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RESPONSE OF SWEET CORN CULTIVATED IN EASTERN POLAND TO DIFFERENT SOWING DATES AND COVERING WITH NON-WOVEN PP. PART I. CORN YIELDS

Robert Rosa

Siedlce University of Natural Sciences and Humanities

Abstract. The area under sweet corn is increasing in Poland due to increased consumption and suitability for cultivation in all regions of the country. However, sweet corn is sown on different dates in these regions. A field experiment was carried out in the years 2006-2008 at the Experimental Station in Zawady (52º03' N; 22º33' E). It was conducted to examine the effect of three sowing dates (26th April, 10th May and 24th May) and covering with non-woven PP on the yields of three sweet corn cultivars (Sweet Nugget F1, Rana F1 and Sheba F1). Weather conditions in 2007 and 2008 were more favourable for sweet corn growth compared with the year 2006, when high air temperatures were accompanied by very low precipitation from mid-June to late July. In 2007 and 2008, higher early, total and marketable yields were produced (by 29 and 13%, 50 and 44%, as well as 72 and 74%, respectively), and more ears were harvested (by 40-45%), too. Moreover, with a delay in the sowing date, kernel yields harvested in these years were twice as high as in 2006, when weather conditions contributed to more rapid maturation of ears and to an increase in the percentage share of early ear yield in the total yield. What is more, over the study years, on average both the total and marketable yields of ears increased with the delayed sowing, however only in the coldest 2008 this increase was significant. Unlike in 2008, delayed sowing in 2006 caused a decline in the number of ears and kernel yield. An application of non-woven PP increased the yields, the share of early yield in the overall yield of marketable ears and the number of ears. Covering was most beneficial in cooler years for the first sowing date. The highest ear and kernel yields were obtained for 'Sweet Nugget F1'. Differences between the cultivars were observed for the first sowing date.

Key words: corn yield structure, covering, number of ears, sowing date, yielding, *Zea mays* L. var. *saccharata* Korn.

Corresponding author – Adres do korespondencji: dr inż. Robert Rosa, Department of Vegetable Crops of Siedlce University of Natural Sciences and Humanities, B. Prusa 14, 08-110 Siedlce, e-mail: robert.rosa@uph.edu.pl

INTRODUCTION

Sweet corn (*Zea mays* L. var. *saccharata* Korn.) is a crop plant grown for fresh human consumption and for raw or processed material for the canned food industry [Bülent *et al*. 2006]. Both total production and value of processed sweet corn has increased by 60% over the last 25 years [Williams *et al*. 2006]. It is becoming more popular in Poland, too. At present, the area under sweet corn is 5-6 th ha [Bereś 2010]. The climate in most parts of Poland is beneficial for cultivation of this crop, though the most favourable conditions are in the south and south-western regions. Sweet corn is sown on different dates depending on the region. Producers choose different sowing dates to extend availability for fresh market [Waligóra and Kruczek 2003].

There is a shortage of Polish literature on the effect of the sowing date and covering on the growth and yields of sweet corn [Kubajak and Ostrowska 1983, Kossowski and Cierkoń 1986, Waligóra 1997, Waligóra and Kruczek 2003, Kruczek 2010]. What is more, there are almost no papers for eastern Poland. Earlier studies by Jabłońska-Ceglarek and Rosa [2005], Zaniewicz-Bajkowska *et al*. [2010], and Rosa *et al*. [2012a, b] indicated that the environmental conditions in eastern Poland are favourable for the cultivation of sweet corn. In these studies seeds were sown in mid-May or early June but the experiments did not include issues related to sweet corn sowing date.

The first two weeks of May is the recommended time for sowing sweet corn in most regions of Poland. The areas where spring arrives earlier (south-west and south-east) may have earlier sowing dates (late April) [Kunicki 2003]. Climate warming has resulted in an extended growing season in Poland, which makes it possible to make earlier sowings of many crop species. Over the last decades, the average annual air temperature in eastern Poland has increased by 1-1.5ºC, and growing season has been extended by about 10 days [Górski and Zaliwski 2002]. As the agri-climate is changing, it is possible to begin sowing sweet corn earlier in eastern Poland than it has been suggested so far. However, spring frosts may pose a threat to earlier sowings. As a result, it seems rational to cover sweet corn sown on earlier dates.

The objective of the present study was to determine the effect of different sowing dates and covering of crop with non-woven PP on the yields of extra-sweet cultivars of sweet corn, and to indicate the most appropriate time of sowing corn under the soil and climatic conditions of eastern Poland.

MATERIAL AND METHODS

The experiment was carried out in the years 2006–2008 at the Experimental Farm in Zawady, 115 km east of Warsaw (52º03' N; 22º33' E). According to the international system of FAO classification, the soil was Luvisol (LV) [World Reference… 1998]. The soil organic matter content averaged 1.5%, and its humus horizon reached the depth of 30-40 cm. Over the years of the experiment, nitrogen (NO_3 + NH_4) content oscillated between 39 and 63, phosphorus (P) 51 and 89, potassium (K) 80 and 105 $mg \cdot dm^{-3}$ in soil, whereas pH in H_2O from 5.6 to 6.0.

The experiment was established as a split-block-split-plot design with three replications. It studied the effect of different sowing dates (26th April, 10th and 24th May) and non-woven PP covering on the yields of sweet corn cultivars. Three early extra-sweet corn cultivars were examined: Sweet Nugget F1 (Agri-Saaten), Rana F1

(since 2010 'NOA F1') (Pop Vriend Seeds), Sheba F1 (Seminis Vegetable Seeds), all registered as vegetable cultivars. Earliness was the basic selection criterion. Compared with the rest of the country, the study area has got a shorter growing season with lower temperatures, particularly at night, occurring earlier in the summer. Such conditions may be favourable for poorer ear set and lower yields. The respective growing seasons from sowing to the milk stage, specified by breeders of the corn cultivars, lasted 70-83, 75-82 and 70-73 days. However, in the study areas they were extended, due to weather conditions, and lasted from 84 to 106 days, depending on the study year, sowing date and cultivation method (Table 1). Detailed results of the study examining the effect of the above-mentioned factors on the length of sweet corn growing season have already been presented [Rosa 2013]. While 'Rana F1' and 'Sheba F1', though still successfully cultivated in other European countries, are no longer included in the Polish National List of Vegetable Plant Varieties, only 'Sweet Nugget F1' was registered in 2013. The field experiment was set up after winter triticale. Ploughing was carried out in autumn, in the years preceding cultivation of corn. At the same time, farmyard manure at the rate of 30 $Mg \cdot ha^{-1}$ was incorporated. In spring, two weeks before sowing the seeds on the successive dates on the suitable combinations of soil, tillage was carried out, and mineral fertilizers were applied at the following rates: 60 kg N, 50 kg P_2O_5, 180 kg K_2O per 1 ha. Mineral fertilizers were in the form of urea, granular superphosphate and 60% potassium chloride.

The seeds of sweet corn were sown on three dates with 14-days intervals, starting from 26th of April, with the spacing of 65 × 25 cm. After sowing, the right plots were covered with non-woven polypropylene (PP) (17 $g \cdot m^{-2}$) for three-four weeks. Soil temperature of the covered and non-covered plots was measured daily (8 am and 2 pm) at a depth of 10 cm. Soil temperature was measured using an automatic electronic soil thermometer PT-401 produced by Elmetron®.

When sweet corn plants were 20 cm high, top dressing with nitrogen (60 kg $N \cdot ha^{-1}$) in the form of ammonium nitrate was applied. The only cultivation practice was manual removal of weeds carried out twice in the initial stages of development.

Ears were picked manually 2 or 3 times in the milk stage of kernels depending on the study year, sowing date and cultivation method. The dates and duration of harvest are presented in Table 1.

The area of each plot for harvest was 20 m^2. During the harvest the following parameters were determined:

- early leafless ear yield ($Mg \cdot ha^{-1}$) defined as the yield of marketable ears from the first harvest,
- total and marketable leafless ear yield ($Mg \cdot ha^{-1}$) according to the norm PN-R-75377:1996,
- number of marketable ears per plant and per hectare.

Thirty marketable ears were sampled randomly from every combination to obtain kernels. The average kernel weight per ear and marketable ear number per hectare were used to calculate kernel yield ($Mg \cdot ha^{-1}$).

The results of the experiment were statistically analysed with ANOVA at $F \leq 0.05$ and $F \leq 0.01$ following the mathematical model for the split-block-split-plot design. Significance of differences was determined by Tukey test at the significance level of $P \leq 0.05$ [Winer *et al*. 1991].

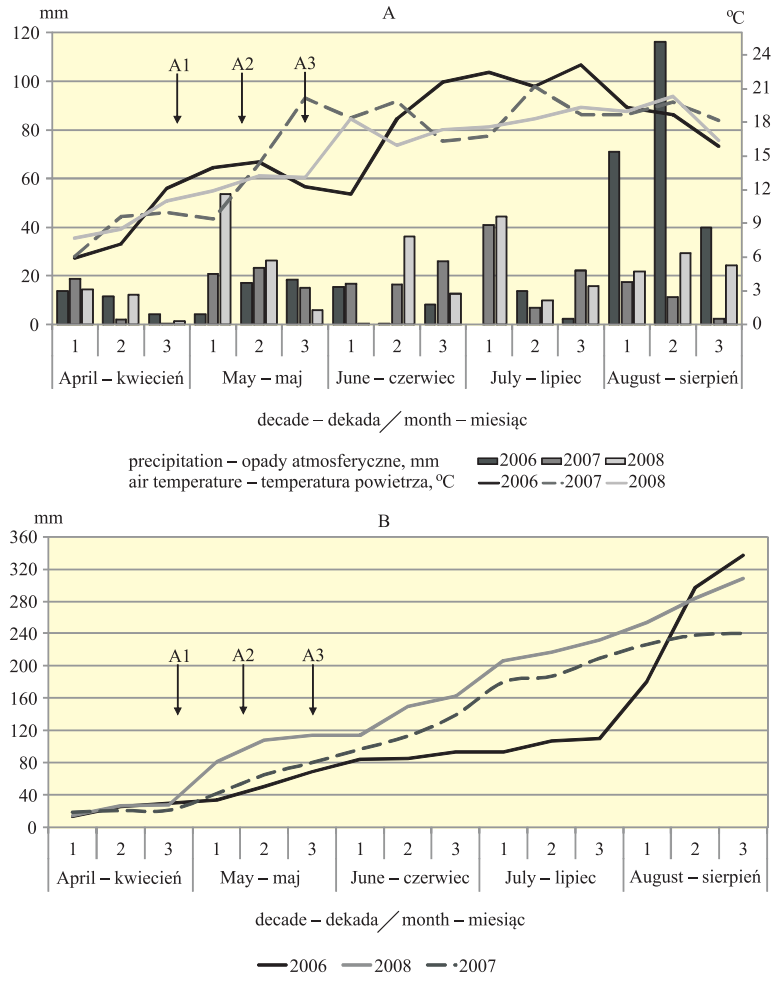
Table 1. Date of ear harvests and length of growing season of sweet corn depending on the examined factors
Tabela 1. Terminy zbioru kolb oraz długość okresu wegetacji kukurydzy cukrowej w zależności od badanych czynników

Sowing date Termin siewu	Covering Osłanianie	Year – Rok		
		2006	2007	2008
April 26th 26 kwietnia	no covering baz osłaniania	1st-5th August – 1-5 sierpnia 98 SN, 96 Ra, 98 Sh*	6th-11th August – 6-11 sierpnia 103 SN, 101 Ra, 103 Sh	10th-16th August – 10-16 sierpnia 106 SN, 106 Sh, 105 Ra
	non-woven PP agrowłóknina	25th-28th July – 25-28 lipca 89 SN, 90 Sh, 90 Ra	30th July – 5th August – 30 lipca-5 sierpnia 94 SN, 96 Sh, 95 Ra	1st-6th August – 1-6 sierpnia 96 SN, 98 Sh, 97 Ra
May 10th 10 maja	no covering baz osłaniania	9th-13th August – 9-13 sierpnia 92SN, 92 Sh, 90 Ra	13th-19th August – 13-19 sierpnia 96 SN, 96 Sh, 94 Ra	15th-22nd August – 15-22 sierpnia 97 SN, 98 Sh, 96 Ra
	non-woven PP agrowłóknina	2nd-5th August – 2-5 sierpnia 83 SN, 84 Sh, 84 Ra	6th-10th August – 6-10 sierpnia 87 SN, 88 Sh, 88 Ra	6th-13th August – 6-13 sierpnia 87 SN, 88 Sh, 88 Ra
May 24th 24 maja	no covering baz osłaniania	20th-30th August – 20-30 sierpnia 88 SN, 87 Sh, 87 Ra	24th August – 1st September – 24 sierpnia-1 września 94 SN, 90 Sh, 91 Ra	22nd-28th August – 22-28 sierpnia 91 SN, 88 Sh, 90 Ra
	non-woven PP agrowłóknina	13th-22nd August – 13-22 sierpnia 80 SN, 81 Sh, 82 Ra	20th-26th August – 20-26 sierpnia 87 SN, 89 Sh, 89 Ra	18th-25th August – 18-25 sierpnia 85 SN, 87 Sh, 87 Ra

* length of the growing season of sweet corn cultivars (in days) counted from the sowing time to the beginning of ear harvest – długość okresu wegetacji odmian kukurydzy cukrowej (w dniach), liczona od momentu wysiewu nasion do początku zbioru kolb
SN – Sweet Nugget F_1, Ra – Rana F_1, Sh – Sheba F_1

The weather in the study area is rather severe and influenced by the continental climate. Yearly precipitation ranges from 500 to 550 mm, reaching 650 mm in wet years, and air temperature averages around 7.5°C. The growing season extends from 200 to 210 days.

Weather conditions in the study years were differentiated. The lowest rainfall in the April-August period was found in 2007 (240.6 mm), the highest one in 2006 (337.2 mm) (Fig. 1).



A1, A2, A3 – the sowing dates of sweet corn, 26th April, 10th and 24th May, respectively
– terminy siewu kukurydzy cukrowej odpowiednio 26 kwietnia, 10 i 24 maja

Fig. 1. Average temperatures and total rainfall (A) as well as cumulative precipitation (B) in the period of study

Rys. 1. Średnie temperatury powietrza i sumy opadów atmosferycznych (A) oraz skumulowana wielkość opadów (B) w okresie badań

In 2007 the quantity of rainfall was the lowest but its distribution was very regular. The worst was 2006, in which after very dry June and July, heavy rainfall was noted in August (227.6 mm). This was 63.6% the amount of rainfall during the period from April to September. However, the precipitation did not affect corn yields because the plants had already reached the milk stage of kernels (the first and second sowing date) or were in the stage of ear maturation (the third sowing date). According to Szulc and Kruczek [2008], sweet corn requires less water, 50-100 mm, when ears are maturing. The year 2008 was characterized by lowest air temperatures, an average temperature for the period April-September amounted to 14.7°C. In this year, among all the study years, air temperature distribution was the most regular, without sudden fluctuations. 2006 was the warmest year. Average air temperatures over the growing season of corn amounted to 15.8°C. After the cold first half of April, the second half of the month and May were very warm. At the turn of May and June there occurred fortnight cooling, and then air temperatures suddenly increased. From mid-June until mid-August it was very hot. 2007 was characterized by very hot second half of the spring (from mid-May until mid-June) and cool beginning of the summer.

Weather conditions during the growing season have the greatest influence on the growth and development of corn, especially the amount and distribution of air temperatures. For rapid and regular emergence, temperature has to be above 10°C and soil moisture has to be moderate [Kovaćecić and Culjat 1993, Stone *et al*. 1999].

Values of Sielianinov's hydrothermal coefficient were calculated in order to present an overall characterisation of weather conditions during the growing season of sweet corn:

$$k = \frac{\mathrm{P}}{\sum \mathrm{t} \cdot 0.1}$$

where:

P – total monthly precipitation (mm),

Σt – total monthly air temperatures > 0°C (Table 2).

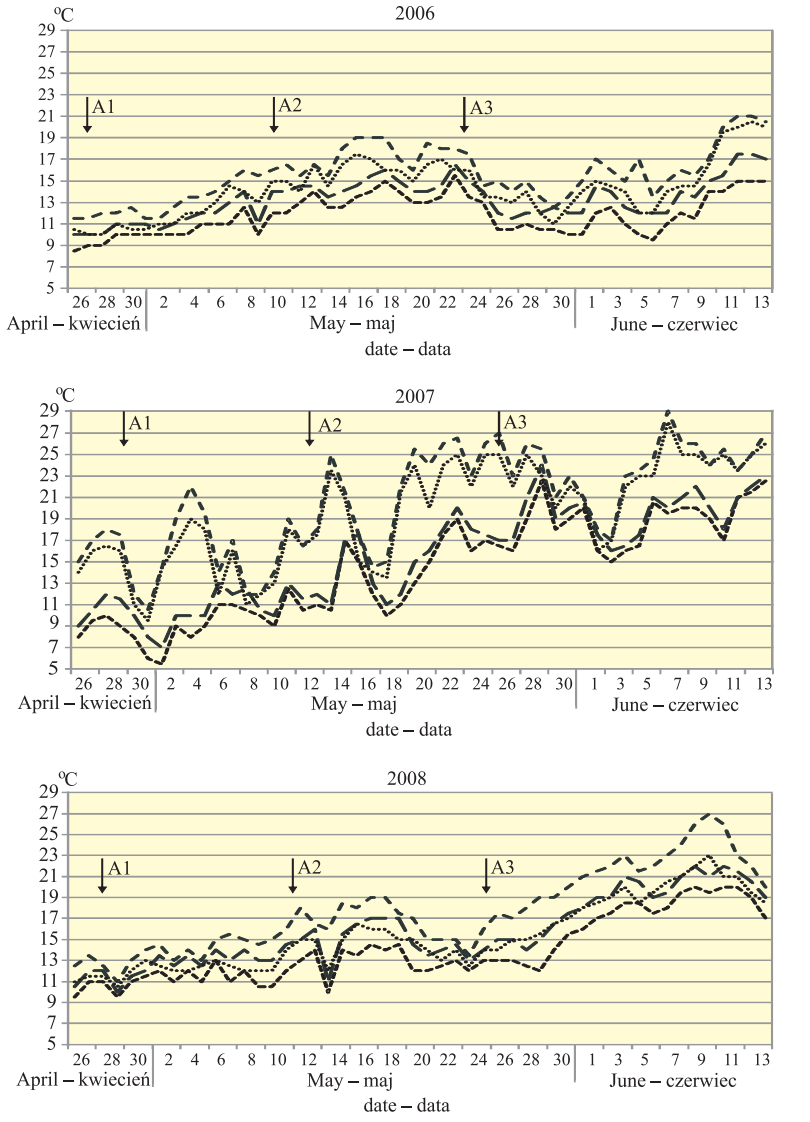
Table 2. Selyaninov's hydrothermal coefficient
Tabela 2. Współczynnik hydrotermiczny Sielianinowa

Month – Miesiąc	Year – Rok		
	2006	2007	2008
April – kwiecień	1.18	0.82	1.04
May – maj	0.97	0.79	2.14
June – czerwiec	0.45	1.31	2.24
July – lipiec	0.24	1.35	2.24
August – sierpień	4.21	1.04	0.72

< 0.50 – drought – susza, 0.51-1.00 – semi-drought – półsusza, 1.01-2.00 – good humidity – dobre uwilgotnienie, > 2.01 – high humidity – duże uwilgotnienie [Waligóra *et al*. 2013]

RESULTS AND DISCUSSION

The use of non-woven PP covers caused an increase in soil temperature at a depth of 10 cm (Fig. 2).



A1, A2, A3 – the sowing dates of sweet corn, 26th April, 10th and 24th May, respectively – terminy siewu kukurydzy cukrowej odpowiednio 26 kwietnia, 10 i 24 maja

Fig. 2. Soil temperature measured at 8 am and 2 pm at the 10-cm depth when sweet corn was covered and non-covered

Rys. 2. Temperatura gleby na głębokości 10 cm mierzona o godzinie 8^{00} i 14^{00} w uprawie kukurydzy cukrowej pod osłoną i bez osłony

The highest temperatures were recorded for both covered and non-covered soils in 2007. The average temperature from 26th April to 14th June was 15.7 and 20.9ºC, at 8 am and 2 pm, respectively. Compared with the remaining study years, 2007 had the hottest second half of spring, thus the soil temperature was higher, too. Also, the differences between temperatures measured at 8 am and 2 pm were the greatest. The lowest temperatures were recorded in 2006; the average temperature over the study period was 15.1ºC at 8 am and 16.8ºC at 2 pm. Despite the fact that 2006 was warm, the second half of May and early June were the coolest months of all the study years. When the soil was covered with non-woven PP, soil temperature increased by 0.5-3.0ºC at 8 am and 0.5-5.0ºC at 2 pm. On average, soil temperature increased most after covering in 2008: 0.8ºC at 8 am and 2.4ºC at 2 pm. Increased air and soil temperatures under non-woven PP have been reported by other authors, e.g.: Hamouz *et al*. [2006], Wadas and Kosterna [2007]. Covers reduce evaporation, catch and retain sunlight during the day and reduce heat loss during the night, which produces a small-scale greenhouse effect. Under such conditions plants have better conditions of growth [Kwabiah 2004, Majkowska-Gadomska 2010].

Table 3 presents the effect of the main factors and their interaction on the examined characteristics of sweet corn.

Table 3. The effect of main factors and their interaction on the examined sweet corn traits
Tabela 3. Wpływ czynników głównych oraz ich interakcji na badane cechy kukurydzy cukrowej

Factor – Czynnik	EY[1]	EY%	TY	MY	NEP	NEH	KY
Year – Rok (Y)	**	**	**	**	**	**	**
Sowing date – Termin siewu (A)	**	**	**	**	*	*	**
Y × A	**	**	**	**	**	**	**
Covering – Osłanianie (B)	**	**	**	**	**	*	**
Y × B	**	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni
A × B	**	*	*	**	ns – ni	ns – ni	ns – ni
Y × A × B	**	**	**	**	*	**	**
Cultivar – Odmiana (C)	**	**	**	*	ns – ni	ns	**
Y × C	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni
A × C	*	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni
Y × A × C	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni
B × C	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni
Y × B × C	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni
A × B × C	**	**	**	**	*	**	**

[1] EY – early yield of ears – plon wczesny kolb, EY% – share of early yield in the overall yield of marketable ears – udział plonu wczesnego kolb w plonie kolb handlowych, TY – total yield of ears – plon kolb ogółem, MY –yield of marketable ears – plon kolb handlowych, NEP – number of marketable ears per plant – liczba kolb handlowych na roślinie, NEH – number of marketable ears per hectare – liczba kolb handlowych na 1 ha, KY – kernel yield – plon ziarna

* significant at $P \leq 0.05$ – istotne przy $P \leq 0,05$

** significant at $P \leq 0.01$ – istotne przy $P \leq 0,01$

ns – ni – non-significant – nieistotne

The highest early ear yield, defined as the yield of marketable ears from the first harvest, was achieved in 2007. It was the lowest in 2006 (Table 4). However, the highest share of early yield in the overall yield of marketable ears (66.4%) was found in 2006 and the lowest in 2008 (41.9%). It was the result of the effect of weather

conditions over the study years. Waligóra and Kruczek [2003], Khan *et al*. [2009], and Waligóra *et al*. [2010] found that in warmer years with lower rainfall, sweet corn ears mature more rapidly and the harvest is shorter, which was also confirmed in the present study. In 2006, when high air temperatures were accompanied by very low rainfall from mid-June to late July, ears matured very rapidly, whereas in 2008, which was cooler and wet, sweet corn ears matured more slowly. As the sowing date of sweet corn was delayed, the early ear yield and its share in the overall yield of marketable ears increased. The increase was from 47.6% (for corn sown on 26th April) to 57.6% (for corn sown on 24th May). However, corn response to delayed sowing dates varied over the study years.

Table 4. Early leafless ear yield depending on the sowing date and covering of sweet corn (average for the examined cultivars), Mg·ha^{-1}

Tabela 4. Plon wczesny kolb odkoszulkowanych w zależności od terminu siewu i osłaniania kukurydzy cukrowej (średnio dla badanych odmian), Mg·ha^{-1}

Sowing date Termin siewu	Covering Osłanianie	Early ear yield Plon wczesny kolb				Share of early yield in the overall yield of marketable ears Udział plonu wczesnego kolb w plonie kolb handlowych, %			
		year – rok			mean średnia	year – rok			mean średnia
		2006	2007	2008		2006	2007	2008	
April 26th 26 kwietnia	no covering bez osłaniania	4.82a*	5.00a	3.01a	4.28a	55.7a	46.2a	36.1a	46.0a
	non-woven PP agrowłóknina	4.73a	7.21b	4.66a	5.53b	60.1a	49.8a	37.7a	49.2a
	mean – średnia	4.78A	6.10A	3.84A	4.91A	57.9A	48.0AB	36.9A	47.6A
May 10th 10 maja	no covering bez osłaniania	5.42a	5.48a	6.62a	5.84a	69.3a	43.8a	41.0a	51.3a
	non-woven PP agrowłóknina	6.17a	6.88a	5.86a	6.30a	69.0a	47.5a	41.4a	52.7a
	mean – średnia	5.80B	6.18A	6.24B	6.07B	69.1B	45.7A	41.2AB	52.0B
May 24th 24 maja	no covering bez osłaniania	3.70a	7.27a	4.13a	5.03a	70.2a	52.2a	37.0a	53.1a
	non-woven PP agrowłóknina	5.75b	7.56a	10.45b	7.92b	74.0a	54.1a	58.1b	62.1b
	mean – średnia	4.73A	7.41B	7.29C	6.48C	72.1B	53.2B	47.5B	57.6C
Mean Średnia	no covering bez osłaniania	4.65a	5.92a	4.59a	5.05a	65.0a	47.4a	38.0a	50.2a
	non-woven PP agrowłóknina	5.55b	7.22b	6.99b	6.59b	67.7a	50.5a	45.7b	54.7b
Mean – Średnia		5.10*A***	6.57*C*	5.79*B*	5.82	66.4*C*	49.0*B*	41.9*A*	52.4

* a, b, A, B – values in columns followed by the same letters do not differ significantly at $P \leq 0.05$ – wartości w kolumnach oznaczone tymi samymi literami nie różnią się istotnie przy $P \leq 0,05$

** *A, B* – values in rows followed by the same letters do not differ significantly at $P \leq 0.05$ – wartości w wierszach oznaczone tymi samymi literami nie różnią się istotnie przy $P \leq 0,05$

In 2006, the share of early yield in the overall marketable yield harvested for the first sowing date was significantly lower compared with the remaining dates. Corn harvest for the last sowing date in 2007 and 2008 produced a significantly higher share of early ear yield compared with the second and first sowing date, respectively. This study indicated that, as the sowing date of sweet corn was delayed, the share of early ear

yield in the overall yield increased because ears had matured more rapidly and, as a result, their harvest was shorter. It was caused by the influence of air temperatures during the growing season. The share of early yield in the overall yield increased more noticeably due to the delayed sowing of sweet corn in the warmer years, compared with the cooler years.

Sweet corn covered with non-woven PP produced significantly higher early ear yields, and had a significantly higher share of early yield in the overall yield of marketable ears, compared with non-covered corn (Table 4). In the cooler and wetter years, the increase was greater but it was only significant in 2008. A statistically significant increase in the share of early yield in the overall yield of marketable ears due to covering was found for the third sowing date of sweet corn. The effects of the aforementioned factors were most visible in the cool and wet 2008.

Sweet corn yields were similar in 2007 and 2008 and they amounted to 14.61-15.39 and 13.32-13.48 $Mg \cdot ha^{-1}$ for the total yield of ears and yield of marketable ears, respectively (Table 5).

Table 5. Total marketable and leafless ear yield depending on the sowing date and covering of sweet corn (average for the examined cultivars), $Mg \cdot ha^{-1}$

Tabela 5. Plon odkoszulkowanych kolb ogółem oraz kolb handlowych w zależności od terminu siewu i osłaniania kukurydzy cukrowej (średnio dla badanych odmian), $Mg \cdot ha^{-1}$

Sowing date Termin siewu	Covering Osłanianie	Total ear yield – Plon kolb ogółem				Marketable ear yield Plon kolb handlowych			
		year – rok			mean średnia	year – rok			Mean Średnio
		2006	2007	2008		2006	2007	2008	
April 26th 26 kwietnia	no covering bez osłaniania	10.78a*	12.03a	9.68a	10.83a	8.70a	10.69a	8.41a	9.27a
	non-woven PP agrowłóknina	9.96a	17.66b	13.30b	13.64b	7.83a	15.18b	12.51b	11.84b
	mean – średnia	10.37A	14.85A	11.49A	12.24A	8.26A	12.94A	10.46A	10.55A
May 10th 10 maja	no covering bez osłaniania	9.08a	14.51a	17.71a	13.77a	7.85a	12.43a	16.13a	12.13a
	non-woven PP agrowłóknina	10.62a	15.93a	15.40a	13.98a	8.95a	14.38a	14.14a	12.49a
	mean – średnia	9.85A	15.22A	16.56B	13.88B	8.40A	13.40A	15.13B	12.31B
May 24th 24 maja	no covering bez osłaniania	9.44a	16.54a	13.26a	13.08a	5.28a	14.05a	11.06a	10.13a
	non-woven PP agrowłóknina	11.49a	15.66a	18.69b	15.28b	7.81a	14.16a	17.67b	13.21b
	mean – średnia	10.47A	16.10A	15.97B	14.18B	6.54A	14.11A	14.36B	11.67B
Mean Średnio	no covering bez osłaniania	9.77a	14.36a	13.55a	12.56a	7.28a	12.39a	11.86a	10.51a
	non-woven PP agrowłóknina	10.69a	16.41a	15.80a	14.30b	8.19a	14.57a	14.77a	12.51b
Mean – Średnia		10.23*A***	15.39*B*	14.67*B*	13.43	7.74*A*	13.48*B*	13.32*B*	11.51

*, ** explanations as in Table 4 – objaśnienia jak w tabeli 4

Significantly lower yields were harvested in 2006, as the total yield was by 33.5% lower, and the yield of marketable ears was by 42% lower than in the remaining study years. Waligóra *et al*. [2010] confirmed that years with higher precipitation and lower air temperatures during the growing season provide better conditions for sweet corn growth and yield production. According to Maddoni *et al*. [1998] and Öktem *et al*.

[2003], lower ear yields of ears are due to high air temperatures and water shortages in the soil, in particular during flowering, emergence of silks on ears and filling of kernels with milk, which was confirmed in this study. In 2006, the water status in the soil was disturbed from late July to late August, as indicated by values of Sielianinov's coefficient (Table 2). Heavy rainfall in August did not contribute to increased corn ear yields, including plots harvested in late August. Similar findings for Poland were reported by Waligóra and Weber [2010], Rosa *et al*. [2012a], and Waligóra *et al*. [2013]. Unfavourable thermal conditions and water shortages during flowering and ear formation, influence the yield of corn kernel [Kunicki 2003, Kruczek 2005, Gołębiewska 2006, Ptaszyńska and Sulewska 2007]. Previous studies on sweet corn yield carried out by the author in eastern Poland indicated that ear yields are predominantly determined by precipitation totals in June [Rosa *et al*. 2012a]. Similar findings for western Poland were reported by Waligóra *et al*. [2010], whereas Sulewska [2004] indicated that precipitation in June and July is critical for corn.

Sowing date of sweet corn influenced total yields and yields of marketable ears, and the effect of this factor depended on the weather pattern in each study year (Table 5). A significant effect of the sowing date on corn yields was found in the cooler and wet 2008. In 2006, the total yields of ears harvested for individual sowing dates were on a similar level. The yield of marketable ears of corn sown on 24th May was by 20% lower compared with the first two sowing dates, and the difference was not statistically significant. In 2007, when the spring was hot, the summer was cool and the rainfall was evenly distributed, the yields of ears harvested were similar for all the sowing dates. Waligóra and Kruczek [2003] and Kruczek [2010], who cultivated sweet corn in western Poland, reported a consistent decline in yields of ears as the sowing date was delayed, regardless of the weather patterns in the study years. In north central USA, delayed sowing of sweet corn (four dates between 14th April and 14th June) did not affect yields of ears in a cool year but when the weather was hot, the yields declined [Williams 2008]. In the studies in different places worldwide, delayed sowing of sweet corn was followed by increased yields of ears, regardless of weather conditions [Kwabiah 2004, Öktem *et al*. 2004, Farsiani *et al*. 2011]. According to Kunicki [2003], the first two weeks of May are the best period for sowing sweet corn in most regions of Poland. In general, the longer are the delays in sowing, the lower are the yields produced. It is due to decreasing average daily temperatures and cooler nights from mid-July. However, studies conducted in eastern Poland indicated that, even if sweet corn is sown in early June, it is still possible to obtain good yields of marketable ears ranging from 14 to18 Mg·ha^{-1} [Jabłońska-Ceglarek and Rosa 2005].

Higher sweet corn yields occurred when plants had been covered with non-woven PP (Table 5). The total yield and yield of marketable ears increased on average by 14 and 19%, respectively, compared with the non-covered corn. The effect of covering depended on the study year and sowing date. In the cooler years, the effect of this factor was more visible. Significantly higher yields of ears were recorded in 2007 for the first sowing date, and in 2008 for the first and third sowing date. Kwabiah [2004] applied plastic mulch in the cultivation of sweet corn, and found a significant increase in yields for each of the three sowing dates. The highest yields of marketable ears were obtained for the first and second sowing date. However, no significant interaction between the studied factors was found. According to Tarara [2000], high air temperature and intense sunlight have an adverse effect on sweet corn growth and yields. Hence, in hot years, when a delayed sowing date is preferable, it is better to grow corn without covering.

A major benefit associated with the use of non-woven PP was the increase in soil temperature at the root zone which is ultimately reflected in a higher plant growth, yields and earlier harvest, compared to soil without covering. Plant roots are known to be less adaptable to extreme fluctuations in soil temperature than shoots are to air temperature [Paulsen 1994]. Therefore, maintaining warm temperature at the root zone, particularly under conditions of low ambient temperature, has a positive effect on physiological processes in roots, such as uptake of water and mineral nutrients [Zobel 1992]. What is interesting in the present study is the fact that yields were higher when corn had been sown on the third date and covered with non-woven PP in 2008. On the non-covered plots the yields were by almost 40% lower, probably due to lower temperatures in spring, which slowed down the process of soil warming, and low rainfall from 20th May to 15th June. The conditions may have had an adverse effect on germination of seeds and initial growth of the non-covered corn.

Weather conditions in the study years affected the number of ears per plant and per hectare (Table 6) In 2006, the number averaged 0.8 marketable ear per plant, which was by 20% less than in 2007 and 2008. Studies by Moser *et al*. [2006] and Farsiani *et al*. [2011] indicated that the number of ears per plant increases when the moisture status of the soil improves, but falls dramatically due to the water stress. Cakir [2004] and Brewbaker [2008] reported that water shortage caused reduction in ear per plant during the sensitive tasselling and ear formation stages. Payero *et al*. [2006] indicated that moisture tension in the soil during any of the phenological stages of the plant causes reduction in growth, delayed maturity and decreased crop yield, which was confirmed in the present study discussed here. In 2006, water status of the soil was disturbed and unfavourable for corn, particularly during the stages of tasselling and ear formation.

Regardless of the study year, significantly fewer marketable ears were formed for the third sowing date compared with the remaining dates. However, it was observed that in the cooler years (2008 in particular) when sowing of corn was delayed, more marketable ears were produced per plant. More ears were harvested from plots of sweet corn for the second date in 2007 and for the third date in 2008. In the studies by Farsiani *et al*. [2011] a different number of ears per plant was obtained depending on the date of sowing. However, it is difficult to unequivocally indicate dependence between delaying sowing date and an increase or decrease in the number of ears per plant.

Covering after sowing the seeds had an influence on an increase in the average number of ears per corn plant. A significant impact of covering sweet corn was observed for the first sowing date in 2007 and 2008.

The average number of ears per 1 ha in the study years was 52,623 (Table 6). In 2006, the number was by around 29 and 31% lower than in 2007 and 2008, respectively. Also in 2006, delayed sowing of sweet corn resulted in decreased numbers of ears per 1 ha. The number of ears harvested for the third date was significantly lower compared with the remaining dates, the difference being 28.5 and 27%, respectively. In 2007 and 2008, sowing date did not affect the number of ears per area unit, whereas in 2006 the number of ears might have been decreased due to a colder spell in late May and early June followed by a rapid increase in air temperature along with very low precipitation. Such conditions had a negative influence on the initial growth and generative development of corn sown on 24th May which, in consequence, set fewer ears. Waligóra and Kruczek [2003] obtained the highest number of ears per 1 ha after sugar maize sown on 4th May.

Table 6. Number of marketable ears depending on the sowing date and covering of sweet corn (average for the examined cultivars)
Tabela 6. Liczba kolb handlowych w zależności od terminu siewu i osłaniania kukurydzy cukrowej (średnio dla badanych odmian)

Sowing date Termin siewu	Covering Osłanianie	Number of marketable ears per plant Liczba kolb handlowych na roślinie				Number of marketable ears per hectare Liczba kolb handlowych na 1 ha			
		year – rok			mean średnia	year – rok			mean średnia
		2006	2007	2008		2006	2007	2008	
April 26th 26 kwietnia	no covering bez osłaniania	0.9a*	0.9a	0.9a	0.9a	47602a	48715a	49881a	48732a
	non-woven PP agrowłóknina	0.8a	1.1b	1.1b	1.0a	43105a	62951b	65044b	57033a
	mean – średnio	0.9B	1.0A	1.0A	1.0B	45353B	55833A	57463A	52883AB
May 10th 10 maja	no covering bez osłaniania	0.8a	1.0a	1.0a	0.9a	42082a	59304a	60844a	54077a
	non-woven PP agrowłóknina	0.9a	1.1a	1.0a	1.0a	47011a	63903a	57022a	55979a
	mean – średnio	0.9B	1.1B	1.0A	1.0B	44547B	61603A	58933A	55028B
May 24th 24 maja	no covering bez osłaniania	0.5a	0.9a	1.0a	0.8a	26694a	54182a	61967a	47614a
	non-woven PP agrowłóknina	0.7b	1.0a	1.1a	0.9a	38167b	56479a	62261a	52302a
	mean – średnio	0.6A	1.0A	1.1B	0.9A	32431A	55330A	62114A	49958A
Mean Średnia	no covering bez osłaniania	0.7a	0.9a	1.0a	0.9a	38793a	54067a	57564a	50141a
	non-woven PP agrowłóknina	0.8a	1.1a	1.1a	1.0b	42761a	61111a	61443a	55105b
Mean – Średnia		0.8*A***	1.0*B*	1.0*B*	0.9	40776*A*	57589*B*	59503*B*	52623

*, ** explanations as in Table 4 – objaśnienia jak w tabeli 4

Sowing date delayed by two weeks significantly decreased the number of ears per 1 ha compared to sowing at the beginning of May. Also Kruczek [2010] found a gradual decrease in the number of ears per 1 ha due to delayed sowing (from 27th April to late May) regardless of the study year. On the contrary, Kara [2011] and Kara and Atar [2013], who conducted their study in Turkey, reported a significant increase in the number of sweet corn ears per 1 ha when sowing was delayed in each study year. An application of covers in the initial stages of corn setting made it possible to obtain, on average, by around 10% more ears compared with the cultivation without covering. The number of ears increased significantly for the last sowing date in 2006, and for the earliest sowing date in 2007 and 2008.

Weather conditions in 2007 and 2008 positively affected sweet corn kernel yields which were almost twice as high as in 2006 (Table 7). The effect of the sowing date on kernel yield varied over the years. The yield was significantly higher for the first vs third sowing date, whereas in 2008 the opposite was true. Moreover, kernel yield harvested for the second and third date was significantly higher compared with the first date. Statistical analysis indicated that, regardless of the study year, kernel yields of sweet corn sown on 10th and 24th May were significantly higher compared with the first sowing date (26th April). Studies conducted in other parts of the world have indicated a varying response of sweet corn to delayed sowing. In their studies carried out in Iran, Farsiani *et al*. [2011] found a gradual increase in kernel yields due to delayed sowing of sweet corn, whereas Panahi *et al*. [2010] reported no significant differences.

Table 7. Kernel yield depending on the sowing date and covering of sweet corn (average for the examined cultivars), $Mg \cdot ha^{-1}$

Tabela 7. Plon ziarna w zależności od terminu siewu i osłaniania kukurydzy cukrowej (średnio dla badanych odmian), $Mg \cdot ha^{-1}$

Sowing date Termin Siewu	Covering Osłanianie	Year – Rok			Mean Średnia
		2006	2007	2008	
April 26th 26 kwietnia	no covering bez osłaniania	5.30a*	6.62a	4.39a	5.43a
	non-woven PP agrowłóknina	4.74a	9.53b	6.99b	7.09b
	mean – średnia	5.02B	8.08A	5.69A	6.26A
May 10th 10 maja	no covering bez osłaniania	3.99a	7.22a	10.18a	7.13a
	non-woven PP agrowłóknina	4.85a	8.55a	9.37a	7.59a
	mean – średnia	4.42AB	7.89A	9.78B	7.36B
May 24th 24 maja	no covering bez osłaniania	2.49a	8.99a	8.47a	6.65a
	non-woven PP agrowłóknina	3.97a	9.23a	9.74a	7.65a
	mean – średnia	3.23A	9.11A	9.11B	7.15B
Mean Średnia	no covering bez osłaniania	3.92a	7.61a	7.68a	6.40a
	non-woven PP agrowłóknina	4.52a	9.10a	8.70a	7.44b
Mean – Średnia		4.22*A***	8.36*B*	8.19*B*	6.92

*, ** explanations as in Table 4 – objaśnienia jak w tabeli 4

In Illinois, the USA, Williams [2008] obtained lower kernel yields as sowing dates of sweet corn were delayed. In turn, Khan *et al*. [2011], who examined five sowing dates of sweet corn in Pakistan, observed a decline in kernel yields for dates 1-3 followed by an increase for dates 3-4. In light of these findings it can be assumed that changes in corn kernel yield due to delayed sowing are affected by weather conditions in the study year as well as local environmental conditions.

Application of covers increased sweet corn kernel yields, the relationship being particularly visible for the first sowing date in 2007 and 2008, probably due to colder weather from 20th April to mid-May, compared with 2006. Covering of sweet corn during this period produced better thermal conditions, seeds germinated more rapidly and young plants had better conditions of development compared with the non-covered cultivation. The result was an increased number of plants per unit area, greater number of ears set on plants, heavier kernels in ears (though not significantly) and, in consequence, higher kernel yields. More favourable conditions created by covers contributed to higher ear yields, which was explained above. Kwabiah [2004] found that an application of plastic mulch made it possible to obtain more kernels per ear, regardless of the sowing date of sweet corn, and suggested that it was due to a better development of plants due to higher temperatures of soil covered with mulch in the initial stage of corn devolopment.

Table 8 presents the response of the examined sweet corn cultivars to the experimental factors. 'Sweet Nugget F1' produced significantly higher early and marketable ear yields compared with 'Rana F1' and 'Sheba F1', regardless of the study year, sowing date and covering. In 2006, early yields were similar for all the cultivars, whereas in 2007 'Sweet Nugget F1' and 'Rana F1' produced significantly higher yields than 'Sheba F1'. In the cooler year 2008, yields of 'Sweet Nugget F1' were significantly higher than the yields of the remaining cultivars. Compared with 'Sheba F1', 'Sweet Nugget F1' and 'Rana F1' had higher early ear yields for the first sowing date. The share of 'Sweet Nugget F1' and 'Rana F1' early yields in the total yields of marketable ears was over 50% higher, and the differences were significant compared with 'Sheba F1'. There was found a significant effect of covering plots for the first sowing date on the share of early yield in the yield of marketable ears of the studied cultivars. The highest total yield of ears was produced by 'Sweet Nugget F1'; it was significantly lower for 'Rana F1.' The difference was the greatest for the non-covered plots sown with corn on the first date. The yield of marketable ears of the non-covered 'Sweet Nugget F1' sown on the first date was by 50% higher compared with 'Sheba F1', and the difference was statistically significant. Regardless of the experimental factors, sweet corn cultivars produced a similar number of marketable ears. However, the non-covered 'Sweet Nugget F1' formed significantly more ears for the first sowing date than 'Rana F1'. For the second sowing date, the non-covered 'Rana F1' produced more ears per unit area than 'Sheba F1'. Regardless of the study years, sowing dates and covering, kernel yields of 'Sweet Nugget F1' were significantly higher compared with 'Rana F1'. For the first sowing date, the non-covered 'Sweet Nugget F1' produced significantly the highest yield of ears which, for the cover-protected 'Sweet Nugget F1', was significantly higher compared with 'Rana F1'.

According to Aziz *et al*. [1992] and Khan *et al*. [1999], kernel yields and ear parameters are significantly affected by sweet corn cultivars, regardless of agronomic practices. However, the differences are genetically-controlled and do not depend on the sowing date.

Table 8. Ear and kernel yields of the examined sweet corn cultivars (means for 2006-2008)
Tabela 8. Plony kolb i ziarna badanych odmian kukurydzy cukrowej (średnie dla lat 2006-2008)

Cultivar Odmiana	Sowing date – Termin siewu									Mean Średnia
	April 26th – 26 kwietnia			May 10th – 10 maja			May 24th – 24 maja			
	covering – osłanianie		mean średnia	covering – osłanianie		mean średnia	covering – osłanianie		mean średnia	
	B1*	B2		B1	B2		B1	B2		
	Early ear yield – Plon wczesny kolb, $Mg \cdot ha^{-1}$									
Sweet Nugget F_1	5.4 b**	6.4b	5.9B	5.8a	6.3a	6.0A	5.2a	8.3a	6.7A	6.2B
Rana F_1	4.2ab	5.8ab	5.0B	6.4a	6.7a	6.5A	4.7a	8.0a	6.4A	6.0A
Sheba F_1	3.2a	4.4a	3.8A	5.3a	5.9a	5.6A	5.2a	7.5a	6.3A	5.3A
	Total ear yield – Plon kolb ogółem, $Mg \cdot ha^{-1}$									
Sweet Nugget F_1	13.1b	14.6a	13.8A	14.0a	13.9a	14.0A	14.2a	16.0a	15.1A	14.3B
Rana F_1	9.3a	12.3a	10.8A	13.7a	13.5a	13.6A	11.1a	14.7a	12.9A	12.4A
Sheba F_1	10.1ab	14.0a	12.1A	13.6a	14.5a	14.1A	13.9a	15.2a	14.5A	13.6AB
	Marketable ear yield – Plon kolb handlowych, $Mg \cdot ha^{-1}$									
Sweet Nugget F_1	11.6b	12.9a	12.2A	12.1a	13.3a	12.7A	11.0a	13.4a	12.2A	12.4B
Rana F_1	8.3ab	11.0a	9.7A	12.6a	12.4a	12.5A	8.8a	13.2a	11.0A	11.1A
Sheba F_1	7.9a	11.6a	9.8A	11.7a	11.8a	11.7A	10.6a	13.0a	11.8A	11.1A
	Number of marketable ears per hectare – Liczba kolb handlowych na 1 ha, $\cdot 10^3$									
Sweet Nugget F_1	53.54a	57.54a	55.54A	52.29ab	57.64a	54.97A	48.18a	52.25a	50.22A	53.57A
Rana F_1	45.62a	56.76a	51.19A	59.55b	57.10a	58.33A	45.25a	50.61a	47.93A	52.48A
Sheba F_1	47.04a	56.80a	51.92A	50.39a	53.19a	51.79A	49.41a	54.05a	51.73A	51.81A
	Kernel yield – Plon ziarna, $Mg \cdot ha^{-1}$									
Sweet Nugget F_1	6.9b	8.0b	7.5A	7.2a	8.1a	7.7A	6.9a	7.6a	7.3A	7.5B
Rana F_1	4.8a	6.1a	5.4A	7.1a	7.1a	7.5A	5.8a	7.8a	6.8A	6.5A
Sheba F_1	4.7a	7.2ab	5.9A	7.0a	7.6a	7.3A	7.2a	7.5a	7.4A	6.8AB

* B1 – no covering – bez osłaniania, B2 – non-woven PP – agrowłóknina
** values in columns followed by the same letters do not differ significantly at $P \leq 0.05$ – wartości w kolumnach oznaczone tymi samymi literami nie różnią się istotnie przy $P \leq 0,05$

CONCLUSIONS

1. Weather conditions in the study years influenced sweet corn ear and kernel yields, number of ears per plant and per hectare, and kernel weight per ear. Higher ear yields, greater numbers of ears and higher kernel yields were obtained in 2007 and 2008 when June and July were colder and wetter than in 2006, when higher air temperatures and lower rainfall over these two months contributed to more rapid maturation of sweet corn ears, and increased the percentage share of early yield in the yield of marketable ears.

2. When averaged over the study years, early yield of ears, its share in the marketable yield, marketable yield of ears and kernel yield increased but the number of marketable ears declined when sweet corn sowing was performed in late May instead of late April. The response of corn to delayed sowing depended on weather conditions in the study years. The overall and marketable yields of ears and kernel yield increased only in the coldest and wettest 2008. In 2006, which was the warmest and driest, delayed sowing was followed by declining kernel yields and numbers of ears harvested per unit area.

3. Covering of sweet corn with non-woven PP in the initial stages of development contributed to increased early, total and marketable yields, share of early yield in the yield of marketable ears, number of ears formed per plant and hectare, and kernel yields. The most visible effect was observed for the first sowing date in 2007 and 2008, when the period from mid-April to mid-May was colder than in 2006.

4. From the examined sweet corn cultivars, the highest ears and kernel yields were produced by 'Sweet Nugget F1'. The greatest differences between cultivars were found in the cooler years and for the first sowing date.

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REAKCJA KUKURYDZY CUKROWEJ UPRAWIANEJ W WARUNKACH WSCHODNIEJ POLSKI NA ZRÓŻNICOWANY TERMIN SIEWU I OSŁANIANIE AGROWŁÓKNINĄ. CZĘŚĆ I. PLONY KUKURYDZY

Streszczenie. Wzrost powierzchni uprawy kukurydzy cukrowej w Polsce wynika ze wzrostu jej konsumpcji oraz możliwości uprawy na obszarze prawie całego kraju.

W poszczególnych rejonach Polski jej uprawę rozpoczyna się w różnych terminach. Eksperyment polowy przeprowadzono w latach 2006-2008 w Rolniczej Stacji Doświadczalnej w Zawadach (52º03' N; 22º33' E). Badano wpływ trzech terminów siewu (26 kwietnia, 10 i 24 maja) oraz osłaniania agrowłokniną na plonowanie trzech supersłodkich odmian kukurydzy cukrowej (Sweet Nugget F1, Rana F1, Sheba F1). Uprawie kukurydzy bardziej sprzyjały chłodniejsze i wilgotniejsze lata 2007 i 2008 niż rok 2006. W latach 2007 i 2008 kukurydza dała większy plon wczesny (o 29 i 13%), ogółem (50%, 44%) i handlowy (72%, 74%) kolb oraz wykształciła więcej kolb na jednostce powierzchni (o 40-45%). W 2006 roku wysokie temperatury powietrza i mała ilość opadów atmosferycznych, szczególnie od połowy czerwca do końca lipca, wpłynęły na szybsze dojrzewanie kolb i jednoczesny wzrost procentowego udziału plonu wczesnego w plonie całkowitym. W miarę opóźniania terminu siewu wzrastał udział plonu wczesnego kolb w plonie całkowitym. Średnio dla lat opóźnienie terminu uprawy powodowało wzrost plonów ogółem i handlowego kolb, jednak tylko w 2008 roku wzrost ten był istotny. Wraz z opóźnianiem uprawy kukurydzy cukrowej w 2006 roku zanotowano spadek liczby wykształconych kolb i plonu ziarna, natomiast w 2008 roku jego wzrost. Osłanianie kukurydzy wpłynęło na wzrost plonów kolb i ziarna, udziału plonu wczesnego kolb w plonie całkowitym oraz liczby kolb. Największe efekty osłaniania stwierdzono w latach chłodniejszych w najwcześniejszym terminie uprawy. Największymi plonami kolb i ziarna charakteryzowała się odmiana Sweet Nugget F1. Największe różnice pomiędzy odmianami obserwowano w pierwszym terminie uprawy.

Słowa kluczowe: liczba kolb, osłanianie, plonowanie, struktura plonu kukurydzy, termin uprawy, *Zea mays* L. var. *saccharata* Korn.

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