha^{-1}$)				
				N	P	K	Ca	Mg
Kind of catch crop	hairy vetch (VV)	18.1	3.0	108.7	11.6	40.5	26.4	6.1
	white clover (TR)	11.6	2.1	64.3	9.6	54.2	22.4	6.2
	winter rye (SC)	35.5	7.3	134.7	55.0	154.0	55.5	26.5
	italian ryegrass (LM)	13.2	2.9	49.2	15.0	131.2	18.0	9.4
	winter turnip rape (BRT)	29.1	4.9	105.4	81.8	195.7	87.1	10.2
ANOVA	*F*-value	1103.43	1048.26	1177.82	269.32	345.10	593.80	338.16
	P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	$LSD_{0.05}$	6.41	1.24	26.66	20.86	61.34	17.00	6.31

Table 2. The weight of marketable ears and kernels per ear and ear fulfillment with kernels depending on the examined factors (mean for 2009–2011)

		Weight of marketable ear (g)			Kernels weight per ear (g)			Ear fulfilment (%)		
		HW	M+T	mean	HW	M+T	mean	HW	M+T	mean
Kind of organic manure	control (NOM)	237.2	217.7	227.5	167.2	150.7	158.9	92.8	90.8	91.8
	farmyard manure (FYM)	240.5	241.4	241.0	170.5	174.7	172.6	93.6	93.6	93.6
	hairy vetch (VV)	232.9	257.3	245.1	171.5	184.4	178.0	93.9	95.8	94.9
	white clover (TR)	216.5	240.4	228.4	155.1	171.0	163.0	92.2	93.9	93.1
	rye (SC)	217.3	244.6	231.0	159.6	170.6	165.1	88.3	89.4	88.9
	italian ryegrass (LM)	226.9	249.2	238.0	161.6	165.5	163.5	91.1	92.8	91.9
	winter turnip rape (BRT)	212.1	229.8	220.9	148.3	164.4	156.3	90.3	91.7	91.0
	mean	226.2	240.1	233.1	162.0	168.8	165.4	91.7	92.6	92.2
ANOVA		*F*-value	*P*	$LSD_{0.05}$	*F*-value	*P*	$LSD_{0.05}$	*F*-value	*P*	$LSD_{0.05}$
	weed control method	3.17	>0.05	NS	1.44	>0.05	NS	1.60	>0.05	NS
	kind of organic manure	15.43	<0.001	9.37	27.93	<0.001	6.77	70.71	<0.001	1.02
	interaction	4.70	0.005	24.39	5.22	0.003	17.25	5.01	0.003	2.00

HW – hand weeding, M + T – Mustang 306 SE + Titus 25 WG, NS – not significant

Table 3. The number of kernel rows per ear, ear length and diameter depending on the examined factors (mean for 2009–2011)

		Number of kernel rows			Ear length (cm)			Ear diameter (cm)		
		HW	M+T	mean	HW	M+T	mean	HW	M+T	mean
Kind of organic manure	control (NOM)	12.8	12.7	12.8	21.2	22.0	21.6	4.6	4.7	4.7
	farmyard manure (FYM)	13.4	12.5	13.0	21.7	21.8	21.7	4.8	4.8	4.8
	hairy vetch (VV)	13.0	13.0	13.0	21.8	21.6	21.7	4.7	4.7	4.7
	white clover (TR)	12.9	12.5	12.7	19.9	21.3	20.6	4.6	4.7	4.6
	rye (SC)	13.7	12.8	13.2	20.3	21.2	20.8	4.7	4.7	4.7
	Italian ryegrass (LM)	12.6	12.9	12.7	20.3	22.2	21.2	4.7	4.8	4.8
	winter turnip rape (BRT)	13.3	12.4	12.9	21.0	21.3	21.2	4.7	4.8	4.8
	mean	13.1	12.7	12.9	20.9	21.6	21.3	4.7	4.7	4.7
ANOVA		*F*-value	*P*	$LSD_{0.05}$	*F*-value	*P*	$LSD_{0.05}$	*F*-value	*P*	$LSD_{0.05}$
	weed control method	16.08	0.004	0.27	41.37	<0.001	0.26	5.06	>0.05	NS
	kind of organic manure	6.30	<0.001	0.35	29.30	<0.001	0.38	10.06	<0.001	0.09
	interaction	9.96	<0.001	0.49	2.59	0.038	1.27	2.28	>0.05	NS

HW – hand weeding, M + T – Mustang 306 SE (florasulam + 2,4 D) + Titus 25 WG (rimsulfuron), NS – not significant

Table 4. Dry matter and sugars content in sweet corn kernels depending on the examined factors (mean for 2009–2011)

		Dry matter (%)			Total sugars (% FM)			Sucrose (% FM)		
		HW	M+T	mean	HW	M+T	mean	HW	M+T	mean
Kind of organic manure	control (NOM)	24.4	23.6	24.0	7.89	8.03	7.96	5.89	5.98	5.93
	farmyard manure (FYM)	24.3	23.8	24.0	8.43	8.40	8.42	6.30	6.28	6.29
	hairy vetch (VV)	23.7	23.8	23.8	8.55	8.43	8.49	6.41	6.30	6.35
	white clover (TR)	24.3	24.4	24.4	8.03	8.01	8.02	5.95	5.88	5.91
	rye (SC)	24.1	23.6	23.8	8.33	7.63	7.98	6.17	5.51	5.84
	Italian ryegrass (LM)	25.5	24.5	25.0	7.93	7.77	7.85	5.85	5.72	5.79
	winter turnip rape (BRT)	23.7	23.9	23.8	8.61	7.87	8.24	6.51	5.71	6.12
	mean	24.3	23.9	24.1	8.25	8.02	8.14	6.16	5.91	6.03
ANOVA		*F*-value	*P*	$LSD_{0.05}$	*F*-value	*P*	$LSD_{0.05}$	*F*-value	*P*	$LSD_{0.05}$
	weed control method	3.48	>0.05	NS	2.34	>0.05	NS	3.86	>0.05	NS
	kind of organic manure	13.05	<0.001	0.56	55.24	<0.001	0.15	28.12	<0.001	0.19
	interaction	4.43	0.005	0.72	6.79	0.001	0.42	9.18	<0.001	0.36

HW – hand weeding, M + T – Mustang 306 SE (florasulam + 2,4 D) + Titus 25 WG (rimsulfuron), NS – not significant

Kernel number rows per marketable ear averaged 12.9 (tab. 3). Irrespective of the weed control method, the most kernel rows were obtained after SC, significantly less after NOM, TR and LM, the latter two being the poorest sources of biomass introduced to the soil. The most kernel rows were found for hand-weeded sweet corn after SC and for M+T-treated sweet corn following VV, SC and LM, and NOM.

The longest ears (21.6–21.7 cm) were produced by corn following FYM and VV and the crop harvested from NOM; ears with the greatest diameter were found after FYM, LM and BRT whereas the shortest ears were formed by corn plants cultivated after TR and SC. The smallest diameter of ears was found for sweet corn following TR. Jędrszczyk and Poniedziałek [2007] reported that the length of sweet corn ears after rye (SC) and white clover (TR) living mulches was similar to the length measured in the control plants whereas ear diameter of corn crop following SC was significantly lower compared with TR and the control treatment. There were no significant differences between TR and the control. Romaneckas et al. [2012] observed significantly shorter corn ears after Italian ryegrass and red clover compared with the control. In the present study and some studies reported by other authors, it was difficult to confirm a clear relationship between the amount of biomass and macronutrients incorporated and the biological parameters of corn ears. Raimbault et al. [1990] pointed to a negative direct effect of some catch crops, particularly rye, on the development and parameters of corn ears as a result of their allelopathic influence.

An application of the herbicides M + T resulted in a decline in the average number of kernel rows per ear but it also increased ear length compared with hand weeding (HW). Waligóra et al. [2010] found no significant differences in the ear length of sweet corn cultivated using either hand weeding or chemical weed control based on Mustang 306 SE + Titus 25 WG + Trend 90 EC. However, they noticed that ears harvested from both weed control treatments were significantly longer compared with mechanical weed control.

The chemical composition of vegetables is genetically conditioned but it is also modified by factors affecting the growing plant [Lee and Kader 2000]. In the study discussed here, dry matter (DM) in sweet corn kernels ranged from 23.6 to 25.5% (tab. 4). The unique taste of sweet corn is associated with a high kernel content of water-soluble polysaccharides. It is well established that an increased dry matter content, e.g. in maturing kernels, is followed by negative changes in carbohydrates. As a result, the flavor, quality and appearance of kernels deteriorates [Marshall and Tracy 2003]. The highest DM content in kernel was determined in sweet corn following LM and TR, being significantly lower after VV, SC and BRT. The dry matter of kernels after LM (Italian ryegrass) was significantly higher compared with FYM and NOM. VV, SC and BRT produced more biomass compared with LM and TR. As a result, the sweet corn plants used more soil water and the greater matter they produced, before it mineralised, constituted a kind of barrier which made it more difficult for water to permeate from deeper soil layer. Due to this, the topsoil was excessively dry. Also Hanly and Gregg [2004] have noticed that as the amount of biomass of non-leguminous cover crops incorporated increased, the DM content of sweet corn kernels declined proportionally. It may have resulted from slow mineralisation of catch crops and overuse of water in the soil. Michałojć et al. [1996] have stressed that the less water is available for sweet corn in the soil, the less DM is accumulated in kernels. By contrast, Zaniewicz-Bajkowska et al. [2010, 2012], who examined summer catch crops, found no significant effect of biomass amount on DM content of sweet corn kernels.

Average total sugars and sucrose in sweet corn kernels amounted to 8.14 and 6.03% FM, respectively. The highest contents of sugars and saccharose were determined after FYM and VV (tab. 4); sweet corn harvested from these treatments contained by 0.40–0.64% more total sugars and 0.36–0.56% sucrose compared with TR, SC, LM and NOM. Both total sugars and sucrose were higher in hand-weeded sweet corn after BRT as well. A positive effect of some catch crops on accumulation of sugars by sweet corn has been reported by the other authors. Zhang et al. [2010] found that clover catch crops preceeding sweet corn increased sugars in kernels compared with no-catch crop cultivation. Also Jędrszczyk and Poniedziałek [2007] pointed to a significant increase in sugars when sweet corn had been planted into white clover living mulch in comparison with the control treatment. The concentration of sugars was similar for rye, living mulch treatments and the control.

Jabłońska-Ceglarek et al. [2005] have reported insignificant differences in sugar contents of sweet corn cultivated following the previous crops used as green manures (oat, field pea, vetch) and farmyard manure. The authors did not find any influence of the amount of catch crop mass incorporated on the accumulation of sugars by sweet corn. Zaniewicz-Bajkowska et al. [2012] found a positive effect of phacelia and amaranth summer catch crops on monosaccharides and total sugars in sweet corn. In turn, Adamavičienė et al. [2009] have pointed to an exceptional allelopathic potential of Italian ryegrass as the factor which contributed to a decline in saccharose content in edible plant parts (sugar beet).

In general, winter catch crops significantly increased ascorbic acid (AA) content of sweet corn compared with cultivation after FYM (by 0.25–0.59 mg·100 g^{-1} FM) and without organic manure (by 0.34–0.68 mg·100 g^{-1} FM) (tab. 5). What is more, TR, SC, LM and BRT contributed to higher ascorbic acid concentrations compared with VV. An application of both weed control methods resulted in different AA contents of sweet corn. The most AA was determined for hand-weeded corn cultivated after LM, SC and BRT, and for M+T-treated crop after TR, VV and BRT. Zaniewicz-Bajkowska et al. [2011] reported no significant differences in AA content of sweet corn following serradella, faba bean summer catch crops, FYM and after mineral fertilisation alone. By contrast, the kernel AA content of sweet corn grown after phacelia planted on the 4th of August and amaranth sown on the 21st July were significantly higher than the control without organic manure [Zaniewicz-Bajkowska et al. 2012].

Other studies have indicated that an application of green manures favourably affected vitamin C and sugar contents of onion, red beet [Jabłońska-Ceglarek et al. 2002], white cabbage [Jabłońska-Ceglarek and Rosa 2003] and leek [Rosa and Jabłońska-Ceglarek 2009]. The positive effect of organic matter incorporation on vitamin C in some vegetable species has been mentioned by other authors. Salama et al. [2014] reported substantially higher vitamin C levels in fennel with organic cultivation compared with mineral cultivation alone. In a study by Worthington [2001], organic manuring increased vitamin C in lettuce, potato, cabbage and spinach compared with cultivation without organic manuring, the effect being negative for carrot. However, Ismail and Fun [2003] observed increased vitamin C levels only in organically manured swamp cabbage; the organic matter had no effect on vitamin C in Chinese mustard, lettuce and spinach. Warman and Havard [1998] have claimed that it is difficult to indicate which sweet corn cultivation method; mineral fertiliser or organic manure-based one, more favourably influences vitamin C content in sweet corn kernels. The vitamin C content can be influenced by kernel maturity, fertility and moisture content in the soil, cultivation, meteorological conditions and even time of the day [Shewfelt 1990].

Table 5. Ascorbic acid and protein contents in sweet corn kernel depending on the examined factors (mean for 2009–2011)

		Ascorbic acid (mg·100 g^{-1} FM)			Protein (% FM)		
		HW	M+T	mean	HW	M+T	mean
Kind of organic manure	control (NOM)	9.62	9.76	9.69	3.41	3.52	3.47
	earmyard manure (FYM)	9.98	9.59	9.78	3.72	3.76	3.74
	hairy vetch (VV)	9.80	10.26	10.03	3.90	3.69	3.79
	white clover (TR)	10.01	10.63	10.32	3.72	3.75	3.73
	rye (SC)	10.53	9.93	10.23	3.31	3.35	3.33
	Italian ryegrass (LM)	10.85	9.61	10.23	3.71	3.71	3.71
	winter turnip rape (BRT)	10.42	10.31	10.37	3.56	3.56	3.56
	mean	10.17	10.01	10.09	3.62	3.62	3.62
ANOVA		*F*-value	*P*	$LSD_{0.05}$	*F*-value	*P*	$LSD_{0.05}$
	weed control method	5.19	>0.05	NS	0.12	>0.05	NS
	kind of organic manure	52.16	<0.001	0.17	51.29	<0.001	0.11
	interaction	11.34	<0.001	0.55	2.29	>0.05	NS

HW – hand weeding, M + T – Mustang 306 SE (florasulam + 2,4 D) + Titus 25 WG (rimsulfuron), NS – not significant

The average protein content of sweet corn kernels was 3.62% FM (tab. 5). The crop following VV, TR and LM as well as FYM contained more protein than the remaining catch crops. It was probably due to the fact that nitrogen was more available for corn as it was more rapidly released from FYM, leguminous catch crops (VV and TR) and Italian ryegrass (LM). Many studies have demonstrated that incorporation of leguminous catch crops (crimson clover, hairy vetch, subclover, red clover) preceeding corn and sweet corn resulted in increased N content in kernels compared with cultivation without catch crops [Caporali et al. 2004, Tejada et al. 2008, Salmerón et al. 2011, Kramberger et al. 2014]. In the present study, protein content fell after SC compared with NOM. Rye and other non-leguminous catch crops which produce much biomass can result in substantial N immobilisation leading to N shortages suffered by the following crop, which has a negative impact on yield quantity and N content in corn edible parts. To prevent this, increased mineral fertilisation of non-leguminous crops can be applied. However, studies by Tejada et al. [2008] demonstrated that protein contents in kernels of corn following oilseed rape and red clover catch crops were similar when the same mineral fertilisation of catch crops had been applied. In turn, Salmerón et al. [2011] noticed that N content in kernels of corn grown after oilseed rape and winter rape cover crops was significantly lower compared with common vetch although it did not differ significantly from the control without catch crop. Caporali et al. [2004] reported a decline in N content after ryegrass compared with cultivation after subclover and hairy vetch catch crops, the N content being similar to the control. Kramberger et al.

[2014] observed a decline in N content in corn kernels harvested from an Italian ryegrass-manured treatment compared with the non-manured control and crimson clover-manured plots. A positive effect of leguminous biomass on nitrogen accumulation of other vegetable species (onion, parsley, white cabbage) has been mentioned by Willumsen and Thorup-Kristensen [2001], Błażewicz-Woźniak and Mitura [2004] and Błażewicz-Woźniak et al. [2008].

CONCLUSIONS

1. The effect of green manures on the biometric parameters of ears varied and depended on the catch crop species. Hairy vetch cultivated for winter catch cropping should be recommended as a manure due to its very beneficial effect on yield, weight and size of ears as well as kernel number per ear, the effect being similar to farmyard manure.
2. The more catch crop biomass was incorporated, the less dry matter was accumulated in sweet corn kernels. Sweet corn following FYM and hairy vetch was the richest in sugars. Ascorbic acid content in the kernels of corn following green manures was significantly higher compared with farmyard manure and control. The highest protein content was determined in corn cultivated after FYM, leguminous catch crops and Italian ryegrass.
3. Chemical weed control was followed by a decline in the average number of kernel rows per ear and increased ear length compared with hand weeding; the remaining biometric parameters remained unaffected. Hand weeding and chemical weed control of sweet corn resulted in similar dry matter, sugars, ascorbic acid and protein levels in kernels.

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JAKOŚĆ PLONU KUKURYDZY CUKROWEJ W ZALEŻNOŚCI OD RODZAJU MIĘDZYPLONÓW OZIMYCH I METODY ODCHWASZCZANIA

Streszczenie. Nawozom zielonym przypisuje się szczególną rolę w podnoszeniu żyzności gleby. Nawożenie organiczne może wpływać także na wielkość i jakość plonu warzyw. Badano wpływ przyoranych międzyplonów ozimych (VV – wyka kosmata, TR – koniczyna biała, SC – żyto, LM – rajgras włoski, BRT – rzepik ozimy) i metody odchwaszczania na plonowanie, parametry biometryczne kolb oraz zawartość w kukurydzy cukrowej suchej masy, cukrów, kwasu askorbinowego i białka. Efekty stosowania międzyplonów porównano z obornikiem (FYM) w dawce 30 $t \cdot ha^{-1}$ oraz kontrolą bez nawożenia organicznego (NOM). Stosowano dwie metody odchwaszczania: dwukrotne pielenie ręczne lub chemiczne herbicydami Mustang 306 SE (florasulam + 2,4 D) + Titus 25 WG (rimsulfuron). Najkorzystniej na plonowanie, masę kolb i ziaren w kolbie oraz zawartość cukrów wpłynęła uprawa kukurydzy po FYM i międzyplonie VV. Po FYM i VV oraz w NOM zebrano najdłuższe kolby, a po FYM, VV i TR kolby najlepiej zaziarnione. Największą średnicę miały kolby po FYM oraz międzyplonach LM i BRT. Najwięcej suchej masy w ziarniakach stwierdzono po międzyplonie LM, a najwięcej białka po LM, VV i TR. Po wszystkich międzyplonach wzrosła zawartość kwasu askorbinowego. Kukurydza odchwaszczana ręcznie charakteryzowała się większą liczbą rzędów ziaren w kolbie, ale mniejszą długością kolb niż odchwaszczana chemicznie.

Słowa kluczowe: *Zea mays* L. var *saccharata*, kolby, nawóz zielony, obornik, wartość odżywcza

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