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PHACELIA AND AMARANTH CATCH CROPS IN SWEET CORN CULTIVATION. PART I. CORN YIELDS

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Abstract. Organic manuring is suggested to be necessary in sweet corn cultivation. It is not always possible to use farmyard manure due to economic, production or technical reasons. Catch crops used as green manures can be an alternative source of organic matter. A field experiment was carried out in central-eastern Poland to investigate the effect of phacelia and amaranth catch crops used as green manures on sweet corn growth and yields. Catch crops were sown at three dates: 21st July, 4th and 18th August, and incorporated in late October. Sweet corn was cultivated in the first year following manuring. The effect of the green manures was compared to farmyard manure applied at a rate of 40 t·ha^{-1} and a non-manured control. Of the catch crops examined, the highest yield of fresh and dry matter was obtained for phacelia sown on the 21st of July (33.6 t·ha^{-1} f.m. and 6.3 t·ha^{-1} d.m.) and 4th of August (33.7 t·ha^{-1} f.m. and 5.5 t·ha^{-1} d.m.). A delayed sowing date of phacelia seeds, from 21st of July to the 18th of August, caused a decrease in the quantity of fresh matter and dry matter by 26 and 37%. Amaranth sown on the 21st of July produced 26.2 and 5.3 t·ha^{-1} fresh and dry matter. Delaying the sowing date of amaranth seeds by 14 and 28 days decreased the yield of fresh and dry matter by 18 and 55–58%. There were found similar effects on yield of farmyard manure, phacelia and amaranth catch crops sown on the 21st of July. Delaying the sowing date of catch crops by 2 and 4 weeks decreased the marketable yields of corn cobs by, respectively, 16.2 and 28.9% for phacelia and by 12.8 and 24.4% for amaranth. The average weight of marketable corn cobs cultivated after farmyard manure, phacelia and amaranth catch crops sown on the 21st of July and phacelia sown on the 4th of August were similar. Biological productivity of corn cobs following farmyard manure and the catch crops examined (except amaranth sown on the 18th of August) was similar and ranged from 66.5 to 72%. 'Chalenger F_1' produced marketable cobs with a higher average weight but with lower biological productivity than 'Sweet Wonder F_1'.

Keywords: organic manuring, green manure, *Phacelia tanacetifolia* Benth., *Amaranthus cruentus* L., *Zea mays* L. var. *Saccharata*, yields

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INTRODUCTION

Sweet corn is becoming more and more popular in Poland and the area under this species is growing all the time. According to the estimated data it amounted to over 4.5 thousand ha a few years ago [Waligóra 2007]. Sweet corn has high nutritional requirements so successful cultivation is determined by appropriate fertilization. The application of farmyard manure is recommended in the autumn. However, it is not always possible to use farmyard manure due to economic, production or technical reasons. As a results, it is necessary to search for alternative sources of organic matter, for example catch crops which, when used as green manures, are a valuable source of organic matter. Catch crops also have a many-sided effect on biological, physical and chemical soil properties. They protect the forms of nutrients that are easily available for plants from leaching into deeper layers of the soil profile and groundwater [Clark et al. 2007, Collins et al. 2007]. During the process of catch crop mineralization the biomass nitrogen is gradually released and becomes available for the subsequent plants [Vos and van der Putten 2001]. Numerous studies have indicated the possibility of using green manures in agricultural and horticultural production [Creamer 1996, Hruszka 1996, Mwaja et al. 1996, Jabłońska-Ceglarek et al. 2004, Kołota and Adamczewska-Sowińska 2004], however, there is a paucity of literature regarding the possibility of using green manures in corn cultivation. Brzeski et al. [1993] have shown that the effectiveness of green manures primarily depends on climatic conditions and incorporated plant mass as well as the rate of catch crop mineralization.

The present work is an attempt to determine the effect of phacelia and amaranth catch crops, sown at the three dates and incorporated as green manures on sweet corn growth and yields. In Poland phacelia is one of the species most commonly used as green manure. However, there is a paucity of research regarding manuring value of amaranth. This species is of interest due to high green mass production over a short period of time. Moreover, it is not related with the majority of plants cultivated in our country. Selection of new plant species helps to add variety to crop rotations, improve growing conditions and health of plants and, as a result, increase yields of the crops that follow. It is not always possible to sow plants for green manure at the optimal date. In the present study different sowing dates of catch crops were chosen to determine how delayed sowing influences their fertilizer value and secondary effect on the yields.

MATERIALS AND METHODS

Data analysed in the current paper were obtained from a field experiment carried out over 2004–2007 at the Experimental Farm in Zawady, 25 km east of Siedlce (52°06’N, 22°55’E). According to the international system of FAO classification, the soil was classified as a Luvisol (LV) [WRB 1998]. The soil organic matter content averaged 1.6% and its humus horizon reached the depth of 30–40 cm, the value of pH determined in KCl was 6.0. The total phosphorus content in was 31, potassium 77, calcium 371, magnesium 26, N-NO_3 22, N-NH_4 18 mg·dm^{-3}.

The experiment was established as a split-block design with four replications. The secondary effect of phacelia (*Phacelia tanacetifolia* Benth.) and amaranth (*Amaranthus cruentus* L.) catch crops on the growth and yields of sweet corn (*Zea mays* L. var *saccharata*) was studied. The area of one plot was 56 m^2. Two corn cultivars: Challenger F_1' and 'Sweet Wonder F_1' were tested. Seeds of phacelia and amaranth were sown as a summer catch crop in 2004–2006 at three dates: on the 21st of July (PA1 – phacelia, AS1 – amaranth), 4th of August (PA2 – phacelia, AS2 – amaranth), and 18th of August (PA3 – phacelia, AS3 – amaranth). The seeding rate for phacelia and amaranth was 17 kg·ha^{-1} and 3 kg·ha^{-1}, respectively. Sowing of catch crop plants was preceded by an application of mineral fertilizers at the following rates: 80 kg N·ha^{-1}, 26 kg P·ha^{-1} and 66 kg K·ha^{-1}. Green mass of all the catch crops was incorporated in late October. The growing season of catch crops lasted: 92 days for phacelia and amaranth sown on the 21st of July, 78 days for phacelia and amaranth sown on the 4th of August, and 64 days for phacelia and amaranth sown on the 18th of August. Directly before catch crop incorporation the samples of plant material were taken to assess fresh and dry matter yields and perform chemical analyses to determine macroelements content. The dry matter content in the catch crops and farmyard manure were determined using the oven-drying gravimetric method according to the norm PN-88/R-04013. Total N of all the plants was determined with a Tecator Kjeltec System 1026 analyzer. Phosphorus content was measured 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.

The effect of the catch crops on yield was compared to the effect of farmyard manure (FYM) at a rate of 40 t·ha^{-1} and the control without organic manuring (NOM). The farmyard manure was ploughed under together with phacelia and amaranth.

Sweet corn was cultivated in 2005–2007, in the first year after the incorporation of green manures and farmyard manure. The seeds were sown in mid-May at the spacing of 65 × 20 cm. The seeding rates of 'Challenger F_1' and 'Sweet Wonder F_1' were 10 and 6 kg·ha^{-1}, respectively. Sowing was preceded by an application of mineral fertilizers to all the plots at the following rates: 110 kg N, 50 kg P, 150 kg K per 1 ha. Mineral fertilizers for the catch crops and corn were in the form of ammonium nitrate, granular superphosphate and 60% potassium chloride. Mineral fertilizers applied in universal doses, recommended for phacelia, amaranth and sweet corn. Other cultivation practices followed the generally established rules of sweet corn agrotechnology.

Cobs were harvested at the stage of milk maturity of kernels, which was at the end of August and the beginning of September. The whole plot area for harvest was 52 m^2. During the harvest there was determined:

– marketable yield of cobs (t·ha^{-1}) according to the norm PN-R-75377:1996,

– mean mass of marketable cobs (g).

In the current paper there was also calculated the percentage of marketable yield of cobs in the total yield and biological productivity of corn cobs (W_b), which was calculated according to the following model:

$$w_b = \frac{m_c - m_p}{m_c} \cdot 100\ (\%)$$

where:

m_c – mass of a cob without cover leaves (g),

m_p – mass of a core (g) [Szymanek et al. 2004].

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

In all the study years there was recorded a shortage of precipitation and an increase in mean air temperatures compared with the long-term mean for 1951–1990 (tab. 1). In the 2004 and 2005 growing seasons of phacelia and amaranth the quantity of precipitation was, respectively, by 45.9 and 62.9 mm lower compared with the long-term mean for July–October, and by 24.3 and 78.8 mm lower for August–October. In 2006 the quantity of precipitation for these periods exceeded the long-term mean by 76.1 mm (July–Oct) and 130.5 mm (Aug–Oct). In sweet corn growing season (May–Aug) a shortage of precipitation was observed in 2005 (-13.3 mm) and in 2007 (-34.6 mm) compared to the long-term mean. The precipitation sum in the period from May–August 2006 amounted to 307.4 mm and exceeded the long-term mean by 53.4 mm, precipitation distribution was very irregular, however. In June and July drought occurred and as much as 74% of precipitation was recorded in August. Wet and warm weather during this period contributed to the development of smut *Ustilago maydis* on tassels and cobs, which decreased the marketable yield of cobs. Waligóra et al. [2008] found that warm and wet weather in 2006 contributed to an occurrence of *Ustilago zeae* (Beckm.) on 1.7 to 27.3% plants of various sweet corn cultivars, depending on their tolerance to this pathogen.

Table 1. Weather conditions in the period of study
Tabela 1. Warunki pogodowe w okresie prowadzenia badań

	Years Lata	I–XII	Vegatation period – Okres wegetacji		
			catch crops – międzyplony		sweet corn kukurydza cukrowa
			VII–X	VIII–X	V–VIII
Precipitation Opady atmosferyczne, mm	1951–1990	514.9	210.6	140.0	254.0
	2004	429.6	164.7	115.7	-
	2005	353.6	147.7	61.2	240.7
	2006	428.4	286.7	270.5	307.4
	2007	507.0	-	-	219.4
Air temperature Temperatura powietrza, °C	1951–1990	7.5	13.8	12.5	16.0
	2004	7.9	14.7	13.8	-
	2005	8.0	15.3	13.7	16.7
	2006	8.2	16.4	14.4	17.8
	2007	8.9	-	-	17.7

Mean air temperatures in the 2004–2006 growing seasons exceeded the long-term mean by 0.9–2.6ºC. In all the study years mean yearly air temperatures over the corn growing season were higher than the long-term mean. Air temperature had the greatest influence on sweet corn growth, development and yields; so, in general, thermal conditions in the study years were favourable for sweet corn. Only in 2006 hot June and July coupled with high rainfall shortages slowed down the growth of corn.

RESULTS AND DISCUSSION

The amount of farmyard manure and the incorporated organic mass of phacelia and amaranth sown at the successive dates and, in consequence, macroelements introduced into the soil, are shown in table 2. Comparison of both the catch crops sown at the three dates demonstrated that phacelia sown on the 21st of July (PA1) and 4th of August (PA2) produced similar amounts of fresh and dry matter. Delaying the sowing date of phacelia seeds to 18th of August (PA3), decreased the quantity of fresh and dry matter, by 26 and 37%, compared with PA1. Amaranth catch crop sown on the 21st of July (AS1) produced 26.2 t·ha^{-1} fresh and 5.3 t·ha^{-1} dry matter. Delaying the sowing date of amaranth seeds by 14 days (AS2) contributed to decreased yields of fresh and dry matter by 18%, and when the date was delayed by the next 14 days (AS3) by further 37–40%. Wyland et al. [1996] have shown that the dry matter yield of phacelia was lower than in the present studies and amounted to 3.64 t·ha^{-1}. Campbell and Abott [1982] have claimed that fresh matter yield of amaranth depended on the planting date and ranged from 4.0 to 16.5 t·ha^{-1}. According to Gregorová et al. [2001], the dry matter yield of amaranth above-ground parts was 8.99 t·ha^{-1}. Lower fresh and dry matter yields of catch crops due to delayed sowing dates are similar to the results reported by other authors. Abdin et al. [1997] compared 12 catch crops and, when delaying planting by 10 days, obtained the biomass yield which was by 17.5–32% lower. Also Richards et al. [1996] showed that, earlier seeding of phacelia, Italian ryegrass, mustard, forage rape and rye catch crops was more beneficial than delayed seeding. Schmid and Klay [1984] reported that the quantity of organic matter introduced into the soil with green manures corresponded to the quantity incorporated with farmyard manure applied at the rate of 22–32 t ha^{-1}, the amount of incorporated dry matter ranging between 4.5 and 5.5 t ha^{-1}. The quantity of dry matter incorporated with the catch crops supplied the quantity which is incorporated with 10.0–24.5 ton farmyard manure.

The rate of 40 t·ha^{-1} FYM supplied 10.3 t·ha^{-1} dry matter and 552.5 kg·ha^{-1} macroelements (N + P + K + Ca + Mg) into the soil. Of the catch crops most macroelements were accumulated by phacelia and amaranth sown on the 21st of July. Amaranth AS1 produced less biomass than phacelia PA1 but accumulated more nitrogen and potassium. Accumulation of the remaining macroelements in both the catch crops was similar. Delaying the sowing date of phacelia catch crop by 2 weeks (PA2) decreased the accumulation of macroelements by 12–16% compared with PA1. When sowing was delayed by 4 weeks (PA3) the decrease was 36–41% compared with PA1. Delaying the sowing date of amaranth resulted in an even higher decrease in macroelements accumulation compared with phacelia. Amaranth sown on the 4th of August (AS2) and 18th of

Table 2. The quantity of dry matter and the amount of macroelements incorporated with farmyard manure catch crops
Tabela 2. Ilość przyoranej suchej masy oraz makroskładników z obornikiem i międzyplonami

Year – Rok	Kind of organic manure Rodzaj nawozu organicznego	Dry matter Sucha masa, $t \cdot ha^{-1}$	Macroelements – Makroskładniki, $kg \cdot ha^{-1}$				
			N	P	K	Ca	Mg
2004	Farmyard manure – Obornik (FYM)	10.2 g	145.7 d	63.3 f	203.0 f	84.2 cd	52.0 e
	Phacelia 1 – Facelia 1 (PA1)*	7.1 f	128.2 c	29.3 d	169.4 e	86.4 d	32.2 d
	Phacelia 2 – Facelia 2 (PA2)	6.4 e	116.3 c	24.0 c	147.4 de	75.9 c	27.1 c
	Phacelia 3 – Facelia 3 (PA3)	4.8 c	83.8 b	17.0 ab	110.8 bc	57.9 b	20.2 b
	Amaranth 1 – Szarłat 1 (AS1)	5.5 d	122.2 c	31.4 e	198.0 f	77.9 cd	31.9 d
	Amaranth 2 – Szarłat 2 (AS2)	3.6 b	72.7 b	20.3 bc	132.3 cd	51.8 b	20.2 b
	Amaranth 3 – Szarłat 3 (AS3)	2.5 a	50.2 a	13.7 a	84.0 a	35.9 a	13.7 a
2005	Farmyard manure – Obornik (FYM)	10.5 e	143.4 f	70.0 f	209.0 f	86.9 e	51.6 e
	Phacelia 1 – Facelia 1 (PA1)	5.8 d	94.5 d	21.0 d	146.3 d	62.1 d	26.2 c
	Phacelia 2 – Facelia 2 (PA2)	4.9 bc	79.2 c	18.4 c	118.9 c	53.3 c	21.2 b
	Phacelia 3 – Facelia 3 (PA3)	3.6 b	54.9 b	13.2 b	88.9 b	42.0 b	15.2 a
	Amaranth 1 – Szarłat 1 (AS1)	5.1 c	108.5 e	24.7 e	181.4 e	69.5 d	33.0 d
	Amaranth 2 – Szarłat 2 (AS2)	4.5 b	90.8 d	21.3 d	146.6 d	61.1 d	25.6 c
	Amaranth 3 – Szarłat 3 (AS3)	1.9 a	37.6 a	9.2 a	66.6 a	26.7 a	11.8 a
2006	Farmyard manure – Obornik (FYM)	10.3 e	140.0 f	69.0 d	197.3 f	90.0 d	52.4 d
	Phacelia 1 – Facelia 1 (PA1)	6.0 d	93.4 cd	25.0 c	145.7 d	70.5 bc	24.7 b
	Phacelia 2 – Facelia 2 (PA2)	5.3 bc	77.3 bc	21.2 b	119.4 c	62.7 b	24.5 b
	Phacelia 3 – Facelia 3 (PA3)	3.7 ab	54.2 a	14.1 a	84.4 a	40.7 a	15.8 a
	Amaranth 1 – Szarłat 1 (AS1)	5.2 bc	113.9 e	24.6 bc	185.4 ef	72.5 c	30.1 c
	Amaranth 2 – Szarłat 2 (AS2)	4.7 b	101.0 de	23.0 bc	163.6 de	66.8 bc	25.8 bc
	Amaranth 3 – Szarłat 3 (AS3)	3.1 a	63.3 ab	14.1 a	109.9 bc	42.5 a	17.9 a
Mean for years Średnie z lat 2004-2006	Farmyard manure – Obornik (FYM)	10.3 e	143.0 f	67.4 d	203.1 d	87.0 e	52.0 d
	Phacelia 1 – Facelia 1 (PA1)	6.3 d	105.4 d	25.1 c	153.8 c	73.0 d	27.7 bc
	Phacelia 2 – Facelia 2 (PA2)	5.5 cd	90.9 c	21.2 b	128.5 b	64.0 c	24.3 b
	Phacelia 3 – Facelia 3 (PA3)	4.0 b	64.3 b	14.8 a	94.7 a	46.9 b	17.1 a
	Amaranth 1 – Szarłat 1 (AS1)	5.3 c	114.9 e	26.9 c	188.3 d	73.3 d	31.7 c
	Amaranth 2 – Szarłat 2 (AS2)	4.3 b	88.2 c	21.5 b	147.5 bc	59.9 c	23.9 b
	Amaranth 3 – Szarłat 3 (AS3)	2.5 a	50.4 a	12.3 a	86.8 a	35.0 a	14.5 a

*The date of sowing of phacelia and amaranth catch crops: PA1 – 21 July, PA2 – 4 August, PA3 – 18 August, AS1 – 21 July, AS2 – 4 August, AS3 – 18 August.
Termin wysiewu nasion międzyplonów facelii i szarłatu: PA1 – 21 lipca, PA2 – 4 sierpnia, PA3 – 18 sierpnia, AS1 – 21 lipca, S2 – 4 sierpnia, AS3 – 18 sierpnia.
**Values followed by the same letters do not differ significantly at $p = 0.05$ – Wartości oznaczone tą samą literą nie różnią się istotnie przy $p = 0,05$

August accumulated, respectively, by 18–24 and 52–56% macroelements less than the 21st of July. Data presented in table 2 show that catch crops sown planted on the 21st of July accumulated by 32–44% of nitrogen and by 133–185% of potassium more, on the 4th of August by 10–14% of nitrogen and by 95–123% of potassium more, and sown on the 18th of August (AS3) by 32–43% potassium more than the amount of these elements contained in mineral fertilizers applied prior to phacelia and amaranth sowing. Wilczewski and Skinder [2005] have showed that potassium amounts in catch crops can be even by 267–428% higher than the amounts introduced with fertilizers. The authors stress that the above fact means that catch crops may be used to prevent nutrients unused by the preceding crops from being lost.

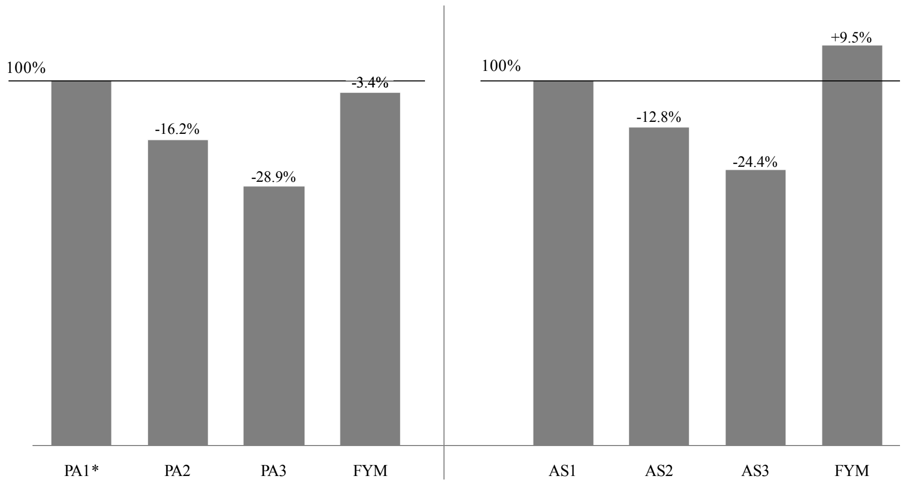
The mean marketable yield of sweet corn cobs in 2005–2007 amounted to 10.3 $t \cdot ha^{-1}$ (tab. 3). Significantly the highest yield (12.3 $t \cdot ha^{-1}$) was harvested in 2007 and the lowest (8.3 $t \cdot ha^{-1}$) in 2006. A decrease in corn cob marketable yield in 2006 compared with 2005 and 2007 (by 28 and 33%) was caused by weather conditions. High rainfall shortages in May (-14.7 mm), June (-45.3 mm), and July (-54.4 mm) compared with the long-term mean influenced sweet corn growth and development. Michałojć et al. [1996] and Waligóra and Kruczek [2003] have reported that seed germination (the end of May in the present study) and flowering (from mid-July) are critical periods of the highest water demand of corn. Due to heavy rainfall in August (227.6 mm), coupled with high air temperatures, corn plants (tassels and developed cobs) were rapidly infected by *Ustilago maydis*.

Table 3. Marketable yield of cob with cover leaves ($t \cdot ha^{-1}$)
Tabela 3. Plon handlowy kolb z liśćmi okrywowymi ($t \cdot ha^{-1}$)

Organic manures Nawożenie organiczne	Years – Lata			Cultivar – Odmiana		$\bar{x}$
	2005	2006	2007	Challenger F_1	Sweet Wonder F_1	
	średnio dla dwóch odmian mean for two cultivars			średnio dla lat mean for years		
Control (NOM) Kontrola	10.1 a**	6.9 a	11.7 a	9.2 ab	9.9 ab	9.5 ab
Farmyard manure (FYM) Obornik	13.0 a	10.0 a	14.8 a	12.6 ef	12.6 d	12.6 ef
Phacelia 21.07 (PA1)* Facelia 21.07	13.5 a	10.8 a	14.8 a	13.7 f	12.4 d	13.0 f
Phacelia 4.08 (PA2) Facelia 4.08	11.2 a	9.3 a	12.3 a	11.0 cd	10.9 bc	10.9 cd
Phacelia 18.08 (PA3) Facelia 18.08	10.2 a	7.2 a	10.5 a	8.8 ab	9.8 ab	9.3 ab
Amaranth 21.07 (AS1) Szarłat 21.07	12.4 a	8.4 a	13.7 a	11.5 de	11.5 cd	11.5 de
Amaranth 4.08 (AS2) Szarłat 4.08	11.2 a	7.5 a	11.4 a	9.9 bc	10.1 abc	10.0 bc
Amaranth 18.08 (AS3) Szarłat 18.08	10.2 a	6.6 a	9.3 a	8.3 a	9.0 a	8.7 a
Mean – Średnio	11.5 B	8.3 A	12.3 C	10.6 A	10.8 A	10.3

The examined sweet corn cultivars yielded on a similar level. The marketable yield of both the cultivars depended on the kind of organic fertilization. The yields were highest after phacelia sown on the 21st of July (PA1) and after FYM. Delaying the sowing date of phacelia and amaranth decreased their secondary effect on yields. The marketable yields of cobs were proportional to the quantity of dry matter and macroelements incorporated with catch crops. A similar relation was reported by Tejada et al. [2008] who observed that the more organic matter was introduced into the soil with green manures, the higher was the corn yield. According to Brzeski et al. [1993], the quantity of biomass incorporated with a catch crop is one of the main factors influencing their secondary effect on yield.

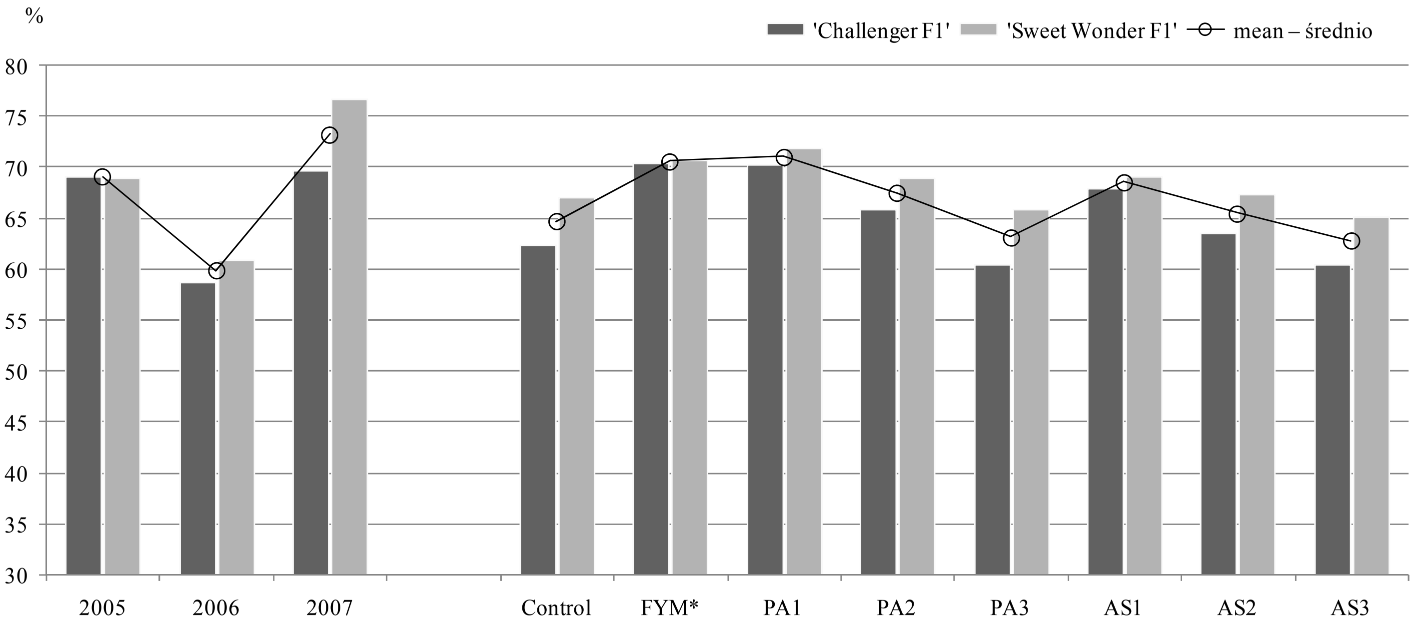
The percentage drop in marketable yields of corn cobs following delays in the sowing date of catch crops are presented in figure 1. Yields of corn cultivated after phacelia sown 2 and 4 weeks later (PA2 and PA3) were lower by 16.2 and 28.9%, compared with the yield after phacelia sown on the 21st of July (PA1). A lower decrease of yields was recorded for corn planted at successive dates of amaranth catch crops. Cob yields of corn cultivated following amaranth seeded at the second (AS2) and third (AS3) sowing date were, respectively by 12.8 and 24.4% lower than after amaranth sown on the 21st of July (AS1).



* **PA1** - phacelia catch crops sown on 21st of July – międzyplon facelii posiany 21 lipca, **PA2** - phacelia catch crops sown on 4th of August – międzyplon facelii posiany 4 sierpnia, **PA3** - phacelia catch crops sown on 18th of August – międzyplon facelii posiany 18 sierpnia, **AS1** - amaranth catch crops sown on 21st of July – międzyplon szarłatu posiany 21 lipca, **AS2** - amaranth catch crops sown on 4th of August – międzyplon szarłatu posiany 4 sierpnia, **AS3** - amaranth catch crops sown on 18th of August – międzyplon szarłatu posiany 18 sierpnia, **FYM** - farmyard manure – obornik

Fig. 1. Changes of sweet corn yielding (in percentage) depending on the sowing date of phacelia and amaranth

Rys. 1. Zmiany plonowania kukurydzy cukrowej (w procentach) zależnie od terminu siewu facelii i szarłatu



* **FYM** - farmyard manure – obornik, **PA1** - phacelia catch crops sown on 21st of July – międzyplon facelii posiany 21 lipca, **PA2** - phacelia catch crops sown on 4th of August – międzyplon facelii posiany 4 sierpnia, **PA3** - phacelia catch crops sown on 18th of August – międzyplon facelii posiany 18 sierpnia, **AS1** - amaranth catch crops sown on 21st of July – międzyplon szarłatu posiany 21 lipca, **AS2** - amaranth catch crops sown on 4th of August – międzyplon szarłatu posiany 4 sierpnia, **AS3** - amaranth catch crops sown on 18th of August – międzyplon szarłatu posiany 18 sierpnia

Fig. 2. Share marketable yield in the total yield of cob (%)
Rys. 2. Udział plonu handlowego w plonie ogółem kolb (%)

The possibility of applying catch crop green manures with field pea, vetch and oat in corn cultivation was indicated in the study by Jabłońska-Ceglarek and Rosa [2005]. A positive effect of green manures on the yields of other vegetable species was also found by Wadas [1998], Franczuk [2003], Kołota and Winiarska [2003]. However, according to Kuo and Jellum [2002] plants for green manures can have a negative influence on the subsequent crops. Raimbault et al. [1990] and Choi and Daimon [2008] pointed to allelopathy as the factor behind the unfavorable effect of some plants on subsequent crops.

Weather conditions in the study years influenced not only marketable yield of cobs but also its percentage share in the total yield. The highest was recorded for corn cultivated in 2007 (fig. 2). Significant differences were found between the cultivars examined in the study. In 2007 the marketable yield of 'Challenger F_1' and 'Sweet Wonder F_1' determined, respectively, 69.5 and 76.5% total yield of cobs. In 2005 the share of cob marketable yield in the total yield of both cultivars was similar and amounted to 69%. The lowest percentage share of marketable yield was found in 2006. It amounted to 58.5% for 'Challenger F_1', and 61% for 'Sweet Wonder F_1'.

Table 4. Mass of a cob with cover leaves (g)
Tabela 4. Masa kolby handlowej z liśćmi okrywowymi (g)

Organic manures Nawożenie organiczne	Years – Lata średnio dla dwóch odmian mean for two cultivars			Cultivar – Odmiana średnio dla lat mean for years		$\bar{x}$
	2005	2006	2007	Challenger F_1	Sweet Wonder F_1	
Control (NOM) Kontrola	282.3 ab**	253.4 abc	305.7 a	288.3 a	272.6 bc	280.5 ab
Farmyard manure (FYM) Obornik	342.2 d	280.9 c	354.0 b	330.0 cd	321.3 e	325.7 d
Phacelia 21.07 (PA1)* Facelia 21.07	354.9 d	265.7 bc	348.8 b	343.0 d	303.3 de	323.1 d
Phacelia 4.08 (PA2) Facelia 4.08	328.7 cd	229.4 ab	340.0 ab	312.8 bc	285.9 cd	299.4 bcd
Phacelia 18.08 (PA3) Facelia 18.08	286.2 abc	211.2 a	324.9 ab	293.5 ab	254.6 ab	274.1 ab
Amaranth 21.07 (AS1) Szarłat 21.07	330.3 cd	251.2 abc	354.3 b	343.2 d	280.7 cd	312.0 cd
Amaranth 4.08 (AS2) Szarłat 4.08	309.7 bcd	238.0 abc	309.5 ab	310.1 bc	261.3 abc	285.7 abc
Amaranth 18.08 (AS3) Szarłat 18.08	262.8 a	221.6 ab	301.7 a	284.0 a	240.1 a	262.1 a
Mean – Średnio	312.1 B	243.9 A	329.9 C	313.1 B	277.5 A	295.3

The percentage share of cob marketable yield in the total yield of corn cultivated following phacelia sown on the 21st of July (PA1) and farmyard manure was similar and amounted to 70.5–71.5%. Incorporation of phacelia sown 2 and 4 weeks later (PA2 and PA3) decreased the percentage share of cob marketable yield by 4.5% and 10% for

'Challenger F_1' and 3% and 6% for 'Sweet Wonder F_1', respectively. Corn cultivated following amaranth sown on the 21st of July (AS1) was characterized by a 68–69% share of cob marketable yield in the total yield. Delaying the sowing date of amaranth resulted in a decrease in the percentage share of marketable cobs of 'Challenger F_1' by 4.5% (AS2) and 7.6% (AS3), and 'Sweet Wonder F_1' by 2% (AS2) and 4% (AS3).

Cobs with significantly highest mass (329.9 g) were harvested in 2007 (tab. 4). In 2005 the mass of marketable cobs was by 5.4%, and in 2006 by 26% lower. In 2005 cobs with the highest mass were produced by corn cultivated after PA1 and FYM. The mass was similar for corn cultivated following AS1, AS2 and PA2. In 2006 FYM incorporation had the most beneficial influence on marketable cob mass. A similar effect was found for PA1, as well as AS1 and AS2. In 2007 AS1, PA1 and FYM had the most favourable effect on the mass of marketable cobs. Cobs with similar mass were harvested when corn had been cultivated after catch crops PA2, PA3 and AS2.

The mean mass of marketable cobs of 'Challenger F_1' amounted to 313.1 g and was by 11.3% higher than mean mass of cobs 'Sweet Wonder F_1'. Cobs of cv. 'Challenger F_1' had the highest mass following phacelia PA1 and amaranth AS1, the mass was similar after farmyard manure (FYM). 'Sweet Wonder F_1' produced the highest mass of cobs in the treatments with FYM, a similar mass being after phacelia catch crop PA1. Cobs harvested from PA2 and AS1 plots were characterized by the mass of cobs similar to PA1. Irrespective of corn cultivars, delaying the sowing date of catch crops decreased the mass of marketable cobs.

Table 5. The biological productivity of cob (%)
Tabela 5. Wydajność biologiczna kolb (%)

Organic manures Nawożenie organiczne	Years – Lata			Cultivar – Odmiana		$\bar{x}$
	2005	2006	2007	Challenger F_1	Sweet Wonder F_1	
	średnio dla dwóch odmian mean for two cultivars			średnio dla lat mean for years		
Control (NOM) Kontrola	62.1 a**	68.1 ab	72.2 a	63.2 abc	71.7 a	67.5 ab
Farmyard manure (FYM) Obornik	63.2 a	77.4 b	75.4 a	71.0 c	73.0 a	72.0 b
Phacelia 21.07 (PA1)* Facelia 21.07	60.5 a	76.1 b	75.0 a	67.1 abc	74.0 a	70.5 ab
Phacelia 4.08 (PA2) Facelia 4.08	63.7 a	73.8 b	73.3 a	68.5 bc	72.0 a	70.3 ab
Phacelia 18.08 (PA3) Facelia 18.08	61.7 a	70.1 ab	74.4 a	68.8 bc	68.7 a	68.7 ab
Amaranth 21.07 (AS1) Szarłat 21.07	66.2 a	68.9 ab	74.5 a	63.9 abc	75.8 a	69.9 ab
Amaranth 4.08 (AS2) Szarłat 4.08	66.4 a	61.7 a	71.4 a	62.8 ab	70.3 a	66.5 ab
Amaranth 18.08 (AS3) Szarłat 18.08	64.0 a	62.7 a	71.1 a	60.1 a	71.7 a	65.9 a
Mean – Średnio	63.5 A	69.9 B	73.4 B	65.7 A	72.2 B	68.9

The biological productivity of cobs was determined on the basis of the mass of kernels manually separated from the core (tab. 5). The highest amounted to 73.4% and was recorded for the cobs harvested in 2007. A similar productivity (69.9%) was determined for corn cobs harvested in 2006 while significantly lower (63.5%) for cobs harvested in 2005. In 2005 and 2007 the kind of organic manuring had no significant influence on the productivity level. In 2006, which was characterized by the highest rainfall in the corn growing season, after phacelia PA1, PA2 and FYM the biological productivity was significantly higher than after amaranth AS2 and AS3.

Cobs of 'Sweet Wonder F_1' were characterized by a higher (by 6.5%) mean biological productivity than cobs of 'Challenger F_1'. An interaction of organic manuring and corn cultivars was significant in terms of the biological productivity of cobs. 'Challenger F_1' cultivated after FYM produced cobs characterized by the highest productivity (71.0%). Cobs with similar parameters were harvested for corn cultivated after PA3, PA2, PA1, AS1 as well as the control NOM. The organic manuring applied did not influence the biological productivity of 'Sweet Wonder F_1' cobs.

CONCLUSIONS

1. Weather conditions in the successive study years were the factor which very much influenced the growth and yield of sweet corn. The worst weather conditions were in 2006. After drought months (June and July) in August was recorded heavy rainfalls coupled with high air temperature. This weather conditions contributed to the development of *Ustilago maydis* on tassels and cobs, which decreased the marketable yield of cobs.

2. Phacelia and amaranth catch crops sown on the 21st of July had the most positive effect on yield of corn which was similar to treatment with farmyard manure.

3. Delaying the sowing date of catch crop green manures contributed to decreased their fresh and dry matter yield.

4. Delaying the sowing date of catch crops resulted in regular decrease of yields, mean mass of cob and biological productivity of corn cobs cultivated after the catch crops. After phacelia and amaranth sown on the 4th of August there were recorded lower marketable yields of corn cobs than after farmyard manure which were significantly higher than the control without organic manuring.

5. Catch crops sown on the 18th of August were characterized by a significantly lower effect on yields compared with farmyard manure and catch crops sown on the 21st of July and 4th of August. It seems ineffective to apply catch crops at this date as yields of sweet corn sown after the catch crops did not differ compared with the corn yields cultivated without organic manuring.

6. 'Chalenger F_1' produced marketable cobs with higher mass but with lower biological productivity than 'Sweet Wonder F_1'.

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MIĘDZYPLONY FACELII I SZARŁATU W UPRAWIE KUKURYDZY CUKROWEJ. CZĘŚĆ I. PLONOWANIE KUKURYDZY

Streszczenie. W uprawie kukurydzy cukrowej zalecane jest nawożenie organiczne. Nie zawsze jest możliwe przyoranie obornika, co wynika z przyczyn ekonomicznych, produkcyjnych lub technicznych. Alternatywnym źródłem materii organicznej mogą być międzyplony przyorywane jako zielony nawóz. Eksperyment polowy przeprowadzono w środkowo-wschodniej Polsce. Badano wpływ międzyplonowych nawozów zielonych z facelii i szarłatu na plonowanie i wzrost kukurydzy cukrowej. Międzyplony wysiewano w trzech terminach: 21 lipca, 4 i 18 sierpnia; przyorywano pod koniec października. Kukurydzę cukrową uprawiano w pierwszym roku po nawożeniu organicznym. Efekty stosowania międzyplonowych nawozów zielonych porównano z obornikiem przyoranym w dawce 40 t·ha^{-1} oraz obiektem kontrolnym bez nawożenia organicznego. Największym plonem świeżej i suchej masy charakteryzowała się facelia posiana 21 lipca (33.6 t ha^{-1} św.m. i 6,3 t ha^{-1} s.m.) i 4 sierpnia (33,7 t ha^{-1} św.m. i 5,5 t ha^{-1} s.m.). Przesunięcie terminu siewu nasion facelii z 21 lipca na 18 sierpnia powodowało spadek ilości wytworzonej świeżej masy o 26%, suchej masy o 37%. Międzyplon szarłatu posiany 21 lipca wytworzył 26,2 t ha^{-1} świeżej i 5,3 t ha^{-1} suchej masy. Opóźnienie terminu siewu nasion szarłatu o 14 dni spowodowało spadek plonu świeżej i suchej masy o 18%, a o 28 dni o 55–58%. Działanie plonotwórcze obornika i międzyplonów facelii i szarłatu posianych 21 lipca było zbliżone. Średni plon handlowy kolb kukurydzy po oborniku wynosił 12,6 t ha^{-1}, po facelii 13,0 t ha^{-1}, a po szarłacie 11,5 t ha^{-1}. Przesunięcie terminu siewu międzyplonów o 2 i 4 tygodnie powodowało obniżkę plonów handlowych kolb kukurydzy odpowiednio o 16,2 i 28,9% w przypadku facelii oraz 12,8 i 24,4% w przypadku szarłatu. Średnia masa kolb handlowych kukurydzy uprawianej po oborniku, międzyplonie facelii i szarłatu z siewu 21 lipca oraz facelii z siewu 4 sierpnia była zbliżona. Wydajność biologiczna kolb kukurydzy po oborniku oraz testowanych międzyplonach (z wyjątkiem międzyplonu szarłatu z siewu 18 sierpnia) była podobna i kształtowała się na poziomie 66,5–72%. Odmiana ‘Chalenger F_1’ wykształciła kolby handlowe o większej masie, ale o niższej wydajności biologicznej niż odmiana ‘Sweet Wonder F_1’.

Słowa kluczowe: nawożenie organiczne, nawozy zielone, facelia, szarłat, kukurydza cukrowa, plon

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