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YIELDING OF MAIZE HYBRIDS FROM DIFFERENT MATURITY GROUPS DEPENDING ON SOWING DENSITY

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Abstract. Field experiment with yielding of maize hybrids of different maturity group depending on the sowing density was carried out in 2009–2011 in the Department of Agronomy at the Poznań University of Life Sciences, in the fields of Experimental Station in Swadzim. The aim of this trial was to study the response of selected maize hybrids to different sowing density, especially in the appearing drought periods. Tested hybrids were yielding at the same level from 9.88 to 12.11 $t \cdot ha^{-1}$ in 2009 and from 6.79 to 7.13 $t \cdot ha^{-1}$ in 2010, with the exception of the early hybrid PR39D60, which grain yield was significantly lowest in both years. Under less favorable conditions, with periodic water shortage in August 2009, and April and June 2010 the yield reached the highest value (10.73 and 6.86 $t \cdot ha^{-1}$ respectively) at density of 7 $plants \cdot m^{-2}$ was decreasing significantly with increasing density to 10 $plants \cdot m^{-2}$. In 2011, the year in which the water needs of plants were met, there was a tendency to yield at a higher level at higher sowing densities.

Key words: maize hybrids, earliness class, sowing density, grain yield

INTRODUCTION

There are many abiotic factors that affect crop yield, but of all the environmental stresses, drought condition affects most plants and can be the most limiting factor in crop production [Bruce et al. 2002, Shekoofa and Emam 2008, Taheri Asghari et al. 2009]. Availability of water for plants is largely dependent on its presence in the soil, but plant density is also important [Loomis and Connors 1992]. Within the grass family maize turns out to be a species particularly sensitive to derogate from the optimum plant density [Abuzar et al. 2011, Sangoi 2000]. Sowing density is one of the most important factor affecting the level of agronomic yield of maize [Borowiecki et al. 1999, Moaveni et al. 2011, Szmigiel and Oleksy 2004], which is of great importance, especially in emerging periods of drought, when the increase in plant density, causes a decrease in the availability of water for each single plant, which in turn lowers the yield [Asafu-Agyei 1990]. In Wielkopolska region during the course of the growing season of maize increasingly there are periods of drought; hence it becomes important selection of optimal sowing density as agrotechnical solutions supporting plant growth in these periods [Sulewska et al. 2011]. In addition, according to the literature data the new maize hybrids have different reaction to the sowing density [Borowiecki et al. 1999] and with lower density also produce only one ear per plant [Abuzar et al. 2011]. According to these authors, grain yield is the result of the genetic characteristics of the variety and the course conditions for its growth. Optimal sowing range is wide and largely dependent on the weather conditions of the location where the maize is grown. Thus to achieve the optimum density in practice by the farmer is a difficult task [Carmer et al. 1965], hence the deep study of plant yields depending on sowing density is desirable. The aim of

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this study was to investigate the response of selected maize hybrids to different sowing density, especially in the appearing water scarcity periods.

MATERIALS AND METHODS

The study was conducted in 2009–2011 in the Department of Agronomy at the Poznań University of Life Sciences, in the fields of Experimental station in Swadzim (52°29′ N, 16°46′ E). The factor of the first order was variety: PR39D60 (FAO 210), PR39T45 (FAO 240), PR38N86 (FAO 280), PR38A24 (FAO 330), a second-order factor was sowing density: 6, 7, 8, 9, 10 plants·m^{-2}. The experiment was established in randomized split-plot block design with four replications, on luvisoil [Marcinek et al. 2011], soil ranking class IV, good rye complex. Soil was characterized by the average abundance of phosphorus, potassium and magnesium. The pH reaction of the soil was slightly acidic. Maize crop management was conducted in accordance with agronomic recommendations. Mineral fertilization was applied before maize sowing in the following doses: nitrogen – 120 kg N·ha^{-1}, phosphorus – 80 kg P_2O_5·ha^{-1}, potassium – 120 kg K_2O·ha^{-1} in the form of Polifoska 5 and urea. The herbicide Guardian Complete Mix 664 EC (a.s. acetochlor, terbutylazyna) at a dose of 3,5 l·ha^{-1} was applied at the stages of 1-3 maize leaf stage for weed control. Sowing of maize were carried out according to the state of optimal soil moisture within a period between 15 and 26 of April. Sowing was performed with precision drill and the seed amount corresponded to assumed plant density. For ten ears collected from randomly selected plants in each row object, length and width were measured, counted the number of seeds in a row and the number of rows in the ears. The harvest was done in the full maturity of grain by Wintersteiger plot combine. At the time of harvest grain moisture was determined by Super-matic moisture meter. The weight of a thousand grains was determined using an electronic grain counter and Sartorius balance with accuracy to 0.1 g. Grain yields were converted into relative moisture of 15%. Weather characteristics are presented based on data from weather station in Swadzim. Sielianinov hydrothermal coefficient K [Molga 1986] was calculated according to the formula: $K = (P \cdot 10)/(T \cdot L)$ where, K – Sielianinov hydrothermal factor, P – total monthly precipitation, T – mean temperature of the month, L – number of days in the month.

The results were analyzed statistically using analysis of variance for orthogonal factorial experiments in randomized block design. Data were subjected to analysis of variance with treatment means compared using Tukey's tests at α=0.05.

RESULTS AND DISCUSSION

Weather conditions varied between studies (Fig. 1). In 2009, there were semi drought periods in April and drought in August, while in 2010 semi drought periods occurred in April and June, which confirms Sielianinow hydrothermal coefficient K. The rainfall in August and September 2010 delayed maturing of plants and encourage the development of *Fusarium*. Growing seasons of 2009 and 2010 should therefore be considered as not meeting the requirements of plants in terms of water supply.

The beginning of the growing season of 2011, compared to the years 2009 and 2010 was characterized by less favorable conditions for the growth and development of maize plants. In the period from April to May there was a drought, while in August and September –semi drought. This year, in comparison with the others characterized by the lowest rainfall (396.5 mm), very irregularly distributed, which have caused negative effects on plant growth. It should be noted, however, that July precipitation (the first was on 30th June, after three months period

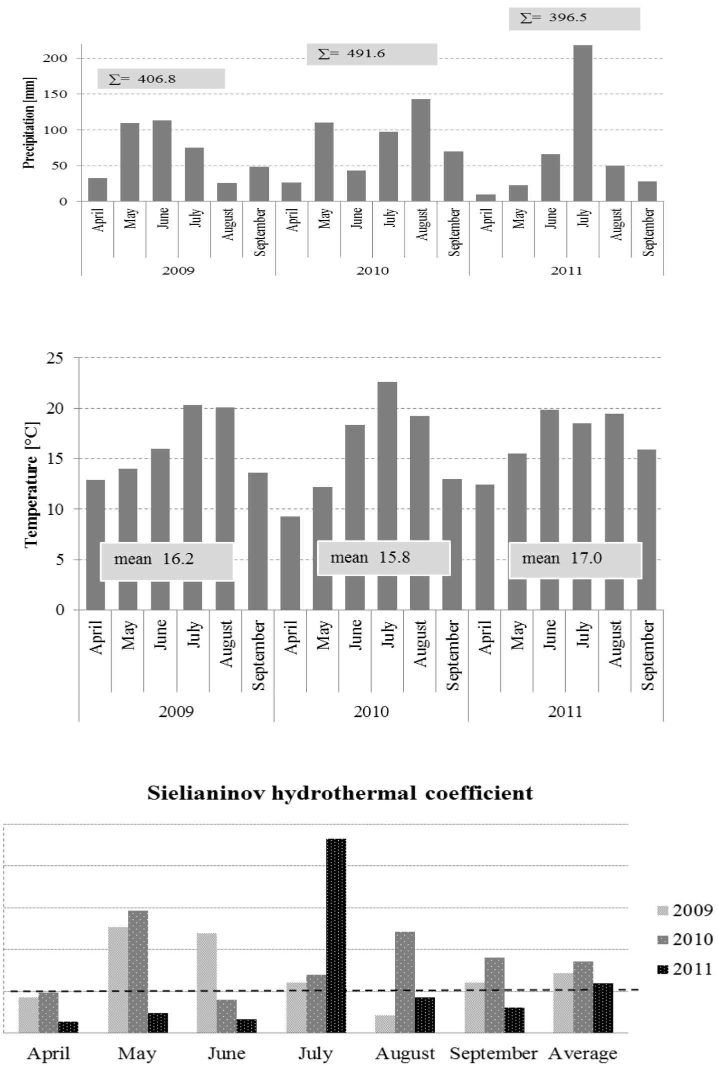
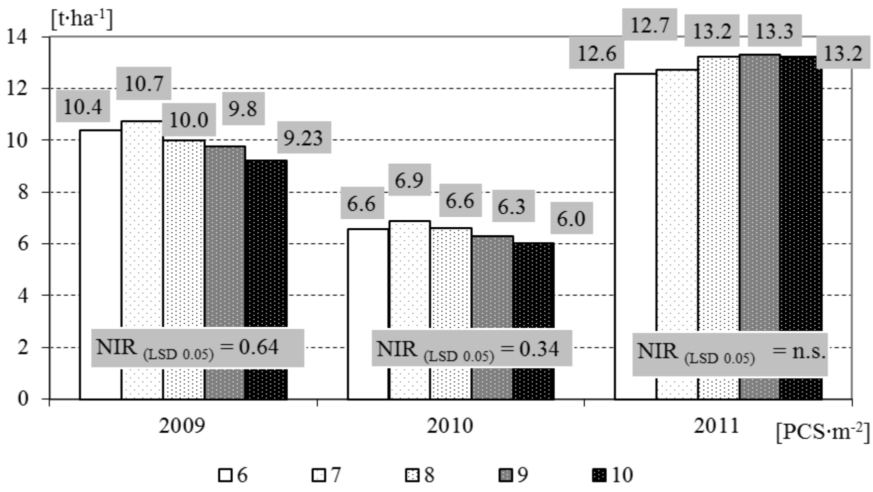


Fig. 1. Weather conditions from April to September at Experimental Station Swadzim in 2009–2011

with lack of effective precipitation) coincided with the period of the greatest water needs of the maize. Differentiation of the weather conditions tends to examine the dependence occurred in each year.

In 2009 and 2010 there were found significant differences between grain yields of tested hybrids (Fig. 2). Both in 2009 and 2010, early PR39D60 (FAO 210) was the worst yielded hybrid. Other varieties yielded at higher range of 9.88–12.11 $t \cdot ha^{-1}$ in 2009 and from 6.82 to 7.13 $t \cdot ha^{-1}$ in 2010. In 2009, the highest grain yields were obtained from variety PR38N86 (FAO 280), in

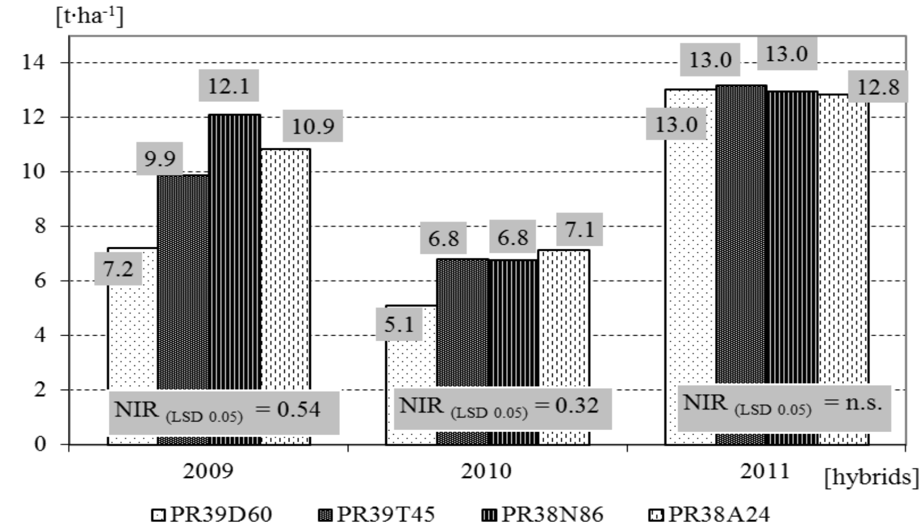


n.s.– non significant differences

Fig. 2. Maize grain yield (t·ha^{-1}) depended on sowing density (PCS·m^{-2})

2010 from variety PR38A24 (FAO 330), and in 2011 it was observed the only tend to yield at higher level in variety PR39T45 (FAO 240). The results indicate the break of close positive correlation between earliness and yield of varieties. Later yielding hybrids usually yield higher than the early ones, which is also reported by Szmigiel and Oleksy [2004] and Borowiecki et al. [1999]. Also in experiments of Gąsiorowska et al. [2009] the yields of hybrids Prosna (FAO 220) and Wiarus (FAO 220) showed a trend towards a higher yield than other tested varieties: Veritis (FAO 240) and Bahia (FAO 240–250).

In the years 2009 and 2010 it was found a significant effect of sowing density on the yield of grain (Fig. 3). In less favorable conditions of 2009, due to the low amount of rainfall in August, an increase in density to 10 plants·m^{-2} resulted in a significant reduction in yield. Sowing density in lower range of 6 and 7 plants·m^{-2} caused yield increase respectively 1.14 t·ha^{-1} and 1.50 t·ha^{-1}. In spring conditions and water shortages in June 2010, it was also proved that lower, 7 and 8 plants·m^{-2} were the sufficient densities. At the highest plant density maize grain yield was lower up to 0.82 t·ha^{-1}. In favorable weather conditions in 2011, there were no significant differences in grain yield depending on plant density. It was observed only tendency to higher yield level of plants sown at a density of 9 and 10 plants·m^{-2}. Similar responses of maize hybrids to different sowing density obtained Borowiecki et al. [1999]. In these studies, the authors, in unfavorable conditions have also proved optimal plant density of 60000 and 70000 plants·ha^{-1}. Similar to the results of own studies, in favorable weather conditions turned out to be more appropriate higher density amounting to 85000–90000 plants·ha^{-2}. Papers of Asafu-Agyei [1990] and Lutz et al. [1971] also confirm this relationship. Weather conditions under which Asafu-Agyei [1990] carried out his experiment were stressful for plants, where the average rainfall during the growing season was 115.93 mm. Under such conditions, the optimal sowing density ranged from 48000 to 66000 plants·ha^{-1}. The study of Abuzar et al. [2011] with the density range of 40000–140000 plants·ha^{-1} also proved to be the optimal density of 60000 plants·ha^{-1}. Based on their findings, and the authors of the above, it can be concluded, that adequate plant density, ensuring less com-



n.s.– non significant differences

Fig. 3. Maize grain yield (t·ha^{-1}) depended on hybrids

petition among plants for water, can to some extent compensate water deficit for plants during the growing season.

An attempt to synthesize the results of years of experience did not confirm interaction of maize hybrid and sowing density with grain yield (Tab. 1). Variety PR38N86 showed a tendency for better yields at lower sowing densities of 7 and 8 plants·m^{-2}, similar to the latest of PR38A24 variety that yielded the highest at a density of 6 and 7 plants·m^{-2}. This relationship does not confirm Sangoi [2000] thesis, that new varieties of maize plants have a higher tolerance to the denser sowing and with less density they do not tiller what generates fewer number of ears and leads to a lower grain yield.

Table 1. Reaction of maize to different sowing density in grain yield (t·ha^{-1}), average from 2009–2011

Hybrid (A)	Sowing density (PCS·m^{-2}) (B)					Average
	6	7	8	9	10	
PR39D60	8.24	8.83	8.57	8.51	8.14	8.46
PR39T45	10.04	10.06	10.24	9.84	9.66	9.97
PR38N86	10.52	10.95	10.66	10.56	10.42	10.62
PR38A24	10.55	10.57	10.26	10.21	9.78	10.27
Average	9.84	10.11	9.93	9.78	9.50	
$LSD_{0.05}$	A – 0.41; B – n.s.; AxB – n.s.; BxA – n.s.					

n.s.– non significant differences

In our study, the number of ears per m^2 significantly increased with higher sowing density (Tab. 2). However, calculated per single plant, each one had one ear, regardless from plant density. In Borowiecki et al. [1999] studies, the average number of productive ears per plant decreased with increasing plant density in the range of 1.25 to 0.5 ears per plant.

Table 2. Yield components depended on sowing density

Sowing ($PCS \cdot m^{-2}$)	2009	2010	2011	Average
Number of grains in the ear ($grains \cdot m^{-2}$)				
6	484	491	504	493
7	495	495	500	497
8	488	509	517	505
9	499	515	511	508
10	489	492	510	497
$LSD_{0.05}$	n.s.	n.s.	n.s.	n.s.
Weight of 1000 kernels (g)				
6	322.8	297.9	320.2	313.6
7	322.1	295.5	317.7	311.7
8	327.3	295.0	314.7	312.4
9	327.2	292.2	319.5	313.1
10	320.9	289.7	313.1	307.9
$LSD_{0.05}$	n.s.	n.s.	n.s.	n.s.
Moisture (%)				
6	26.8	30.8	26.6	28.0
7	27.3	31.1	26.8	28.4
8	26.9	30.7	26.8	28.1
9	27.1	30.8	26.6	28.2
10	27.0	31.2	26.3	28.2
$LSD_{0.05}$	n.s.	n.s.	n.s.	n.s.
Ear volume (cm^3)				
6	231	228	253	237
7	221	233	245	233
8	222	230	248	233
9	221	236	248	235
10	228	226	247	234
$LSD_{0.05}$	n.s.	n.s.	n.s.	n.s.
Number of ears ($pc \cdot m^{-2}$)				
6	6.0	6.1	6.2	6.1
7	7.2	7.2	7.2	7.2
8	8.3	8.1	8.2	8.2
9	9.2	9.1	9.2	9.2
10	10.3	10.1	10.4	10.3
$LSD_{0.05}$	0.1	0.2	0.2	0.1

n.s.– non significant differences

There were no significant differences found in the number of grains in the ear. It was showed only a tendency to achieve a higher number of grains in the ear at the sowing density of 9 plants·m^{-2}.

Thousand kernels weight (TKW) of maize did not change under the influence of sowing density, the highest was at 60000 seeds per 1 m^2. The largest reduction of TKW with increasing of plant density from the smallest (6 plants·m^{-2}) to the largest (10 plants·m^{-2}) occurred in 2010 and amounted 8.2 g. The smallest reduction was found in 2009. In the experiment Moaveni et al. [2011] significantly highest TKW of 260.2 g was achieved at the lowest sowing density of 70000 plants·ha^{-1}. Similarly Szmigiel and Oleksy [2004] showed, that as a result of competition between plants, resulting from an increase of plant density, a reduction in TKW was observed.

Maize grain moisture at harvest varied in years, but these differences were not significant. There was a trend for higher moisture with increased sowing density. The study of Szmigiel and Oleksy [2004] and Borowiecki et al. [1999] showed that significantly higher grain moisture was found with the highest maize plant density, which is confirmed by own results obtained in 2010.

Ear volume was the feature also not significantly changing under the influence of sowing density. It was only a trend for larger volume of maize ears on the plants sown at a density of 6 plants·m^{-2} in 2009 and 2011, and 7 and 9 plants·m^{-2} in 2010.

CONCLUSIONS

1. Under the conditions of the study there was a trend to decrease the yield of maize hybrids with higher plant density. The highest grain yield of tested varieties was obtained at sowing of 7 and 8 plants·m^{-2}.
2. Tested varieties yielded at the same level from 9.88 to 12.11 t·ha^{-1} in 2009 and from 6.79 to 7.13 t·ha^{-1} in 2010, with the exception of the early hybrid PR39D60, which grain yield was significantly lowest in both years.
3. Grain yield depended on the density of sowing. Under less favorable conditions, with periodic water shortage in August 2009, and April and June 2010, the yield reached the highest value (10.73 and 6.86 t·ha^{-1}) at a density of 7 plants·m^{-2} and significantly decreased with increasing plant density to 10 plants·m^{-2}. In 2011, the year in which the water needs of plants were met, there was a tendency to yield at a higher level at sowing density of 9 plants·m^{-2}.
4. Increasing the sowing density did not affect significantly the number of ears and grains per m^2, and on TKW, grain moisture and ear volume.

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H. Sulewska, W. Koziara, K. Śmiatacz, G. Szymańska, K. Panasiewicz

PLONOWANIE ODMIAN KUKURYDZY O RÓŻNEJ KLASIE WCZESNOŚCI W ZALEŻNOŚCI OD GĘSTOŚCI SIEWU

Synopsis. Doświadczenie z plonowaniem odmian kukurydzy o różnej klasie wczesności w zależności od gęstości siewu, przeprowadzono w latach 2009–2011 w Katedrze Agronomii Uniwersytetu Przyrodniczego w Poznaniu, na polach Zakładu Doświadczalnego w Swadzimiu. Celem podjętych badań było rozpoznanie reakcji wybranych mieszańców kukurydzy na różną gęstość siewu, zwłaszcza przy pojawiających się okresach niedoboru wody. Badane odmiany plonowały na wyrównanym poziomie od 98,8 do 12,11 $t \cdot ha^{-1}$ w 2009 roku oraz od 6,79 do 7,13 $t \cdot ha^{-1}$ w 2010, za wyjątkiem wczesnego mieszańca PR39D60, którego plon ziarna był istotnie najniższy w obu latach. W warunkach mniej korzystnych, przy okresowych niedoborach wody w sierpniu 2009 roku oraz kwietniu i czerwcu 2010 roku, plon istotnie malał wraz ze zwiększeniem gęstości do 10 $szt. \cdot m^{-2}$, osiągając najwyższą wartość (10,73 i 6,86 $t \cdot ha^{-1}$) przy gęstości 7 $szt. \cdot m^{-2}$. W 2011 roku, w którym potrzeby wodne roślin były zaspokojone, zaobserwowano tendencję do plonowania na wyższym poziomie przy gęstszym wysiewie ziaren.

Słowa kluczowe: odmiany kukurydzy, klasa wczesności, gęstość siewu, plon ziarna

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