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PRODUCTIVITY OF SELECTED VARIETIES OF MAIZE (*Zea mays* L.) IN ORGANIC AND INTEGRATED SYSTEMS

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ABSTRACT

Background. In recent years there has been increased interest in the possibilities for maize cultivation in organic farms. The development of organic agriculture is a global trend. Growing maize through organic agriculture can increase its quality and the value added to agricultural products and allow for the recovery of traditional foods. The aim of the study was to evaluate the yields and yield characteristics of selected varieties of maize grown in the integrated and organic systems.

Material and methods. A field experiment was conducted in the years 2011–2013 at the Agricultural Research Center Osiny, Poland, following a split-plot design, with four replications. The first factor was the system of production: organic and integrated while the second factor was maize (*Zea mays* L.) variety: Bosman, Opoka, Ułan and Vitras. The yield of green and dry matter of maize and the yield characteristics were determined.

Results. The production system had a significant impact on the maize yield. In all years of the study significantly higher yields of green and dry matter were obtained in the integrated system as compared to the organic one. The Vitras variety was the most suitable for growing in the organic system and the least suitable was Bosman, while in the integrated system the Ułan variety had the best yield and Opoka the lowest. The maize grown in the integrated system was characterized by higher dry matter content in the whole plants and cobs, the plants formed a significantly higher number of kernels on the cobs and the cobs were characterized by a lower share of the corncob and cover leaves. The largest number of kernels per cob was recorded for the Vitras variety grown in the organic system and for Ułan that was grown in the integrated system.

Conclusion. The study has shown that maize grown in the integrated system had a significantly higher yield than in the organic system. The average yield of green matter was higher by 31.4% and dry matter yield by 38.4% in the integrated system as compared to the organic system. The higher yield was caused by a higher content of dry matter in the whole maize plants and a higher number and proportion of kernels per cob. The Vitras variety turned out to be the most useful for cultivation in the organic system, while in the integrated system Ułan was the best variety.

Key words: dry mater yield, green matter yield, maize, production system, variety, yield characteristics

INTRODUCTION

Maize (*Zea mays* L.) is one of the most widely grown plants in the world. In terms of cultivated area (185 million ha) it takes second place after wheat, while in terms of grain harvest (975 million t) it has no competition and holds first place in the world (FAOSTAT, 2015). According to long-term forecasts

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the demand for maize will double by 2050, and its production will exceed the production of all other cereals (Rosegrant *et al.*, 2009). In Polish agriculture there has been a dynamic increase in the cultivated area of maize since 2000, and its importance has been significantly growing. In 2000, maize was grown on 314.8 thousand ha, including 152.3 thousand ha for grain, and in 2015 on 1 225.4 thousand ha, including 670.3 thousand ha for grain (GUS, 2011; 2016). The increased interest in the cultivation of maize is due to its versatile use. It can be used as animal feed, but it is also an important nutritional, industrial and energy plant (Michalski, 2004). In Poland, maize is grown mainly as a grain and as a raw silage material for use as livestock feed.

In recent years, there has been increasing interest in the possibilities for maize cultivation in organic farms. The development of organic agriculture is a global trend (Willer, 2013). According to Revilla *et al.* (2008) the new maize hybrids are most suited for intensive agriculture, involving herbicides and insecticides, but that there are some traditional varieties that have their best performance under organic conditions. Organic production of traditional maize varieties could be valuable for raising the income of small local farmers and for matching the demands of consumers. An important part of organic farming is raising ruminant animals whose nutritional needs for roughage should be met with crops grown on the farm. In such farms, there is usually a higher percentage of permanent grassland in the structure of the agricultural land as compared with conventional farms, but due to the need to ensure the right amount of energy feed, particularly for dairy cattle, there is also a need for maize cultivation, which is used for silage production.

In the available literature, there are a number of studies on the level of yield of other cereals (Kuś, 1998; Kuś and Bochniarz, 1999; Kuś and Jończyk, 2009; Kuś *et al.*, 2011), potatoes (Kuś and Stalenga, 1998; Sawicka and Kuś, 2000) and legumes (Księżak and Kawalec, 2006; Księżak and Kuś, 2005) grown under different production systems, but there are very few studies on maize (Revilla *et al*., 2015). According to Helander (1997) and Jończyk and Kopiński (2009), there is a need to evaluate different production systems and their impact on the environment. The studies that have been being conducted for 25 years in the Agricultural Research Center Osiny enable a comparison of entire production systems, as well as of various species of plants in crop rotations in subsequent years and facilitates carrying out detailed research under similar habitat conditions and agricultural practices. The present study attempts to assess the level of yield and yield characteristics of selected varieties of maize grown in the integrated and organic systems.

MATERIAL AND METHODS

The studies were conducted between 2011 and 2013 at the Agricultural Research Center Osiny (Poland) (51°27’ N; 22°03’ E), in a split-plot experimental design with four replications. The main experimental factor was the production system: organic (O) and integrated (I), while the sub-factor was Polish forage maize varieties: Bosman, Opoka, Ułan and Vitras. The organic system consisted of a 5-field crop rotation (maize – spring barley + undersown red clover with grass utilized for two years – winter wheat + intercrop). The integrated system consisted of a 4-field crop rotation (maize – spring barley – legumes – winter wheat + straw + intercrop). Plot size for harvest amounted to 30 m^2. The experiment was conducted on grey-brown podsolic soil (heavy loamy sand), good wheat complex class III a. The content of available phosphorus ($mg \cdot kg^{-1}$ of the soil) varied in the range from 10.6–12.4, potassium 6.1–8.6, magnesium 9.2–13.0 and humus 1.5–1.8. Soil pH, as determined in 1 N KCl, was 6.0.

Maize sowing was performed in the period from 26 April to 2 May, and the harvest was performed between 7 and 10 September. Plant density was 10 plants per 1 m^2 (inter-row spacing 75 cm, intra-row spacing 17 cm). In the organic system, natural fertilization was applied a dose of 40 $Mg \cdot ha^{-1}$ of composted manure per ha, while in the integrated system, in addition to the same dose of manure, mineral fertilization was also used at the amount of ($kg \cdot ha^{-1}$): N 150.0, P 39.2, K 49.8. In the organic system, weeds were controlled mechanically (3-times use of a brush weeder), while in the integrated system the herbicide Zegran 340 SE (4.0 $dm^3 \cdot ha^{-1}$) was applied. In the experiment the yields of green and dry matter and the yield characteristics were determined.

Before harvesting, biometric measurements of the plants were undertaken.

The significance of the impact of the experimental factors on the observed characteristics was evaluated by analysis of variance with the determination of confidence half-intervals by Tukey's test at the significance level $\alpha = 0.05$.

RESULTS AND DISCUSSION

The course of weather had a significant effect on the yield of maize. The highest yield of green and dry matter was obtained in 2012, which was characterized by the most even distribution of rainfall during the growing season (Fig. 1). Quite favorable weather conditions were also recorded in 2011. The high rainfall that occurred in July of that year, after a period of drought in the second half of June, contributed to the very rapid growth of plants. The lowest yields were obtained in 2013 (about 30% lower than in 2012), a year with low rainfall in July and August and when drought and high air temperature were recorded, which together reduced the normal growth and development of plants. According to Machul and Księżak (2007), high air temperatures and low rainfall in July cause a lower number of kernels per cob, which adversely affects the yield of maize.

The production system had a significant impact on the maize yield. In all years of the study, significantly higher yields of green and dry matter were obtained in the integrated system compared to the organic one (Table 1 and 2). In the first year of the study (2011), the yield of green matter in the integrated system was on average 39% higher than in the organic system, in the second year (2012) – higher by 27%, and in the third (2013) – by 28%, while the yield of dry matter increased by, respectively, 53%, 24% and 43%. The higher level of maize yields in the integrated system was determined by, primarily, the use of organic fertilization applied in conjunction with mineral ones and a good forecrop. This forecrop was characterized by a high content of organic matter, which increased the sorption capacity of the soil and improved its ability to retain water. This was particularly visible in the year with lower rainfall.

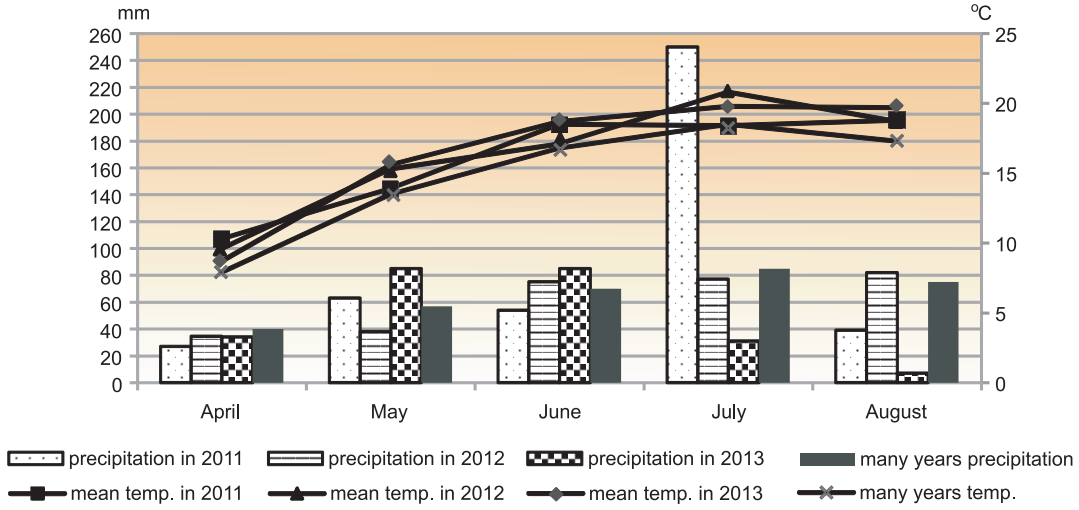

Fig. 1. Average monthly sum of precipitation (mm) and daily temperature of air (°C) in vegetation periods (2011-2013) compared to average multi-years period (1950–2005)

Table 1. Yield of green matter of maize varieties depending on the production system, Mg·ha^{-1}

Variety	Production system							
	organic				integrated			
	2011	2012	2013	mean	2011	2012	2013	mean
Bosman	27.8 a*	44.3 a	33.2 a	35.1 a	54.5 a	65.9 c	41.3 b	53.9 b
Opoka	38.5 b	46.8 ba	30.3 a	38.5 ab	51.5 a	55.7 a	36.3 a	47.8 a
Ułan	46.5 c	48.7 b	32.0 a	42.4 bc	61.7 b	64.5 bc	49.9 c	58.7 c
Vitras	44.6 c	54.3 c	38.9 b	45.9 c	51.3 a	61.1 b	44.3 b	52.2 ab
Mean	39.4	48.5	33.6		54.8	61.8	43.0	

* values marked with the same letter (in columns) did not differ significantly (α = 0.05)

Table 2. Yield of dry matter of maize varieties depending on the production system, Mg·ha^{-1}

Variety	Production system							
	organic				integrated			
	2011	2012	2013	mean	2011	2012	2013	mean
Bosman	8.9 a*	16.3 b	11.9 b	12.4 a	19.6 b	24.0 c	16.3 b	20.0 c
Opoka	12.2 b	15.2 a	11.3 a	12.9 ab	18.5 a	17.6 a	15.0 a	17.0 a
Ułan	15.0 c	15.6 ab	11.9 b	14.2 bc	21.9 c	20.1 b	20.8 d	20.9 c
Vitras	15.0 c	17.9 c	13.6 c	15.5 c	18.2 a	19.4 b	17.6 c	18.4 b
Mean	12.8	16.3	12.2		19.6	20.3	17.4	

* values marked with the same letter (in columns) did not differ significantly (α = 0.05)

The comparison of yield levels of the studied varieties of maize indicated that Vitras was the most suitable for growing in the organic system and the least suitable one was Bosman, while in the integrated system the Ułan variety had the best yield and Opoka – the worst. The largest difference in yield (by over 50%) in the integrated system in relation to the organic system was recorded for Bosman. In the available literature there are only a few studies comparing the level of maize yields, or other species with C_4 photosynthesis, grown in the integrated and organic systems. According to Kaffka *et al.* (2005) the average grain yields on a dry weight basis for maize cropped in a conventional system were significantly higher (by about 65%) compared to yields obtained in an organic system. According to these authors, soil quality, measured as total and protected organic C, can be improved using organic systems, but there appears to be unavoidable yield loss associated with plant protection of organic maize. Revilla *et al.* (2015) reported that differences between organic and conventional agriculture were not significant for the yield, but differences were significant for most quality traits. The results presented by Kuś *et al.* (2011) indicated that the average grain yield from four varieties of spring wheat grown in the integrated system was about 34% higher than in organic farming, which was due to a 16% higher spike density and a higher thousands seeds weight. Other studies have also shown that grain yields of spring cereals (wheat and barley), winter wheat and potato tubers were respectively

20%, 30% and 30% higher in the integrated production system compared to the organic one (Kuś and Jończyk, 2009). A higher yield of potato in the integrated system than in the organic one has also been reported by other authors (Kuś, 1998; Kuś and Stalenga, 1998).

Variable weather conditions in the course of the years, and especially the amount of rainfall during the growing season, had a relatively small impact on the morphological characteristics of the maize plants, hence the obtained results are shown as the mean for the three years (Table 3 and 4). In this study, the maize grown in the integrated system was characterized by a higher dry matter content in whole plants and cobs, the plants formed a significantly higher number of kernels in the cobs, and the cobs were characterized by a lower ratio of the corncob and cover leaves (Fig. 2). It was also found that maize plants in the integrated system had a considerably greater height than those organically grown. In contrast, the cultivation system had relatively little effect on the ratio of cob to the total plant as well as on the length and diameter of the cob.

The comparison of the evaluated maize varieties indicates that, on average for the three years, they had similar dry matter content in whole plants, but the content of dry matter in the cobs was significantly larger in maize varieties Ułan and Opoka, compared with the other two varieties. The cob had a larger percentage in the plant structure in maize varieties Bosman and Opoka, compared to the Vitras and Ułan varieties. The largest number of kernels per cob for each system was recorded for the variety Vitras growing in the organic system and for the variety Ułan growing in the integrated system. Longer cobs were formed by Opoka and Bosman varieties. Moreover, the maize variety Bosman formed the lowest number of kernels per cob and its plants were the shortest compared to the other varieties.

Table 3. Dry matter (DM) content in whole plants and maize cobs and share of cobs in maize structure depending on production system and variety of maize, mean from 2011–2013

Variety	DM content in whole maize plant, %		DM content in maize cob, %		Share of cobs in maize structure, %	
	Production system					
	organic	integrated	organic	integrated	organic	integrated
Bosman	35.0 a*	37.3 a	48.8 ab	52.3 b	66.2 b*	65.2 b
Opoka	33.9 a	36.4 a	50.2 b	53.6 bc	64.7 b	64.5 ab
Ułan	33.9 a	36.1 a	49.9 b	54.4 c	59.1 a	61.2 a
Vitras	33.9 a	35.7 a	48.2 a	50.2 a	60.0 a	62.7 a
Organic	34.2 a		49.3 a		62.5 a	
Integrated	36.4 b		52.6 b		63.4 b	
Bosman	36.2 b		50.6 b		65.7 b	
Opoka	35.2 ab		51.9 c		64.6 b	
Ułan	35.0 ab		52.1 c		60.2 a	
Vitras	34.8 a		49.2 a		61.3 a	

* values marked with the same letter did not differ significantly ($\alpha = 0.05$)

Table 4. The height of plants and some characteristics of maize cob depending on production system and variety of maize, mean from 2011–2013

Maize variety	The height of plant, cm		Number of cobs per plant		Number of kernels per maize cob		Length of cob, cm		Diameter of cob, mm	
	Production system									
	organic	integrated	organic	integrated	organic	integrated	organic	integrated	organic	integrated
Bosman	243	276	1.0	1.1	487.1	448.7	20.9	20.8	47.8	49.6
Opoka	254	274	1.1	1.0	522.3	528.2	21.1	21.3	46.0	45.7
Ułan	280	313	1.1	1.1	513.1	604.0	19.4	20.6	44.9	49.1
Vitras	268	303	1.0	1.0	524.3	545.3	19.5	19.7	47.6	49.4
Mean	261	291	1.05	1.05	511.7	529.9	20.2	20.6	46.6	48.4

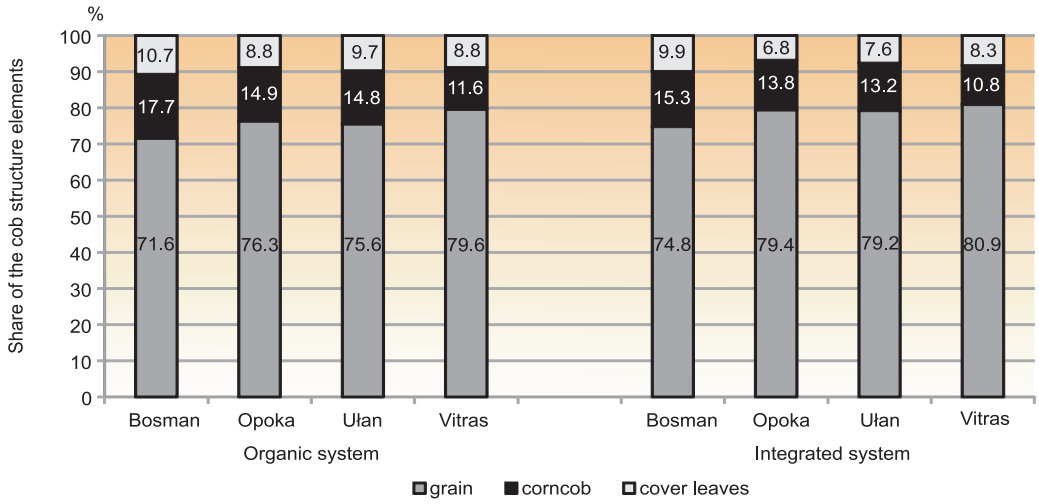

Fig. 2. Cob structure of maize plant (average of three years)

CONCLUSIONS

Maize grown in the integrated system had a significantly higher yield than in the organic system. The green matter yield was higher by 31.4% in the integrated than in the organic system, and dry matter yield was higher by 38.4%. The higher level of yield in the integrated production system was caused by a higher content of dry matter in the whole maize plants and a higher number and proportion percentage of kernels per cob. The evaluated maize varieties were characterized by similar dry matter content in whole plants, while the largest share of kernels per cob was found for the Vitras variety. The maize of the Vitras variety turned out to be the most productive useful for cultivation in the organic system, while in the integrated system it was the Ułan variety.

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PRODUKCYJNOŚĆ WYBRANYCH ODMIAN KUKURYDZY (*Zea mays* L.) UPRAWIANYCH W SYSTEMIE EKOLOGICZNYM I INTEGROWANYM

Streszczenie

Celem przeprowadzonych badań była ocena poziomu plonowania oraz elementów struktury plonu wybranych odmian kukurydzy (*Zea mays* L.) uprawianych w systemie ekologicznym i integrowanym. Doświadczenie polowe przeprowadzono w latach 2011–2013 w Rolniczym Zakładzie Doświadczalnym IUNG-PIB w Osinach (woj. lubelskie), metodą split-plot, w czterech powtórzeniach. Czynnikiem I rzędu był system produkcji: ekologiczny i integrowany, zaś czynnikiem II rzędu – odmiana kukurydzy: Bosman, Opoka, Ułan i Vitras. Oceniano plon zielonej i suchej masy kukurydzy oraz elementy struktury plonu. Badania wykazały, że system produkcji miał istotny wpływ na plon kukurydzy. We wszystkich latach badań największe plony zarówno zielonej, jak i suchej masy uzyskano w systemie integrowanym

w porównaniu z ekologicznym. W systemie ekologicznym najbardziej wydajna była odmiana Vitras, a najmniej – Bosman, zaś w systemie integrowanym najlepiej plonowała odmiana Ułan, a najsłabiej – Opoka. Kukurydza uprawiana w systemie integrowanym charakteryzowała się większą zawartością suchej masy w kolbach i w całych roślinach, zawiązywała więcej ziaren, a kolby charakteryzowały się mniejszym udziałem osadki kolbowej i liści okrywających. W systemie ekologicznym największym udziałem ziarna w kolbie odznaczała się odmiana Vitras, zaś w integrownym – Ułan. Na podstawie przeprowadzonych badań stwierdzono, że spośród badanych odmian kukurydzy najbardziej przydatną do uprawy w systemie ekologicznym jest odmiana Vitras, zaś w integrowanymi – Ułan.

Słowa kluczowe: elementy struktury plonu, kukurydza, odmiana, plon suchej masy, plon zielonej masy, system produkcji