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ORIGINAL PAPER

COMPARISON OF MAIZE YIELD AND SOIL CHEMICAL PROPERTIES UNDER MAIZE (*ZEA MAYS* L.) GROWN IN MONOCULTURE AND CROP ROTATION

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Abstract

Maize is one of the crop species that are increasingly grown in no-tillage systems. This approach is conducive better utilization of the agricultural production areas, which - as well as enabling farmers to obtain high yields - improves an overall organization of the agricultural production and its economic efficiency. The aim of this study was to evaluate the yield of maize grown for grain cultivated in monoculture with two methods of soil pre-sowing preparation, and to compare it to the yield achieved in crop rotation. Another aim was to determine the influence of cultivation simplifications on soil chemical properties.The results were derived from field experiments, which were carried out in two sites in Poland. The study showed that the lowest average maize yield was achieved in monoculture with direct sowing. The yields obtained in the monoculture tested in Baborówko were lower by approximately 17% than in the crop rotation system, while in Grabów the respective difference was about 27%. Grain yields in Baborówko were higher by about 33% compared to Grabów. Abandonment of the mechanical cultivation of maize grown in monoculture caused a decrease in the weight of cobs and in the number of grains per cob. The pH of the soil in which maize was grown was more acidic at the end than prior to the experiment, especially in the treatment with crop rotation. The content of P_2O_5 in the soil was higher after three years of maize cultivation in the direct sowing or full ploughing systems than before the beginning of the experiment, while a decrease in its concentration was recorded in soil cropped with maize grown in crop rotation. The total amount of nitrogen in the soil decreased regardless of the method of pre-sowing soil preparation. The humus content of soil under maize grown in monoculture with direct sowing or with full tillage did not change, while its amount increased in soil under maize grown in crop rotation with cereals.

Keywords: yields, *Zea Mays*, soil pre-sowing preparation, chemical properties.

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INTRODUCTION

Maize (*Zea mays* L.) is one of the most important crop species widely used in agriculture and industry. It is cultivated on over 184 million ha and its further dynamic growth is expected in Europe in the coming years, by up to 10% (www.fao.org/faostat/en, http://ec.europa.eu/eurostat/data/database). Cultivation of maize requires much energy, labour and use of many production means. These economic aspects encourage the implementation of simplified tillage cultivation. The biggest economic savings in maize cultivation are obtained by using a no-tillage method with direct sowing (Księżak 2010). Maize is a plant species grown increasingly often in no-tillage systems. This approach is conducive to better utilization of the agricultural production areas, which – as well as enabling farmers to obtain high yields – improves an overall organization of the production and its economic efficiency (Księżak, Bojarszczuk 2010). In Poland, the cultivation of maize without deep ploughing is carried out only on some farms that use new technologies, tools and machinery, and especially the ones which own seed drills for direct sowing. Both in Europe and in Poland, the cultivation of maize usually involves ploughing, which consumes large amounts of energy and funds.

Tillage is crucial for crop establishment, growth and ultimately yield (Atkinson et al. 2007). Tillage practice influences soil physical, chemical and biological characteristics, which in turn may alter plant growth and yield (Ozpinar, Cay 2006, Rashidi, Keshavarzpour 2009). They also have an important influence on soil biological activity (Swędrzyńska et al. 2013, Ghimire et al. 2014). The highest biological activity of soil is observed in cases of direct sowing in monoculture (Gałązka et al. 2017*a*,*b*). Soil microorganisms play a fundamental role in promoting growth and development of plants (Scherer et al. 2011, Zhang et al. 2012).

Soil biological properties of the surface layer are more favourable under the no-tillage method with crop residue mulch than under the plough-tillage method without residue mulch (Księżak 2010). In addition, leaving the soil uncovered for winter leads to stronger water and wind erosion, as well as more intensive mineralization of humus.

The aim of the study was to evaluate the yield of maize grown in monoculture with two methods of soil pre-sowing preparation, and to compare it to the yield achieved in crop rotation. Another aim was to determine the influence of cultivation simplification on soil chemical properties.

MATERIAL AND METHODS

The study was conducted in 2010-2012, at two experimental sites: one located at the Agricultural Experimentation Station (AES) of the Institute of Soil Science and Plant Cultivation in Grabów in the Mazowieckie Province

[51°23′ N; 21°38′ E], (central-eastern Poland), and the other one situated at the Experimental Station (ES) in Baborówko, [52°36′ N; 16°34′ E] in the Wielkopolskie Province (central-western Poland). The design of the experiment involved the following treatments: maize monoculture with zero tillage (direct sowing), maize monoculture with full ploughing tillage including cultivation measures, and cultivation in crop rotation (spring barley, winter wheat, maize) with full ploughing tillage. The research at AES in Grabów was conducted on grey brown podsolic soil underlain by light loam classified as very good rye complex, whereas the experimental fields in at ES Baborówko lay on podsolic soil with the textural structure of loamy sand (USDA soil classification) and classified as good rye complex. The soil ploughing layer was characterized by the following abundance of minerals: low in magnesium, medium in potassium, and high in phosphorus. The size of a plot 27.0 m^2 at the set-up of the experiment and 21.0 m^2 at harvest. The experiment was established using a long strip design with four replications. Mineral fertilizers were applied at the following doses: 140 kg ha^{-1} N (70 + 70), 34.9 kg ha^{-1} P and 103.8 kg ha^{-1} K. The yields of maize (plant height, weight of 1000 grains, parameters of maize cobs, plant density of harvest, grain yields of cereals) were determined. To this aim, 5 plants were used in each replication. The cobs were hand-crushed and threshed in a laboratory thresher (Wintersteiger LD 350). The grain moisture was measured in a Unimeter Super Digital grain moisture meter.

Soil samples were collected from three levels (Ap): 0-10, 11-20 and 21-30 cm, from all the treatments with 4 replications.

Basic chemical properties of the soil material were determined at the AES in Grabów, in the autumn of 2009 (a year before the experiment) and in 2012 (the year when the experiment was terminated). After preparation, the soil material was determined for: humus content (redoxymetry – by the Tiurin method), pH in KCl (potentiometrically), the content of available forms of potassium and phosphorus (by the Egner-Riehm's method with the use of appropriate spectrometers), content of available magnesium (by atomic absorption spectrometry with flame atomization FASS), total nitrogen (%) – by Elemental Analysis.

Significance of the effects of the soil preparation methods on maize yield was evaluated with analysis of variance including confidence coefficients from the Tukey's test at the significance level of $\alpha = 0.05$. All calculations were supported by Statgraphics Plus 4.1 software.

RESULTS AND DISCUSSION

The weather conditions had a major impact on the yields of maize cultivated in monoculture in both tillage systems, and of the cereals (spring barley, winter wheat) grown in rotation with this species. In Grabów, the total precipitation during the growing period was higher in the first and the second year of the study than the average multi-annual precipitation (by 40 and 33%, respectively) – Table 1. In 2010, high precipitation occurred in August and September, while a rain deficit took place in June and July. In 2011, very abundant precipitation was recorded in July (3.5-fold higher than the multi-year average), while a shortage of rainfall occurred in June and August. The third year of the study (2012) was more favourable in terms of the quantity and distribution of precipitations. Same deficits were recorded in May and June. In Baborówko, high precipitation appeared in May and August in 2010, while a rainfall deficit occurred in April. In April 2011, there was a drought, which limited the growth and development of plants (Table 2). The rainfall in July 2011 was very high (double the multi-year

Table 1

Course of weather conditions during the plant growing seasons in Grabów

Specification	Year	Month						
		April	May	June	July	August	September	sum / average (IV-IX)
Rainfalls (mm)	2010	20.8	114.0	50.7	53.4	155.1	135.7	529.7
	2011	35.9	74.5	52.4	298.8	35.6	3.6	500.8
	2012	37.8	36.5	54.3	81.6	64.2	21.8	296.2
Rainfalls mean from multi-years (mm)*		39.0	57.0	71.0	84.0	75.0	50.0	376.0
Temperature (°C)	2010	9.0	13.9	17.6	21.5	19.9	12.1	15.7
	2011	10.3	13.9	18.5	18.4	18.8	14.7	15.8
	2012	9.6	15.3	17.7	20.9	18.8	14.5	16.1
Temperature multi-annual mean (°C)		7.7	13.4	16.7	18.3	17.3	13.2	14.4

Source: Bulletin of State Hydrological and Meteorological Service IMGW-PIB
* average from years 1871-2000

Table 2

Course of weather conditions during the plant growing seasons in Baborówko

Specification	Year	Month						
		April	May	June	July	August	September	sum / average (IV-IX)
Rainfalls (mm)	2010	-	110.1	13.0	111.4	124.1	72.4	431.0
	2011	4.5	20.7	41.2	157.7	63.8	31.1	314.5
	2012	23.0	76.7	97.8	92.6	62.5	21.5	351.1
Rainfalls mean from multi-years (mm)*		30.8	49.7	60.5	78.7	54.2	42.9	316.8
Temperature (°C)	2010	-	12.1	18.4	23.2	19.4	13.2	17.3
	2011	-	15.8	19.9	18.8	19.7	16.1	18.1
	2012	9.9	16.1	17.0	20.2	19.7	15.0	17.6
Temperature multi-annual mean (°C)		7.8	13.4	16.3	18.2	17.9	13.3	14.5

* average from years 1871-2000

average). In 2012, a deficit of precipitation occurred in September. In the study of Machul, Księżak (2007), it was found that an increase of temperature by 4°C in July and lower rainfall (by about 10 mm) caused maize plants to form partially or completely seedless cobs, which adversely affected the yield. Majchrzak et al. (2002) and Sekutowski, Rola (2010) showed that the maize yields depended primarily on the course of weather conditions.

The maize yield was significantly influenced by the region of its cultivation, weather conditions during the growing season and the methods of pre-sowing soil preparation. Grain yields obtained in Baborówko were higher by about 33% compared to yield in Grabów (Table 3). The lowest maize yields

Table 3

Yield of grain and straw depending on methods of soil pre-sowing preparation (t ha^{-1})

Method of soil pre-sowing preparation	Grabów							
	2010		2011		2012		mean	
	grain	straw	grain	straw	grain	straw	grain	straw
Monoculture – no tillage	5.07^{a}*	5.15^{a}	6.84^{a}	7.11^{a}	5.32^{a}	5.25^{a}	5.74^{a}	5.84^{a}
Monoculture – full tillage	5.02^{a}	4.96^{a}	9.54^{b}	9.65^{b}	5.92^{b}	6.56^{b}	6.83^{b}	7.06^{b}
Crop rotation –full tillage	5.46^{b}	5.21^{a}	10.92^{c}	10.82^{c}	7.05^{c}	8.72^{c}	7.81^{c}	8.25^{c}
Mean	5.18	5.11	9.10	9.19	6.10	6.84	6.79	7.05
	Baborówko							
Monoculture – no tillage	9.20^{a}	8.50^{b}	9.42^{a}	8.79^{a}	8.74^{a}	7.43^{a}	9.12^{a}	8.24^{a}
Monoculture – full tillage	9.39^{a}	8.64^{b}	11.71^{b}	9.77^{b}	10.95^{b}	9.56^{b}	10.68^{b}	9.32^{b}
Crop rotation – full tillage	9.42^{a}	8.21^{a}	12.49^{c}	9.90^{c}	11.05^{b}	9.89^{c}	10.65^{b}	9.33^{b}
Mean	9.34	8.45	11.21	9.49	10.25	8.96	10.15	8.96

* numbers in columns (referring to the same location) assigned the same superscript do not differ significantly

occurred in the treatments where the crop was grown in monoculture with direct sowing. The yields obtained in this treatment were approximately 17% lower than in crop rotation. A review of the literature concerning the research on the effects of simplified soil cultivation on maize yield shows a large discrepancy of the results. The most common opinion is that the use of reduced tillage, especially direct sowing, leads to a significant reduction in maize grain and straw yield (Machul 1993, Machul 1995, Burgess et al. 1996, Kapusta et al. 1996, Drury et al. 1999, Menzel, Dubas 2003, Blecharczyk et al. 2004, Włodek et al. 2005. Dubas et al. (2012) and Gul et al. (2011) found that the yield is influenced by weather conditions. According to Machul (1995), the negative impact of using monoculture manifests itself as early as in the second year of such cultivation. This author reported that the yield was only a few percent lower compared to full tillage, while Menzel, Dubas (2003) demonstrated a 16% difference. Szulc, Dubas (2014) reported that 13-year maize grain yield in no-tillage system and direct sowing was 10.4% lower than the yield obtained in a conventional tillage system. Many authors attribute the decrease in grain yields of maize cultivated in direct sowing to lower plant density and a smaller number of cobs per area unit (Machul 1995, Menzel, Dubas 2003). Machul, Księżak (2007), however, did not observe differences in maize yields grown in crop rotation and in monoculture, regardless of the method of pre-sowing soil preparation. According to many authors (Pierce et al. 1994, Mahboubi, Lal 1998), direct sowing used repeatedly over a few years causes changes in the soil environment, which initially affect maize yields adversely, but yields become stable in later years, which ensures positive economic effects.

The current study did not show a significant impact of pre-sowing soil preparation on the number of grains per cob, or the length and diameter of the cob in either location (Tables 4, 5). However, the weight of cobs was influenced by soil pre-sowing methods. Maize cultivated in crop rotation was

Table 4

The structure of maize yield depending on methods of soil pre-sowing preparation in Grabów

Year	Method of soil pre-sowing preparation	Weight of cob (g)	Share (%)		Number of grain in cob	Cob size	
			grain	corncob		length (cm)	diameter (mm)
2010	monoculture – no tillage	97.0[a]*	88.6	11.4	416.5[a]	15.0[a]	37.8[a]
	monoculture–full tillage	97.5[a]	88.1	11.9	408.6[a]	14.4[a]	36.5[a]
	crop rotation– full tillage	110.5[b]	87.3	12.7	423.8[a]	15.3[a]	37.1[a]
2011	monoculture – no tillage	111.8[a]	88.7	11.3	455.2[a]	15.7[a]	38.7[a]
	monoculture–full tillage	125.9[b]	88.1	11.9	473.6[a]	17.2[a]	38.4[a]
	crop rotation– full tillage	146.7[c]	89.3	10.7	490.3[a]	17.9[a]	38.8[a]
2012	monoculture – no tillage	98.7[a]	88.7	11.3	334.7[a]	13.7[a]	39.6[a]
	monoculture–full tillage	112.2[b]	88.2	11.8	374.3[a]	11.4[a]	37.9[a]
	crop rotation– full tillage	191.7[c]	88.7	11.3	391.8[a]	13.6[a]	35.6[a]
Mean	monoculture – no tillage	102.5[a]	88.7	11.3	402.1[a]	14.8[a]	38.7[a]
	monoculture – full tillage	118.9[b]	88.1	11.9	418.8[a]	14.3[a]	37.6[a]
	crop rotation – full tillage	149.6[c]	88.4	11.6	435.3[a]	15.6[a]	37.2[a]

* see Table 3

characterized by the biggest corn weight. In Grabów, the cob weight noted in the crop rotation was about 46% higher than in monoculture with direct sowing, and about 26% higher than in monoculture with full ploughing tillage (Table 4). In Baborówko, the differences were 11% and 5%, respectively (Table 5). The results obtained by Machul (1995), Menzel, Dubas (2003) indicate that treatments with full ploughing tillage resulted in significantly higher plant density than treatments with zero tillage, where seeds remained uncovered during the sowing. The number of cobs per unit area was also influenced by a method of soil cultivation. The results reported by Aikins et al. (2012) showed that maize cultivated in no-tillage system was distinguished by the shortest plant height, lowest number of leaves per plant, smallest leaf area index, lowest dry matter yield, lowest fresh cob weight, lowest dry cob weight, and the smallest 1000-seed weight. In Grabów, maize grown in the monoculture with direct sowing was characterized by significan-

Table 5

The structure of maize yield depending on methods of soil pre-sowing preparation in Baborówko

Year	Method of soil pre-sowing preparation	Weight of cob (g)	Share (%)		Number of grain in cob	Cob size	
			grain	corncob		length (cm)	diameter (mm)
2010	monoculture – no tillage	158.5^{a}*	87.8	12.2	465.3^{a}	19.4^{a}	39.5^{a}
	monoculture – full tillage	167.6^{b}	87.9	12.1	472.4^{a}	18.4^{a}	40.8^{a}
	crop rotation – full tillage	174.0^{c}	88.3	11.7	489.3^{a}	18.0^{a}	40.1^{a}
2011	monoculture – no tillage	169.4^{a}	89.2	10.8	523.5^{a}	17.8^{a}	41.8^{a}
	monoculture – full tillage	173.7^{b}	86.9	13.1	534.1^{a}	17.1^{a}	38.9^{a}
	crop rotation – full tillage	187.5^{c}	87.9	12.1	548.3^{a}	17.5^{a}	41.2^{a}
2012	monoculture – no tillage	151.9^{a}	88.3	11.7	464.1^{a}	16.6^{a}	33.9^{a}
	monoculture – full tillage	165.3^{b}	89.4	10.6	502.3^{a}	17.5^{a}	40.0^{b}
	crop rotation– full tillage	169.8^{b}	88.4	11.6	547.2^{b}	16.6^{a}	39.1^{b}
Mean	monoculture – no tillage	159.9^{a}	88.4	11.6	484.3^{a}	17.9^{a}	38.4^{a}
	monoculture – full tillage	168.9^{b}	88.1	11.9	502.9^{a}	17.7^{a}	39.9^{a}
	crop rotation – full tillage	177.1^{c}	88.2	11.8	528.3^{a}	17.4^{a}	40.1^{a}

* see Table 3

tly lower thousand grain weight, while in Baborówko, this result occurred only in the first year of the experiment (Table 6). The highest thousand grain weight was noted for maize cultivated in crop rotation while the lowest one was in maize cultivated in the monoculture with direct sowing. It was also found that grains of maize cultivated in central-western Poland were characterized by about 16% higher moisture content than maize grain harvested in central-eastern Poland. However, no significant differences were found between the soil pre-sowing preparation method (Table 6). In addition, maize grain cultivated in the monoculture with direct sowing was characte-

Table 6

The thousand grain weight and grain moisture at harvest time (%) depending on methods of soil pre-sowing preparation

Method of soil pre-sowing preparation	Thousand grain weight (g)				Grain moisture (%)			
	2010	2011	2012	mean	2010	2011	2012	mean
Grabów								
Monoculture – no tillage	257.6^{a}	220.6^{a}	267.3^{a}	248.5^{a}	31.2^{a}	26.8^{a}	15.7^{a}	24.6^{a}
Monoculture – full tillage	272.1^{b}	254.9^{b}	288.1^{b}	271.7^{b}	32.0^{a}	27.4^{a}	16.4^{a}	25.3^{a}
Crop rotation – full tillage	283.9^{c}	284.9^{c}	321.8^{c}	296.9^{c}	32.9^{a}	28.3^{a}	16.7^{a}	26.0^{a}
Mean	271.2	253.5	292.4	272.4	32.0	27.5	16.3	25.3
Baborówko								
Monoculture – no tillage	303.4^{a}	255.3^{a}	269.9^{a}	276.2^{a}	32.5^{a}	25.5^{a}	27.9^{a}	28.6^{a}
Monoculture – full tillage	306.5^{a}	267.2^{b}	276.8^{a}	283.5^{b}	32.6^{a}	26.6^{a}	29.1^{a}	29.4^{a}
Crop rotation – full tillage	315.7^{a}	273.5^{c}	279.9^{a}	289.7^{b}	32.8^{a}	29.0^{a}	29.1^{a}	30.3^{a}
Mean	308.5	188.7	275.5	283.1	32.6	27.0	28.7	29.4

* see Table 3

rized by about 2% less moisture compared to the treatments with full ploughing. Similar results were obtained by Machul (1995), Menzel, Dubas (2003). However, Dubas, Szulc (2006) found that the grain from direct sowing treatments had only a slightly higher moisture content.

There were significant differences in the height of cob set depending on the method of pre-sowing soil preparation. There were also significant differences in the height of maize plants (Table 7). In both regions, the lowest

Table 7

The height of cob set and the height of maize plants before harvesting (cm) depending on methods of soil pre-sowing preparation

Method of soil pre-sowing preparation	The height of cob set (cm)				The height of maize plant (cm)*			
	2010	2011	2012	mean	2010	2011	2012	mean
Grabów								
Monoculture – no tillage	76[a]**	90[a]	88[b]	85[a]	215[a]	245[a]	216[a]	225[a]
Monoculture – full tillage	87[b]	96[b]	86[b]	90[b]	229[b]	253[b]	228[b]	237[b]
Crop rotation – full tillage	87[b]	93[b]	79[a]	86[a]	231[b]	251[b]	238[b]	240[b]
Mean	83	93	84	87	225	250	227	234
Baborówko								
Monoculture – no tillage	66[a]	58[a]	65[a]	63[a]	210[a]	201[a]	188[a]	200[a]
Monoculture – full tillage	87[b]	66[b]	67[a]	73[b]	221[b]	232[b]	223[b]	225[b]
Crop rotation – full tillage	87[b]	66[b]	69[a]	74[b]	229[b]	235[b]	228[b]	231[b]
Mean	80	63	67	70	220	223	213	219

* measured from the soil surface to the top of the plant
** see Table 3

plants were recorded in the treatments with direct sowing compared to ones, where full tillage was used in both monoculture and crop rotation.

The study showed that methods of pre-sowing soil cultivation have some influence on soil pH. A decrease in the soil pH was noted in 2012, especially in the crop rotation system (Table 8). In the autumn of 2009, pH in the soil under the monoculture with direct sowing was lower in the 20-30 cm soil layer than in the 0-20 cm horizon. However, in the same year, soil pH was similar in all the treatments with full ploughing tillage. In 2012, there was an increase of pH in the deeper layers of the soil, regardless of the method of pre-sowing soil preparation. Dubas et al. (2012) observed slightly lower pH in upper layers of the soil compared to deeper ones. However, according to Machul (1995), annual application of direct sowing causes acidification of soil, especially topsoil. This is most likely the result of superficial input of mineral fertilizers, shallower distribution of the root system and unilateral depletion of the upper soil levels from some elements. The content of P in the treatments with direct sowing and full ploughing tillage in monoculture was higher after the trials than prior to them, while in the treatments, where maize was grown in crop rotation, the P content decreased (Table 8). Less phosphorus was determined in the deeper, 20-30 cm layer under maize grown in the monoculture with zero tillage. In contrast, the use of winter ploughing resulted in the amounts of phosphorus being similar in both evaluated soil layers. The comparison of mean content of K in the soil layer of 0-30 cm before and after the experiment showed a slight decrease in the concentration of this element during the study. It was also found that the content of K in the soil under maize grown in monoculture with direct sowing was the highest among all the treatments. In addition, the K content in this treatment was higher in the 0-10 cm soil layer than at the depths of 10-20 and 20-30 cm, which was not observed in the other two treatments with mechanical cultivation. The content of potassium in the soil after the study was similar to that recorded before it had started. Its content in individual soil layers in the treatments where maize was cultivated in the monoculture with full ploughing tillage was similar, while in the monoculture with direct sowing it was by about 70% higher in the 0-10 cm layer than at the 20-30 cm layer.

An increase in the content of available phosphorus, potassium and magnesium in the soil upper layers in the treatments with direct sowing compared to traditional cultivation was reported by MACHUL (1995). DUBAS et al. (2012) recorded the lowest amount of phosphorus in treatments with deep ploughing and direct sowing. According to PUDEŁKO et al. (1994), an increase in the content of nitrogen, phosphorus, potassium, and carbon in the top layer of the soil is caused by a lower rate of erosion. In our study, the total nitrogen content in the soil decreased in all the treatments, regardless of the method of soil preparation (Table 8). The humus content in the soil shows a dependence on the intensity of soil cultivation. In 2012, its amount in the soil where maize grown in monoculture with direct sowing and full ploughing tillage was the same as in the year preceding the experiment. In contrast, less humus was found in the soil where maize grown in rotation with cereals. Cultivation of maize with direct sowing resulted in the lowering of the humus content in the deeper soil layers, while full ploughing increased its amount in the 10-30 cm layer. Increased accumulation of organic matter in the upper horizon of topsoil and its reduced amounts in deeper layers with simplified cultivation were also observed by other authors, such as ALVAREZ et al. (1995), MACHUL (1995). In contrast, DUBAS et al. (2012) determined less humus in the topsoil in treatments with deep ploughing than in treatments with direct sowing. These authors did not observe an increase in the amount of humus in the top layer (0-15cm) with no-tillage cultivation in comparison with other simplifications. ALVAREZ et al. (1995) reported that the accumulation of organic matter in the upper layer of soil increases the organic carbon content by 42-50%. MACHUL (1995) found that changes in the humus content were also associated with the type of soil (a higher increase occurred in mineral soil compared with fluvial one).

Table 8

The influence on different methods of pre-sowing soil preparation on chosen soil properties

Method of soil presowing preparation	The depth of soil layer (cm)	Autumn – 2009							Autumn - 2012				
		pH_{KCl}	content macroelements in soil (mg kg^{-1})			content of humus (g kg^{-1})	% total nitrogen (g kg^{-1})	pH_{KCl}	content macroelements in soil (mg kg^{-1})			content of humus (g kg^{-1})	% total nitrogen (g kg^{-1})
			P	K	Mg				P	K	Mg		
Monoculture – no tillage (direct sowing)	0-10	6.5^{b}*	83.7^{b}*	128^{b}	22.3^{b}	8.1^{b}	0.89^{b}	6.06^{a}	84.6^{c}	168^{c}	33.5^{c}	8.3^{b}	0.74^{b}
	10-20	6.5^{b}	82.8^{b}	112^{a}	22.9^{b}	7.4^{a}	0.83^{a}	6.12^{a}	78.9^{b}	120^{b}	25.5^{b}	7.5^{a}	0.64^{a}
	20-30	5.9^{a}	62.8^{a}	108^{a}	16.9^{a}	7.3^{a}	0.85^{a}	6.31^{b}	75.4^{a}	82.2^{a}	19.7^{a}	7.0^{a}	0.59^{a}
	Mean	6.3	76.4	116	20.7	7.6	0.86	6.16	79.6	123	26.3	7.6	0.66
Monoculture – full tillage	0-10	6.8^{a}	107^{a}	63.1^{b}	21.1^{a}	7.4^{a}	0.83^{a}	6.63^{a}	109^{a}	56.4^{a}	22.6^{a}	7.3^{a}	0.61^{a}
	10-20	6.9^{a}	106^{a}	54.8^{a}	21.1^{a}	7.4^{a}	0.84^{a}	6.83^{b}	109^{a}	52.3^{a}	23.3^{a}	7.7^{a}	0.62^{a}
	20-30	7.0^{a}	103^{a}	65.6^{b}	22.3^{a}	7.5^{a}	0.86^{a}	6.97^{b}	114^{b}	73.9^{b}	24.9^{b}	7.8^{a}	0.61^{a}
	Mean	6.9	105	61.0	22.0	7.4	0.84	6.81	111	60.9	23.6	7.6	0.61
Crop rotation – full tillage	0-10	6.7^{a}	91.6^{a}	61.4^{a}	19.9^{a}	6.9^{a}	0.80^{a}	5.58^{a}	79.4^{a}	60.6^{a}	20.8^{a}	7.2^{a}	0.60^{a}
	10-20	7.1^{b}	91.6^{a}	65.6^{b}	21.1^{a}	7.1^{a}	0.79^{a}	6.06^{b}	84.6^{b}	58.9^{a}	21.5^{a}	7.5^{a}	0.64^{b}
	20-30	7.1^{b}	95.0^{b}	68.9^{b}	21.7^{a}	6.8^{a}	0.79^{a}	6.12^{b}	78.9^{a}	61.4^{a}	25.5^{b}	8.3^{b}	0.64^{b}
	Mean	7.0	92.7	65.3	20.9	6.9	0.79	5.92	81.0	60.3	22.6	7.7	0.63

* see Table 3

CONCLUSIONS

1. The lowest maize yield was recorded in the treatment where maize was grown in monoculture with direct sowing. The yields were lower by approximately 17% in Baborówko and by about 27% in Grabów compared to the treatment where maize was grown in crop rotation.

2. Abandonment of mechanical soil cultivation under maize grown in monoculture caused decrease in the weight of cobs and the number of grains per cob.

3. The pH of soil under maize grown crop rotation at the end of the experiment was more acidic than prior to the trials, especially in the treatment with crop rotation.

4. The content of P in the soil after three years of direct sowing or full ploughing was higher than before the experiment, while a decrease in its concentration was recorded in soil under maize grown in crop rotation. During this period, the total amount of nitrogen in the soil decreased regardless of the method of pre-sowing soil preparation.

5. The comparison of an average content of K in the 0-30 cm soil layer before and after the experiment showed a slight decrease in the concentration of this element. The K content in soil under maize monoculture with direct sowing was the highest in the 0-10 cm soil layer, a result which was not observed in the other two treatments with mechanical cultivation.

6. The humus content of soil under maize grown in monoculture with direct sowing or full ploughing tillage did not change, while its amount increased in soil under maize grown in crop rotation with cereals and with the use of natural fertilization.

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