Polish Journal of Agronomy
2021, 45, 12–20

doi: 10.26114/pja.iung.461.2021.45.02

Yield evaluation of maize varieties grown for grain in the organic and integrated system

Jerzy Księżak

Department of Forage Crop Production
Institute of Soil Science and Plant Cultivation – State Research Institute
Czartoryskich 8, 24-100 Puławy, POLAND

Abstract: The research aimed to determine the yield level of selected maize varieties grown for grain with organic and integrated farming systems. The field experiment was conducted in 2017–2019 at Kępa Agricultural Experimental Station using the method of crossed sub-block method in 4 replications. The first-order factor was the maize variety, the second-order factor – the production system. The assessed maize varieties cultivated in the integrated system (after wheat and stubble intercrop in combination with natural and mineral fertilization) yielded better, on average by 12.1% than in the organic system. Maize grown in the integrated system was characterized by a 4.1% greater weight of a thousand grains, a 3.6% greater weight of grain from one cob, and a 2% greater number of grains per cob than in the organic system. The maize plants were about 6.5% higher and set the cob about 10% higher than in the organic system. However, the length and diameter of the cob as well as the proportion of grain in the cob were similar in both production systems. In the organic system, the cultivation of the cultivars Ambrosini and Silvestre ensured a yield level higher by about 8% (on average 9.4 t ha^{-1}) compared to the average yields of the cultivars Smolitop and Ricardinio. In the integrated system, Ambrosini and Ricardinio yielded better (on average 10 t ha^{-1}), the grain yield was 9.2% higher than the other two cultivars. In both production systems, Smolitop had the lowest yield; its yield was around 10% lower than that of Ambrosini in the organic system and that of Ricardinio in the integrated system. The highest weight and number of grains per cob, irrespectively of the production system, was characterized by Ricardinio, and the lowest by Smolitop (the difference was 5.1% and 9.4%, respectively). Ambrosini was characterized by the smallest caryopsis (307 g on average), while Smolitop was larger by about 21 g. Plants of Ricardinio were the tallest and set the cob highest on the stem regardless of the production system. However, the length and diameter of the cob of the tested cultivars were similar.

Keywords: maize, grain yield, organic production system, integrated production system, plant structure, cob structure, biometric measurements

Corresponding author:
Jerzy Księżak
e-mail: Jerzy.Ksiezak@iung.pulawy.pl
phone +48 81 4786 791

INTRODUCTION

For many years, significant changes have been taking place in world agriculture but also in Polish agriculture. In line with the principles of sustainable development, preference is given to systems that ensure economic profitability, but also have a positive impact on the environment. Currently, in agricultural practice, the conventional system is most often used in the cultivation of many plant species, including maize (Cox, Cherney, 2018; Hossar et al., 2016; Kaffka et al., 2005). In this system, intensive farming technologies are used, but also simplified crop rotation and tillage. The use of this system is also associated with the use of industrial means of production, which may have a negative impact on the environment. The observed effect of these changes is a significant increase in interest in the organic farming system, the development of which is a global tendency (Willer, Kilcher, 2011). In recent years in Poland, this production system has been used in about 20 thousand farms, which covered an area of about 500 thousand ha, which accounted for 3.4% of the total area of agricultural land (IJHARS, 2017, 2018). In this system, synthetic fertilizers and plant protection products are not used, and proper crop rotation and the selection of varieties that allow for better utilization of the habitat potential, play the primary role in yielding (Baresel et al., 2008; Cesevičienė et al., 2009; Eisele, Köpke, 1997; Jończyk, 2010; Kuś, Jończyk, 2018). The comparison of productivity in various systems mainly concerned cereals (Kuś, Jończyk, 2009; Kuś et al., 2011), potato (Kaffka et al., 2005; Zarzyńska, Jończyk, 2017) and legumes (Księżak, Kuś, 2005; Księżak, Kawalec, 2006).

Maize is a species that can be grown in the conventional, integrated and organic system. Whole of its biomass is used for the production of silage. Maize grain is the basic ingredient of poultry feed mixtures, for instance for chickens and turkeys. In mixtures for the first rearing period, from 45 to 55% of maize grain is used, and in mixtures for the second rearing period, maize grain is used in the amount of 20–30% of the feed mixture (Smolikowska, Rutkowski, 2005; Szczurek et al., 2013). The nutritional value of maize grain in the full maturity phase depends on the amino acid composition of protein, including essential amino acids (lysine, methionine) and starch content.

For animals kept on farms, and especially according to organic principles, the demand for fodder should be met from the plant species grown on the farm. One of them may be maize, which is used in the production of poultry mixes.

This research aimed to determine the yield level of selected maize varieties grown for grain with the organic and integrated farming systems.

MATERIALS AND METHODS

The field experiment was conducted in 2017–2019 at Kępa Agricultural Experimental Station on the soil of the good wheat complex. In 2017–2019, the content of nutrients in the soil (mg in 100 g of soil) was: P_2O_5 – 8.2–8.9, K_2O – 9.6–10.5, MgO – 8.7–9.3, humus – 1.4–1.6%, pH in KCl – 5.7–5.9. The experiment was carried out using method of crossed sub-block in 4 replications, The first-order factor (A) was the maize variety (Table 1). The second-order factor (B) was the production system: organic (maize ++, spring barley (Radek variety) + red clover sowing with grass (2 years), winter wheat (Bamberka variety) + stubble intercrop, a mixture of oats with spring vetch) and integrated (maize ++, spring barley (Radek variety), legumes, winter wheat (Bamberka variety) + straw + stubble intercrop) (Table 2).

In the experiment, the yield of maize grain, the weight of one thousand grains, the structure of the plant, and the cob structure were determined. Before harvest, plant biometric measurements were performed. Before harvesting, the plant height was measured from the soil surface to the top of the panicle, and the first cob height was measured from the soil surface to the cob attachment. The length of the cob was determined from the beginning to the end of graining, and the diameter at the half of the cob length. The number of cobs was determined on 10 consecutive plants.

Each variety of maize was grown on an area of 0.15 ha, which made it possible to adopt a crop management similar to that used for commercial production. Sowing maize with 9 seeds per 1 m^2 was performed in the third decade of April or in the first decade of May and harvested at the turn of the second and third decade of October. The significance of the influence of the examined factors on the observed features was assessed using the analysis of variance, determining the half-intervals of confidence using Tukey's test at the significance level of $\alpha = 0.05$.

Weather conditions

In the first year of the experiment (2017), at the end of the second decade of April and in the first days of May, there were spells of very cool weather, and there were frosts at night, which made it impossible to sow maize (Table 3). In June and the first decade of July, a small amount of precipitation was recorded compared to long-term average, which had an unfavorable effect on the growth and development of plants. Significant precipitation in the second decade of July, August, and September had a positive effect on the development of plants. On the other hand, in July 2018, the precipitation exceeded the long-term average, as well as the amount of precipitation in this month in 2019, which contributed to a better yield of plants. However, in 2019,

Table 1. Maize varieties tested in experiment.

Variety	Breeder	FAO grain/silage	Grain type	Variety type	Stay-green
Ambrosini	KWS	220/220	FD	TC	+
Silvestre	KWS	220/230	FD	TC	+
Smolitop	HR Smolice	220/230	FD	TC	+
Ricardinio	KWS	230/240	FD	SC	+

SC – simple hybrid, TC – triple-cross hybrid, FD – flint dent

Table 2. Crop management treatments in maize production.

Crop management treatments	Organic system	Integrated system
Seed dressing	-	+
Weed control	Mechanical (3 × brush weeder – 1–2 leaves, 4-6 leaves, at a plant height of 25–30 cm)	Shedo 300 SC (1 l ha^{-1}) + Innovate 250 EC (0.2 l·ha^{-1}): BBCh 14-16
Natural fertilization	40 t of composted manure#	30 t of manure
Mineral fertilization [kg ha^{-1}]	-	N – 150 (urea) P – 39.2 (triple superphosphate) K – 49.8 (potassium salt)

N – 4.9, P_2O_5 – 3.1, K_2O – 6.2, CaO – 4.1, MgO – 1.1 kg t^{-1}

Table 3. Average monthly sum of precipitation (mm) and daily temperature of air (°C) in vegetation periods (2017–2019) compared to average multi-years period (1961–2017).

Parameter		MAR	APR	MAY	JUN	JUL	AUG	SEP	Sum
	decade				**2017**				
Rainfall [mm]	I	10.7	10.7	28.4	5.2	7.3	3.1	41.6	
	II	12.0	9.6	0.0	16.2	101.4	100.1	46.7	
	III	10.4	51.4	39.1	12.2	10.9	4.4	21.8	
	sum	33.1	71.7	67.5	33.6	119.6	107.6	110.1	543.2
Temperature [°C]	I	5.8	10.8	10.0	16.7	17.3	22.9	15.4	
	II	4.1	5.5	14.4	17.5	18.0	19.8	14.4	
	III	7.8	6.2	16.9	20.0	20.4	16.5	12.3	
	mean	5.9	7.5	13.8	18.1	18.6	19.7	14.0	
					2018				
Rainfall [mm]	I	3.4	16.6	4.8	0.9	6.6	12.2	14.4	
	II	14.8	7.7	35.4	3.9	64.0	7.1	3.5	
	III	13.0	5.5	19.2	33.3	51.9	8.4	30.1	
	sum	31.2	29.8	59.4	38.1	122.5	27.7	48.0	356.7
Temperature [°C]	I	-3.7	11.1	17.3	19.6	19.3	23.4	18.2	
	II	1.5	14.7	15.0	20.1	19.5	21.2	17.4	
	III	2.6	15.0	19.1	16.8	23.0	17.8	11.4	
	mean	0.13	13.6	17.2	18.8	20.6	20.8	15.7	
					2019				
Rainfall [mm]	I	11.3	1.7	7.0	1.0	9.9	10.5	10.9	
	II	10.9	3.2	65.9	23.0	4.3	72.6	6.2	
	III	0.5	30.6	13.2	14.7	19.7	3.6	40.2	
	sum	22.7	35.5	86.1	38.7	33.9	86.7	57.3	360.9
Temperature [°C]	I	5.5	8.2	9.5	20.2	17.1	19.4	17.8	
	II	4.7	7.1	13.7	22.9	17.1	19.8	12.8	
	III	6.4	13.4	15.5	22.0	21.7	21.3	12.9	
	mean	5.5	9.6	12.9	21.7	18.6	20.2	14.5	
Average rainfall over many years [mm]		34	50	67	79	87	71	58	446
Average temperature over many years [°C]		2.1	8.0	13.6	16.8	18.5	17.8	13.2	

a small amount of precipitation was recorded in June and July, which resulted in a much lower level of maize yield compared to the two previous years.

RESULTS AND DISCUSSION

The performed synthesis of the obtained results showed a significant influence of the weather conditions during the growing season on the growth, development, and yields of maize, therefore the data were presented separately for each year. The grain yield of the assessed maize varieties was significantly influenced by the production system used and the weather conditions during the growing season (Table 4). On average, in three years the maize cultivated in the integrated system yielded better, and the yield increase was on average about 12%. In the 2017 and 2019 growing seasons, the maize gave better yields under the integrated system while the 2018 season under the organic system. In the 2017 season with a large amount of precipitation in the period of July–September and in the season of 2019 with a large amount of precipitation in August, in the integrated system, natural fertilization in combination with mineral fertilization and with a better field on which maize was grown (wheat + straw + stubble catch crop) characterized by a higher content of organic matter increasing the capacity of the sorption complex of the soil and the ability to retain more water. The results of the research obtained by Machul and Księżak (2007) showed that at 4 °C higher than the long-term average temperature in July and low precipitation (by about 10 mm), maize plants formed

Table 4. Yield of seeds of maize varieties depending on the production system [$t \cdot ha^{-1}$].

Variety	2017		2018		2019		3-year average	
	E	I	E	I	E	I	E	I
Ambrosini	9.8	9.8	11.4	11.6	7.2	10.1	9.5	10.5
Silvestre	10.2	11.6	10.9	9.4	6.8	8.5	9.3	9.8
Smolitop	9.2	10.9	10.0	9.3	6.6	8.9	8.6	9.7
Ricardinio	10.1	11.0	9.9	9.0	6.3	12.4	8.8	10.8
Mean	9.8	10.8	10.6	9.8	6.7	10.0	9.1	10.2
LSD α = 0.05 for:								
system (B)	0.062		0.062		0.306			
variety (A)	0.135		0.071		0.393			
B/A	0.153		0.153		0.58			
A/B	0.084		0.130		0.470			

E– organic system
I – integrated system

Table 5. Grain moisture at harvest of maize varieties depending on the production system [%].

Variety	2017		2018		2019		3-year average	
	E	I	E	I	E	I	E	I
Ambrosini	32..1	30..3	21.9	21.6	22.4	23.3	25.5	25.1
Silvestre	32.9	30.7	22.8	22.3	22.4	22.5	26.0	25.2
Smolitop	36.4	31.4	21.1	22.2	22.1	22.1	26.5	25.2
Ricardinio	36.0	33.5	22.0	21.2	22.8	23.2	26.9	26.0
Mean	34.4	31.5	21.9	21.8	22.4	22.8	26.2	25.4
LSD α = 0.05 for:								
system (B)	1.118		0.000		0.186			
variety (A)	0.424		0.804		0.268			
B/A	0.643		ns		0.300			
A/B	1.164		ns		0.212			

E– organic system
I – integrated system
ns – nonsignificant differences

Table 6. Weight of 1000 grain of maize varieties depending on the production system [g].

Variety	2017		2018		2019		3-year average	
	E	I	E	I	E	I	E	I
Ambrosini	300.7	317.1	338.1	330.7	259.9	293.8	299.6	313.9
Silvestre	308.1	328.3	329.7	319.0	278.3	291.2	305.4	312.8
Smolitop	322.3	337.2	354.6	339.2	294.3	321.3	323.7	332.6
Ricardinio	328.6	345.2	340.0	336.3	266.4	316.2	311.7	332.6
Mean	314.9	331.9	340.6	331.5	274.7	305.6	310.1	322.9
LSD α = 0.05 for:								
system (B)	4.474		ns		1.304			
variety (A)	4.022		ns		1.168			
B/A	ns		ns		1.325			
A/B	ns		ns		1.373			

E– organic system
I – integrated system
ns – różnice nieistotne; nonsignificant differences

Table 7. Bulk density of corn of maize varieties depending on the production system [$kg\ hl^{-1}$].

Variety	2017		2018		2019		3-year average	
	E	I	E	I	E	I	E	I
Ambrosini	81.5	80.5	79.5	78.2	76.7	81.5	79.2	80.1
Silvestre	82.0	83.6	76.3	76.9	78.8	79.9	79.0	80.1
Smolitop	84.4	81.6	77.9	76.9	78.8	80.6	80.4	79.7
Ricardinio	80.6	83.9	77.7	77.0	77.9	81.7	78.8	80.9
Mean	82.1	82.4	77.8	77.3	78.1	80.9	79.3	80.2
LSD α = 0.05 for:								
system (B)	ns		0.259		0.062			
variety (A)	0.692		0.725		ns			
B/A	1.254		ns		1.087			
A/B	2.117		ns		0.653			

E– organic system
I – integrated system
ns –nonsignificant differences

Table 8. Weight grain per maize cob of maize varieties depending on the production system [g].

Variety	2017		2018		2019		3-year average	
	E	I	E	I	E	I	E	I
Ambrosini	147.4	153.6	138.8	137.4	134.4	156.2	140.2	149.1
Silvestre	154.2	166.2	138.4	135.6	133.6	150.7	142.1	150.8
Smolitop	139.3	150.3	137.0	130.5	146.8	150.6	141.0	143.8
Ricardinio	164.5	160.1	148.3	139.2	136.5	151.0	149.8	150.1
Mean	151.4	157.6	140.6	135.7	137.8	152.1	143.3	148.4
LSD α = 0.05 for:								
system (B)	ns		0.767		0.559			
variety (A)	ns		1.523		1.190			
B/A	ns		2.103		1.695			
A/B	ns		1.438		1.162			

E– organic system
I – integrated system
ns – nonsignificant differences

Table 9. Number kernels per maize cob of maize varieties depending on the production system.

Variety	2017		2018		2019		3-year average	
	E	I	E	I	E	I	E	I
Ambrosini	443.2	457.4	457.6	458.8	380.6	443.4	427.1	453.2
Silvestre	449.5	459.3	448.5	433.6	413.4	426.5	437.1	439.8
Smolitop	431.6	444.7	413.8	405.7	389.4	383.7	411.6	411.4
Ricardinio	464.1	481.2	475.2	463.2	411.8	427.6	450.4	457.3
Mean	447.1	460.6	448.8	440.3	398.8	420.3	431.6	440.4
LSD α = 0.05 for:								
system (B)	3.229		1.056		1.740			
variety (A)	1.076		1.936		1.830			
B/A	1.704		2.575		3.007			
A/B	3.346		1.760		2.615			

E – organic system
I – integrated system

Table 10. Length of cob of maize varieties depending on the production system [cm].

Variety	2017		2018		2019		3-year average	
	E*	I	E	I	E	I	E	I
Ambrosini	15.8	15.2	17.8	16.9	15.1	16.6	16.2	16.2
Silvestre	14.8	14.3	16.9	16.1	16.1	16.5	15.9	15.6
Smolitop	16.1	17.1	16.8	17.1	17.3	16.7	16.7	17.0
Ricardinio	16.7	15.1	17.6	16.6	16.2	16.1	16.8	15.9
Mean	15.8	15.4	17.3	16.7	16.2	16.5	16.4	16.2
LSD α = 0.05 for:								
system(B)	0.200		0.124		ns			
variety (A)	0.324		0.182		0.115			
B/A	0.360		0.305		0.141			
A/B	0.233		0.240		0.376			

E– organic system
I – integrated system
ns –nonsignificant differences

Table 11. Diameter of cob of maize varieties depending on the production system [mm].

Variety	2017		2018		2019		3-year average	
	E	I	E	I	E	I	E	I
Ambrosini	44	45	46	46	41	42	44	44
Silvestre	42	43	44	44	41	41	42	43
Smolitop	42	41	44	44	41	41	42	42
Ricardinio	44	45	43	45	40	43	42	44
Mean	43	43	44	45	41	42	42	43
LSD α = 0.05 for:								
system (B)	ns		ns		0.621			
variety (A)	1.778		2.120		ns			
B/A	1.914		ns		1.527			
A/B	3.134		ns		0.840			

E – organic system
I – integrated system
ns –nonsignificant differences

Table 12. Height of corn cob of maize varieties depending on the production system [cm].

Variety	2017		2018		2019		3-year average	
	E	I	E	I	E	I	E	I
Ambrosini	68	68	111	110	61	96	80	91
Silvestre	94	90	118	107	63	94	92	97
Smolitop	94	92	114	107	61	92	90	97
Ricardinio	94	93	114	107	66	106	91	102
Mean	87	86	114	108	63	97	88	97
LSD α = 0.05 for:								
system (B)	ns		1.242		3.726			
variety (A)	2.675		1.413		2.942			
B/A	3.213		1.999		3.462			
A/B	2.325		1.681		3.932			

E– organic system
I – integrated system
ns –nonsignificant differences

Table 13. Height of plants of maize varieties depending on the production system [cm].

Variety	2017		2018		2019		3-year average	
	E*	I	E	I	E	I	E	I
Ambrosini	208	202	244	241	170	234	207	226
Silvestre	252	221	259	260	172	211	228	231
Smolitop	242	224	242	249	169	222	218	232
Ricardinio	256	250	252	254	183	238	230	247
Mean	239	224	249	251	173	226	220	234
LSD α = 0.05 for:								
system (B)	7.453		ns		3.726			
variety (A)	3.739		6.464		2.448			
B/A	7.953		ns		3.053			
A/B	9.248		ns		3.932			

E– organic system
I – integrated system
ns –nonsignificant differences

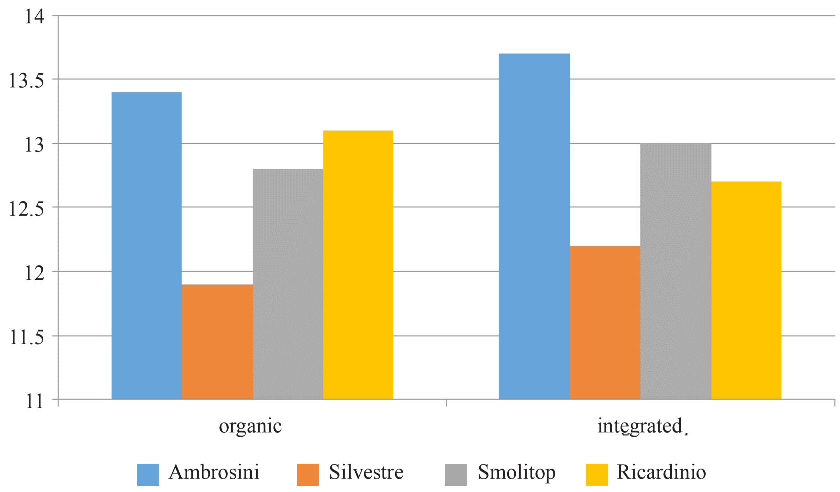

Figure 1. Share of corncob in cob of maize varieties depending on the production system (average of three years) (%).

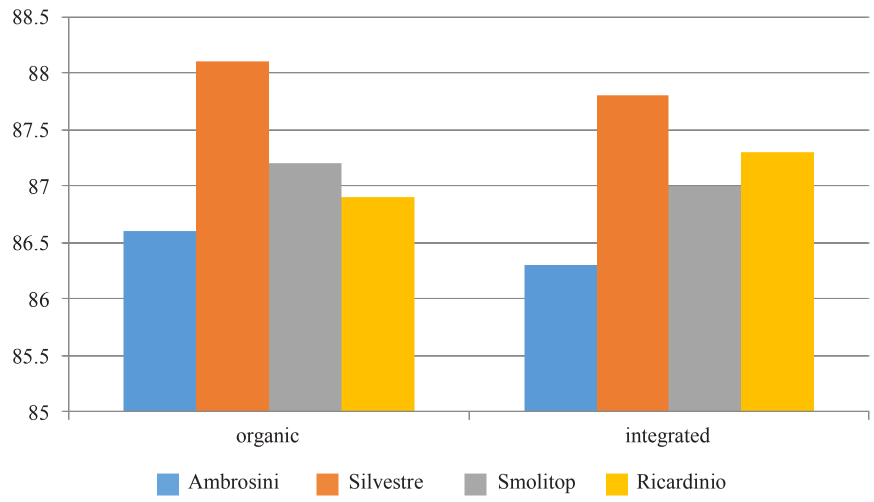

Figure 2. Share of seeds in cob of maize varieties depending on the production system (average of three years) (%).

cobs, some of which were partially or completely grainless, which adversely affected the yield. The comparison of the yielding of the varieties included in the research shows that in the organic system, the highest grain yield was obtained by cultivating the cultivars Ambrosini and Silvestre, Ambrosini and Ricardinio were the best yielders in the integrated system, and Smolitop was the lowest yielder, regardless of the system used. The analysis of the literature shows that there is relatively little work on comparing the productivity of maize varieties or other C4 species grown in different systems. According to Ącher et al. (2007), the productivity of maize grown in the organic system, compared to conventional cultivation, was lower by 34% in the transformation period, and the lower yield was mainly due to the low nitrogen content in the soil. In other studies (Coulter et al., 2013) conducted in Minnesota, the reduction of the yield in the organic system compared to the conventional one (maize-soybean rotation) was 24%. A study conducted in Maryland by Cavigelli et al. (2008) showed that organic maize yielded 28% lower at transition compared to that grown conventionally and 40% lower after transition, mainly due to low nitrogen availability in the soil. Hossar et al. (2016) report that in the organic system maize yields are usually about 25% lower than those from the conventional system, while according to Cox and Cherney (2018) and Kaffka et al. (2005) the yields are lower by 32–35%. Revilla et al. (2015) did not observe any yield differences in maize grown in these systems but noted their significant impact on the quality of the crop obtained. Moreover, a comprehensive study by USDA ERS (2015) indicates that organically grown maize, despite higher prices and subsidies, was characterized by lower yields and higher production costs per unit area compared to conventionally grown maize. An analysis by Seufert et al. (2012) showed that the yields of organic farming are low in the first years of the conversion period and are gradually increasing, mainly due to improvements in soil fertility. Księżak et al. (2011) recorded a 32% higher yield of maize grown for silage in the integrated system than in the organic one. Research conducted by Kuś et al. (2011) with four spring wheat varieties gave, on average over three years, a 34% lower productivity of this species in the organic system than in integrated cultivation. The lower grain yield in the ecological system was the result of a smaller number of ears of grain by about 16% and a similar reduction in the weight of 1000 grains. Whereas Kuś et al. (2007), in the period of ten years of research, recorded lower wheat yields compared to those cited previously (Kuś et al., 2011). Kuś and Jończyk (2009) found the highest yields of winter wheat, potato, and spring cereals in the integrated production system, while the reported yield reduction in the organic system for winter wheat and potato compared to the integrated system was 30%, and for spring wheat 20%.

In 2018 and 2019, the production system used did not have a significant impact on the grain moisture content, in 2017 the grain of maize grown under the ecological system had a higher moisture content (Table 5). In addition, the average water content of the grains of the four varieties over the period of 3 years was very similar. Significantly larger grains were produced (in 2017 and 2019) by maize grown in the integrated system than the organic one, and the smallest grains were found in cv. Ambrosini (Table 6). The cultivation system had no significant effect on the bulk density of maize grain (Table 7), bulk density was slightly higher in 2017. Higher weight (differences significant in 2018 and 2019) and the number of grains per cob were produced by maize plants grown under the integrated vs. organic system one (Table 8, 9). Regardless of the cultivation system used, Ricardinio was characterized by a large number and weight of grains per cob (Table 8, 9). Silvestre had the highest proportion of grain in the cob and Ambrosini had the highest proportion of corncob in the cob (Fig. 1, 2). The cob diameter of the evaluated varieties was similar in both production systems and the cob length was slightly higher in the organic system (significant differences in 2017 and 2018) (Table 10, 11). In 2017 and 2018, the cultivation system did not significantly affect the height of cob attachment nor did it influence the height of the plants. On the other hand, in 2019 both the plant height and the height of cob attachment were lower in the ecological system, which was mainly caused by low rainfall in June and July (Table 12, 13). Regardless of the production system, among the varieties evaluated, Ambrosini had the lowest cobs, while the Ricardinio variety was characterized by the highest plants. On the other hand, the number of cobs per one maize plant on all treatments was similar and ranged from 0.95 to 1.0 pcs.

CONCLUSIONS

1. The evaluated maize varieties grown in the integrated system (after wheat and stubble intercrop in combination with natural and mineral fertilization) yielded on average 12.1% better than they did in the organic system.
2. Maize grown in the integrated system was characterized by a 4.1% higher weight of a thousand grains, a 3.6% higher weight of grain per cob, and a 2% greater number of grains per cob than in the organic system. The maize plants were about 6.5% higher and set the cob about 10% higher than in the ecological system. However, the length and diameter of the cob as well as the proportion of grain in the cob were similar in both production systems compared.
3. In the organic system, Ambrosini and Silvestre (FAO – grain 220, grain type – FD, type of variety – TC, stay-green)(on average 9.4 $t \cdot ha^{-1}$) gave about 8% higher yields compared to the average yields of Smolitop and

Ricardinio. In the integrated system, Ambrosini and Ricardinio yielded better (on average 10 t·ha-1), with yields higher by 9.2% compared to the other two varieties. In both production systems, Smolitop v had the lowest yield; inferior by about 10% in the organic system vis-a-visAmbrosini, and the integrated system vis-a-vis Ricardinio.

4. Cultivar Ricardinio had the highest weight and number of grains per cob and Smolitop the lowest, (5.1% and 9.4% lower, respectively) averaged over the production system. The grains of Smolitop were approximately 21 g heavier than those of Ambrosini, the cultivar with the lightest grains (307 g on average). On average plants of Ricardinio were the tallest and its cobs grew highest on the stem regardless of the production system. However, the length and diameter of the cob of the tested cultivars were similar.

REFERENCES

Archer D.W., Jaradat A.A., Johnson J.M.F., Lachnicht-Weyers S., Gesch R.W., Forcella F., Kludze,H.K., 2007. Crop productivity and economics during the transition to alternative cropping systems. Agronomy Journal, 99: 1538-1547, doi: 10.2134/agronj2006.0364.

Baresel J.P., Zimmermann G., Reents, H.J., 2008. Effects of genotypes and environment on N uptake and N partition in organically grown winter wheat (Triticum aestivum L.) in Germany. Euphytica, 163: 347-354, doi: 10.1007/s10681-008-9718-1.

Cavigelli M.A., Teasdale J.R., Conklin A.E., 2008. Long-term agronomic performance of organic and conventional field crops in the mid-Atlantic region. Agronomy Journal, 100: 785-794, doi: 10.2134/agronj2006.0373.

Cesevičienė J., Leistrumaitė A., Paplauskienė V., 2009. Grain yield and quality of winter wheat varieties in organic agriculture. Agronomy Research, 7: 217-223.

Cox W.J., Cherney J.H., 2018. Agronomic comparisons of conventional and organic maize during the transition to an organic cropping system. Agronomy, 8(7), 113, doi: 10.3390/agronomy8070113.

Coulter J.A., Delbridge T.A., King R.P., Sheaffer C.C., 2013. Productivity, economic, and soil quality in the Minnesota Variable-Input Cropping Systems Trial. Crop Management, 12(1): 1-11, doi: 10.1094/CM-2013-0429-03-RS.

Eisele J.A., Köpke U., 1997. Choice of cultivars in organic farming: New criteria for winter wheat ideotypes. 1. Light conditions in stands of winter wheat affected by morphological features of different varieties. Pflanzenbauwissenschaften, 1: 19-24.

Hossar L., Archer D.W., Bertrand M., Colnenne-David C., Debaeke P., Ernfors M., Helene Jeuffroy M., Munier-Jolain N., Nilsson C., Sanford G.R., 2016. Meta-analysis of maize and wheat yields in low-input vs. conventional and organic systems. Agronomy Journal, 108: 1155-1167, doi: 10.2134/agronj2015.0512.

IJHARS, 2017. The report on organic farming in Poland in 2015–2016. Warszawa, www.ijhars.gov.pl (in Polish)

IJHARS, 2018. The report on organic farming in Poland in 2017–2018. Warszawa, https://ijhars.gov.pl/raporty-i-analizy.html

Jończyk K., 2010. Problemy agrotechniki w rolnictwie ekologicznym. Studia i Raporty IUNG-PIB, 26: 51-61.

Kaffka S., Bryant D., Denison F., 2005. Comparison of organic and conventional maize and tomato cropping systems from a long-term experiment in California. International Scientific Conference on organic agriculture. Research sustainable systems. Adelaide Australia, pp. 21-23.

Księżak J., Kawalec A., 2006. Dependence of white lupine yielding on protection intensity and percentage in crop rotation. Progress in Plant Protection, 46(2): 44-46. (in Polish + summary in English)

Księżak J., Kuś J., 2005. Faba bean yielding in varying systems of plant production. Annales UMCS Sectio E, vol. LX, 195-205. (in Polish + summary in English)

Księżak J., Staniak M., Bojarszczuk J., 2011. Evaluation of yielding of maize growing in organic farming dependingon cultivation method and doses of organic fertilization. Journal of Research and Applications in Agricultural Engineering, 56(3): 227-231. (in Polish + summary in English)

Kuś J., Jończyk K., 2009. Production and environmental consequence of the ecological and conventional crop production systems. Journal of Research and Applications in Agricultural Engineering, 53(3): 183-188. (in Polish + summary in English)

Kuś J., Jończyk K., 2018. Produkcyjne i środowiskowe skutki stosowania różnych systemów gospodarowania w Osinach. Eksperymenty wieloletnie w badaniach rolniczych w Polsce. Monografia pod red. Marksa M., Olsztyn, ISBN 978-83-8100-132-8, pp. 133-156.

Kuś J., Jończyk K., Kawalec A., 2007. Factors limiting the yields of winter wheat in different crop production systems Acta Agrophysica, 10(2): 407-417. (in Polish + summary in English)

Kuś J., Jończyk J., Stalenga J., Feledyn-Szewczyk B., Mróz A., 2011. Yields of the selected spring wheat varieties cultivated in organic and conventional crop production systems. Journal of Research and Applications in Agricultural Engineering, 56(4): 18-23. (in Polish + summary in English)

Machul M., Księżak J., 2007. Evaluation of yielding of maize depending on pre-sowing soil cultivation and method of nitrogen doses in conditions of monoculture and crop rotation, Fragmenta Agronomica, 95(3): 292-299. (in Polish + summary in English)

Revilla P., de Galarreta J.I.R., Malvar R.A., Landa A., Ordas A., 2015. Breeding maize for traditional and organic agriculture. Euphytica, 205: 219-230, doi: 10.1007/s10681-015-1430-3.

Seufert V., Ramankutty N., Foley J.A., 2012. Comparing the yields of organic and conventional agriculture. Nature, 485: 229-232, doi: 10.1038/nature11069.

Smulikowska S., Rutkowski A., 2005. Zalecenia żywieniowe i wartość pokarmowa pasz. Normy żywienia drobiu. Instytut Fizjologii i Żywienia Zwierząt, Jabłonna, 136 pp.

Szczurek W., Szymczyk B., Arczewska-Włosek A., Józefiak D., Alloui M.N., 2013. The effects of dietary whey protein concentrate level on performance, selected intestinal tract and blood parameters, and thiobarbituric acid reactive substances in the liver and breast meat of broiler chickens. Journal of Animal and Feed Sciences, 22: 342-353.

USDA. ERS. 2015. The Profit Potential of Certified Organic Field Crop Production. Available online: http://www.ers.usda.

gov/media/1875176/err188_summary.pdf (accessed 8.05. 2018).

Willer H., Kilcher L. (eds.)**, 2011.** The world of organic agriculture. Statistics and emerging trends 2011. FiBL-IFOAM Report. IFOAM, Bonn and FiBL, Frick.

Zarzyńska K., Jończyk K., 2017. Yield and commercial tuber quality of potatoes grown under two crop production systems in different environmental conditions. Journal of Research and Applications in Agricultural Engineering, 62(4): 211-115.

Author	ORCID
Jerzy Księżak	0000-0002-1991-1141

received – 22 February 2021
revised – 22 March 2021
accepted – 5 May 2021

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution-ShareAlike (CC BY-SA) license (http://creativecommons.org/licenses/by/4.0/).