Polish Journal of Agronomy
2010, 2, 33–40

Assessment of maize yields as affected by seedbed preparation method

Jerzy Księżak

Department of Forage Crop Production
Institute of Soil Science and Plant Cultivation – National Research Institute
ul. Czartoryskich 8, 24-100 Puławy, Poland

Abstract. The aim of this study was to compare the yields of maize grown continuously under two seedbed management systems vs. the conventional rotation-based system and to compare the changes in the soil environment brought about by those tillage methods.

Results for the study were derived from maize investigations performed at two experiment sites: at the Agricultural Experiment Station at Grabów, province of Mazovia, Poland, at an experiment station at Baborówko, province of Great Poland. It was a stationary field trial established in 2004 which involved maize cropped continuously and rotated with other crops. The layout of the experiment involved the following treatments: maize cropped continuously – zero tillage (direct seeding), maize cropped continuously – plough-based tillage with complementary cultivation practices, maize in crop rotation (spring barley – winter wheat – maize) – conventional plough-based tillage.

The highest grain yields, regardless of site area, were obtained from maize grown under a three-year rotation scheme with organic fertilization. Under such a management the yields were higher by 10% compared to those from a treatment which combined maize monoculture and direct seeding. The grain yields recorded in Wielkopolska (Greater Poland) were higher than those in the mid-eastern region. In terms of cereal units, lower yields were obtained from the rotation scheme – spring barley, winter wheat – maize than from maize grown under monoculture, regardless of tillage method and experiment site. Direct seeding of continuously cropped maize increased grain moisture at harvest by ca. 2%, did not affect number of grains per cob, but decreased weight of 1000 grains. The contents of humus and P_2O_5 in the 0–30 cm soil layer were higher and that of K_2O was lower at the termination of the trial that at its commencement, but the content of MgO remained little changed. The contents of humus and K_2O in the topsoil (0–10 cm) under continuously cropped and directly seeded maize were higher that in the 10–30 cm soil layer. Total N varied but little among seedbed preparation methods and also showed little variation across the soil profile.

key words: maize, seedbed preparation, monoculture, zero-tillage

Corresponding author:
Jerzy Księżak
e-mail: jerzy.ksiezak@iung.pulawy.pl
tel. +48 (81) 8863421 ext. 350, fax +48 (81) 8864547

Received 12 April 2010

INTRODUCTION

Simplified cropping schemes and reduced tillage methods are increasingly used in contemporary farming. Reduced tillage usually consists in the reduction of tilling depth or in the reduction of tillage passes down to stopping tillage completely (zero-tillage). A reduction in the number of crops to be grown in a field can vary from short crop sequences to continuous cropping. Maize is a crop that tolerates continuous cropping well and in many countries it is grown from direct seeding (Cox et al., 1990; Pudełko et al., 1994; Radecki, Opic, 1991; Szymankiewicz, 1988). According to Dubas (1980) and to Dubas and Menzel (1999) the yields of maize seeded directly and grown under monoculture undergo reduction as compared to the yields of maize grown under the conventional plough-based tillage system. Pabin et al. (2003) share a similar opinion. They report the reduction in yields of maize grown under such management to occur in the first 3–5 years. In another study Dubas and Szulc (2006) found the yields to decrease over the successive years regardless of tillage system but the yield reduction was greater for direct seeding as compared to conventional tillage. The results obtained by other investigators (Dzienia, Sosnowski, 1991; Dubas, Menzel, 1999; Dubas et al., 2002) also point to yield reduction attributable to simplified tillage and direct seeding. Those researchers point out that the scale of yield reduction varied with the environment in which maize was grown. By contrast, Griffith et al. (1988) found yields of maize seeded directly to level off vs. those obtained under regular tillage. The investigators also emphasize the fact that direct seeding, when applied for some time, causes some physical,

chemical, and biological properties of the soil to become stabilized and thus favours high yields in maize.

In Poland, since the year 2000 there has been a dynamic growth in the area under maize. In 2000 the crop occupied 314 000 ha whereas in 2008 the area cropped to maize increased to 733 000 ha. In the years 2001–2004 maize for grain was the leading crop but beginning with 2006 there has been a significant increase in the area cropped to maize grown for silage (60% of the total area in 2008). On many farms, especially on large-size farms, maize is not only grown in short maize-after-maize sequences but also under continuous cropping schemes of several years' duration. In addition, once the cobs have been harvested the remaining maize straw is not harvested for fodder but, rather, the residue is shredded and turned under. Nearly half of the produced biomass is returned to the soil thereby increasing the soil content of organic substance and of nutrients. By contrast, whole of the aboveground biomass of maize for silage is removed from field and has no positive effect on organic matter content in soil. In Poland, due to a substantial proportion of light and acidified soils such an approach is of considerable significance. The soils most frequently cropped to maize are rated as classes IIIa–IVb or as very good and good rye-growing complexes. Furthermore, the EU soil strategy of 2002 covers many hazards to soil fertility, and one of its major tenets is the prevention of soil degradation by restricting the reduction of soil organic matter. Poland, like the remaining EU member states, will be under obligation to develop soil degradation prevention programmes.

The aim of this study was to compare the yields of maize grown continuously under two seedbed management systems vs. the conventional rotation-based system and to compare the changes in the soil environment brought about by those tillage methods.

It was assumed that maize grown under monoculture would give yields similar to those of maize grown after cereals and that the adverse changes to physico-chemical and biological properties of the soil related to continuous cropping would be efficiently offset by the incorporation of maize straw residues.

METHODS

Results for the study were derived from maize investigations performed at two experiment sites: at the Agricultural Experiment Station at Grabów, province of Mazovia, Poland, located on lessive soil developed from a light loam and rated as very good rye-growing complex and at an Experiment Station at Baborówko, province of Great Poland, on a lessive soil with a granulometric composition characteristic of loamy sand and rated as good rye-growing complex. At both sites the arable layer of the soil was high in phosphorus, medium-high in potassium and low in magnesium. It was a stationary field trial established in 2004 which involved maize cropped continuously and rotated with other crops. The layout of the experiment involved the following treatments:

1. maize cropped continuously – zero tillage (direct seeding)
2. maize cropped continuously – plough-based tillage with complementary cultivation practices
3. maize in crop rotation (spring barley – winter wheat – maize) – conventional plough-based tillage

Maize grown under monoculture involved two seedbed preparation methods: plough-based tillage and zero tillage (direct seeding). In the conventional tillage treatment straw residues left after the cob harvest were shredded and turned under. By contrast, in the non-tilled treatment the straw was shredded but left on the soil surface. Under the crop rotation management all crop species involved were grown each year and full FYM dose was applied to maize. On dairy farms it is frequently the only species to which FYM can be applied. The experiment was set up as a long strip design with the mirror image of treatments.

Maize cv. Delitop was seeded using a precision maize plantler. Cv. Antek of spring barley and cv. Turnia of wheat were seeded at Grabów whereas cv. Weneda of spring barley and cv. Ludwiq of wheat were grown at Baborówko. Nitrogen was applied to maize at a rate of 140 kg N ha^{-1} (70 + 70), phosphorus and potassium rates (kg ha^{-1}) were P_2O_5 – 80 and K_2O – 125. Annual fertilizer rates supplied to barley were: N – 60, P_2O_5 – 35 and K_2O – 50 kg ha^{-1}, and to wheat: N – 120, P_2O_5 – 40 i K_2O – 70 kg ha^{-1}.

In order to assess the effect of maize tillage prior to the onset and after the termination of the trial pH in KCl and the soil contents (mg per 100 g of soil) of P_2O_5 (CFA method), K_2O (FES method), MgO (AAS method), percentage of total nitrogen (CFA method) and humus content (Tiurin's method) were assayed.

The maize was grown for grain. The yielding performance for the individual approaches to managing maize production were determined as total cereal units obtained from the continuous cropping of maize over three successive years and, for maize grown under crop rotation management, as total cereal units obtained from the combined crops of maize, wheat and barley over the full rotation cycle. In addition, records were also taken of grain yield and yield components. During plant growth biometrical measurements were taken. The crop stands were also evaluated for pest and disease infestation and, in maize, for lodging.

ANOVA was used to test the significance of treatment-to-treatment differences, confidence half-intervals being determined using Tukey's test at a significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Weather pattern had a significant effect on the yields of maize and cereals. In 2007 at Grabów small amounts of rainfall were recorded in the second and the third decade of

Table 1. Meterological conditions during the growing season (experiment stations at Grabów and at Baborówko, 2007–2009).

Years	April	May	June	July	August	September	April–September
	Average air temperatures [°C]						
	Grabów						
2007	7.8	15.2	18.7	19.2	19.1	12.8	15.5
2008	9.0	13.1	17.6	18.9	18.9	12.5	15.0
2009	10.7	13.0	16.4	19.7	18.1	14.9	15.5
Long-term mean	7.7	13.4	16.7	18.3	17.3	13.2	14.4
	Baborówko						
2007	9.8	16.0	19.8	19.5	19.7	14.0	16.5
2008	8.2	15.1	19.4	20.7	19.1	13.6	16.0
2009	12.8	14.1	16.2	20.3	20.2	15.8	16.6
Long-term mean	7.8	13.4	16.3	18.2	17.9	13.3	14.5
	Sum of precipitation [mm]						
	Grabów						
2007	13.3	74.6	99.9	75.5	151.7	77.4	492.4
2008	71.8	87.6	51.1	85.4	54.5	19.7	370.1
2009	0.6	57.5	117.9	117.8	74.6	32.3	400.7
Long-term mean	39	57	71	84	75	50	376
	Baborówko						
2007	9.7	119.4	59.0	94.7	42.4	27.1	352.3
2008	99.7	14.9	18.0	69.5	91.2	25.9	319.2
2009	17.5	76.8	91.4	75.8	27.3	45.50	334.3
Long-term mean	30.8	49.7	60.5	78.7	54.2	42.9	316.8

June and in the first decade of July whereas in 2008 there was no rainfall at all in the third decade of May and in the first decade of June and also no rainfall in April of 2009. Accompanying high air temperature and high insolation intensified water deficit. At Baborówko, drought occurred at the end of May and in the beginning of June resulting in restricted plant growth and development (Table 1). In an earlier study by Machul and Księżak (2007) the authors found that in July with the temperatures higher by 4 degrees C and with a lower rainfall (by ca. 10 mm) maize plants set ears a part of which was partly or completely void of seeds, a development which had a negative effect on yields.

Over the three-year period of the study, total cereal units recorded at Baborówko were substantially higher than those in Grabów (Table 2). It was chiefly due to much higher maize yields at the former location. Relatively low cereal yields, especially those of spring barley, caused the yields of cereal units at Grabów and at Baborówko to be lower under crop rotation than under maize monoculture both when conventional plough-based tillage or direct seeding were applied. At Grabów, the differences were ca. 6%, but at Baborówko they were substantially higher and reached ca. 23%. Total cereal units obtained over three years were much higher than those obtained by Machul and Księżak (2007). Those investigators also report that, in that period, in the central-eastern region the lowest yields in terms of cereal units were recorded under the management which combined conventional tillage and rotation whereas in the Great Poland region the lowest cereal units were obtained from the combination of continuous cropping and zero tillage.

Yields were substantially affected by region, weather pattern during the growing season and by the seedbed preparation methods applied. At Baborówko, yields higher

Table 2. Yields of cereal units obtained in the years 2007–2009.

Management system	RZD Grabów				SD Baborówko			
	2007	2008	2009	sum	2007	2008	2009	sum
Monoculture – zero tillage	75.10	73.30	83.80	232.2	97.70	88.90	95.80	282.3
Monoculture – conventional tillage	70.50	69.10	91.90	231.5	101.00	98.10	98.40	289.9
Crop rotation – conventional tillage	61.80	61.20	94.70	217.7	75.06	71.83	74.83	221.7
LSD ($\alpha = 0.05$)	4.62	3.93	3.61		4.93	5.23	3.96	

by about 25% were recorded for the study period (Figures 1, 2). At Baborówko, the highest yields were obtained in 2007 whereas at Grabów maize gave the best yields in 2009. Averaged over the three years, in both maize-growing regions the lowest yields of maize were obtained from the treatment that combined maize monoculture with direct seeding. In that treatment at Baborówko, the yields were 10% lower than those in the treatment involving a three-year rotation scheme. At Grabów, those differences were a little smaller. A survey of the literature on the effect of reduced tillage on maize yields reveals that the reported results show substantial discrepancies. There is a prevailing opinion that reduced tillage, and direct seeding in particular, leads to significant reductions in the yields of maize grain and straw (Burgess et al., 1996; Drury et al., 1999; Dubas, Menzel, 1999; Gregorich et al., 1993; Griffith et al., 1988; Ismail et al., 1994; Kapusta et al., 1996; Kaspar et al., 1987; Machul, 1993; Machul, 1995; Szymankiewicz, 1988). As reported by Dzienia and Sosnowski (1991) weather has an important impact since in warm years maize from direct seeding gave superior yields whereas in the years with spells of cool and moist weather maize grown under conventional tillage showed a better yielding performance. According to Machul (1995), an adverse impact of monoculture on maize yields becomes apparent as early as in the second year. According to Griffith et al. (1988) and to Machul (1995) yield reduction from direct seeding vs. conventional tillage is several percentage points whereas according to Menzel et Dubas (2003) it amounts to 16%. According to Sekutowski and Sadowski (2008) the application of reduced tillage in the preparation of seedbed that involved no weed control resulted in a yield reduction of ca. 42% over the plough-based tillage while in the treatments with herbicide application yield restrictions were small. According to many investigators (Cox et al., 1990; Dubas, Menzel, 1999; Gregorich et al., 1993; Machul, 1995; Menzel, Dubas, 2003) the major cause of decreased yields under the direct seeding management was reduced plant density and hence reduced number of cobs per unit area. By contrast, Machul and Księżak (2007)

Table 3. Weight of 1000 grains [g].

Management system	RZD Grabów			SD Baborówko		
	2007	2008	2009	2007	2008	2009
Monoculture – zero tillage	253	259	242	271	286	304
Monoculture – conventional tillage	262	245	255	279	294	303
Crop rotation	260	260	252	289	292	311
LSD (α = 0.05)	6.95	5.98	4.63	5.23	3.69	6.21

Table 4. Parameters of maize cobs.

Management system	Weight [g]		Number of seeds per cob	Proportion of rachis [%]	Cob measures [cm]	
	cob	grain			length	diameter
			Grabów			
Monoculture – zero tillage	119.2	108.7	434.0	10.9	17.3	3.7
Monoculture – conventional tillage	119.2	108.1	437.3	11.1	17.3	3.7
Crop rotation	121.4	107.9	440.7	11.0	17.3	3.8
LSD (α = 0.05)	ns	ns	ns	ns	ns	ns
			Baborówko			
Monoculture – zero tillage	151.2	132.3	450	12.1	17.9	4.0
Monoculture – conventional tillage	153.0	136.0	460	12.1	17.9	4.0
Crop rotation	165.1	147.2	474	12.8	18.3	4.0
LSD (α = 0.05)	5.24	4.12	12.3	ns	ns	ns

ns – non significant

Table 5. Plant density at harvest [thousand plants ha^{-1}].

Management system	RZD Grabów			SD Baborówko		
	2007	2008	2009	2007	2008	2009
Monoculture – zero tillage	86.3	71.8	88.7	88.4	72.3	89.4
Monoculture – conventional tillage	87.2	73.8	89.1	89.0	74.1	90.8
Crop rotation	87.7	73.2	89.8	89.4	74.9	91.3
Mean	86.8	72.9	89.2	88.9	73.8	90.5

Table 6. Grain moisture at harvest [%].

Management system	RZD Grabów			SD Baborówko		
	2007	2008	2009	2007	2008	2009
Monoculture – zero tillage	34.2	31.8	32.7	33.8	32.2	27.9
Monoculture – conventional tillage	33.0	30.0	30.3	32.9	31.3	27.0
Crop rotation	32.0	29.2	29.6	32.3	30.8	25.9
Mean	33.1	30.3	30.9	33.0	31.4	26.9
LSD (α = 0,05)	1.82	1.64	1.60	ns	ns	1.59

ns – non significant

Table 7. Plant height# of maize at harvest [cm].

Management system	RZD Grabów			SD Baborówko		
	2007	2008	2009	2007	2008	2009
Monoculture – zero tillage	200	139	205	210	148	195
Monoculture – conventional tillage	190	160	218	194	162	210
Crop rotation	192	160	224	190	164	215
Mean	194	153	216	198	158	207

measured from base to tip of the plant

Table 8. Grain yields of cereals [t ha^{-1}] in the treatment involving crop rotation.

Cereal species	RZD Grabów				SD Baborówko			
	2007	2008	2009	average	2007	2008	2009	average
Spring barley	4.46	4.76	3.00	4.07	4.12	3.57	5.1	4.26
Winter wheat	7.16	6.69	5.29	6.38	5.07	7.48	7.3	6.62
LSD (α = 0.05)	0.48	0.51	0.33		0.29	0.98	0.96	

failed to observe any variation in the yields of rotated vs. continuously cropped maize, regardless of the seedbed preparation method.

In both maize-growing regions the weight of 1000 grains from directly seeded maize grown under monoculture was lower than that from maize grown in crop rotation. There was no significant effect of seedbed preparation method on the proportion of rachis, cob length and diameter, and at Grabów no effect was also found on number of seeds per cob, cob weight and weight of seeds per cob. By contrast, when grown in crop rotation at Baborówko the maize had a higher number of seeds per cob, higher cob weight and higher weight of seeds per cob than maize grown under continuous management regardless of seedbed preparation method (Tables 3 and 4).

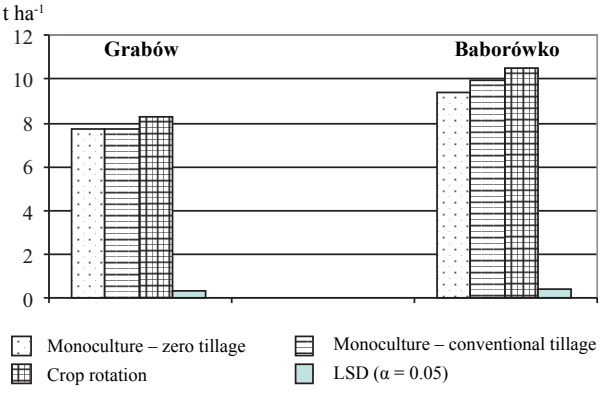

Fig. 1. Maize yields as affected by seedbed preparation (averages of 2007–2009).

The effect of seedbed preparation method on the number of plants per unit area at harvest was also slight (Table 5). It is only in 2008 that a substantially lower than planned plant density was recorded in all studied treatments. Results obtained by Machul (1995) and Menzel and Dubas (2003) indicate that plant density in the treatment with conventional tillage was much higher that that in those non-tillage treatments in which the seeds remained uncovered at seeding. The same effect was observed concerning number of cobs per unit area. Szymankiewicz (1987, 1988) holds the opinion that increased soil compactness and decreased soil capillary capacity may result in a reduced plant density per unit area.

Over the three years, the grain from maize grown under the management that involved monoculture and direct

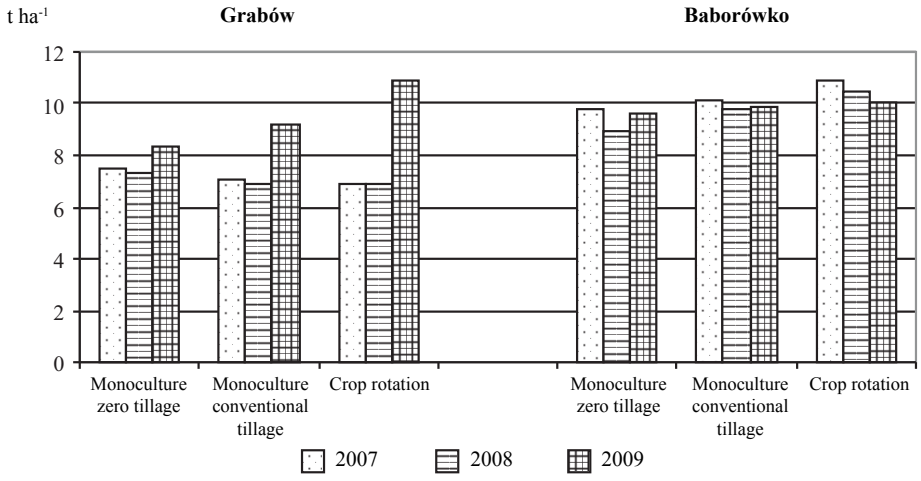

Fig. 2. Maize yields as affected by seedbed preparation method.

seeding was found to contain ca. 2% more moisture that the grain from maize under rotation (Table 6). Similar results were obtained by Griffith et al. (1988), Kaspar et al. (1987), Machul (1995), and also by Menzel and Dubas (2003). By contrast, Dubas and Szulc (2006) found but a slight increase in grain humidity in the directly seeded treatments. As stated by Gregorich et al. (1993) it can be caused by inferior growth conditions of young seedlings caused by lower soil temperatures. Additionally, in the 2009 experiments of this study higher moisture was found in the grain from the middle-eastern region as compared to that from Greater Poland

In the period under evaluation, recorded plant height in maize varied substantially depending on seedbed preparation method (Table 7). In 2007, in the non-tillage treatments the plants were taller than those grown in the treatments where conventional tillage was applied, both under monoculture and under rotation. Probably, it was caused by the impact of improved soil moisture in the non-tilled vs. pre-sowing tilled treatments. Conversely, in 2008 in both regions the plants were taller in the tilled treatments.

Over the duration of the study, the mean yields of spring barley and winter wheat at Grabów were similar to those recorded at Baborówko, even though in the latter region much higher yields of both crop species occurred in 2009 (Table 8). In both regions, winter wheat gave substantially higher yields than did spring barley. A similar yielding pattern of both species regardless of the growing area was earlier observed by Machul and Księżak (2007).

The average humus content of the 0–30 cm soil layer was much higher in the year 2009 than prior to the onset of the study (Table 9). A much higher rise was recorded in the treatments in which maize was grown continuously regardless of seedbed preparation method. However, the increase in the humus content of the soil cropped to maize in 33% was but slight despite the application of organic fertilizers. The highest humus content was recorded in the 0–10 cm layer under corn cropped continuously from direct seeding. Contrastingly, the humus content of that treatment at a layer of 10–30 cm and of the remaining two treatments at a layer of 0–30 cm varied little. An increased buildup of organic matter in the topsoil and its smaller content in the deeper soil layers occurring under reduced tillage was also observed by Alvarez et al. (1995), Blevins (1983), Dzienia and Sosnowski (1991), Machul (1995), Radecki (1986). Alvarez et al. (1995) state that the accumulation of organic matter in the topsoil increases the organic carbon content by 42–50%. Machul (1995) found changes in humus content to be related to the type of soil (a greater increase occurred in brown soil compared to that in alluvial soil). Szymankiewicz (1987) failed to demonstrate changes in humus content in response to annual changes of crop management method. Śmierzchalski (1980), though, is of an opinion that the buildup of organic matter in the topsoil can be looked upon as a non-beneficial alteration to the soil profile.

When compared at the termination of the study (2009) and before its commencement, the soil pH data indicate a rise in pH regardless of the soil management system (Table 9). Before the trial was started, soil pH was higher at the 20–30 cm layer than at the 0–10 cm layer regardless of the system adopted. By contrast, in the autumn of 2009 in the treatment involving continuously grown and directly seeded maize the pH was lower at 20–30 cm than at 0–20 cm. In the treatments which received conventional plough-based tillage, pH was similar in the soil layers assayed for that trait. As a result of direct seeding applied on the year-by-year basis, acidification of the soil and of the topsoil in particular was observed by Dzienia and Sosnowski (1991), Machul (1995), Radecki (1986). According to Radecki (1986) it is most likely caused by surface application of mineral fertilizers and progressively more shal-

Table 9. Effect of different crop and soil management methods on some soil properties (RZD Grabów).

Management methods	Soil layer [cm]	Autumn – 2006					Autumn – 2009					
		pH in KCl	content [mg/100 g of soil]			humus content [%]	pH in KCl	content [mg/100 g of soil]			humus content [%]	total N [%]
			P_2O_5	K_2O	MgO			P_2O_5	K_2O	MgO		
Monoculture – zero tillage	0–10	6.06	16.3	18.1	4.0	1.17	6.5	19.2	15.4	3.7	1.40	0.089
	10–20	6.29	14.8	16.4	3.2	1.14	6.5	19.0	13.5	3.8	1.28	0.083
	20–30	6.32	15.2	11.7	3.8	1.14	5.9	14.4	13.0	2.8	1.26	0.085
	mean	6.22	15.4	15.4	3.7	1.15	6.3	17.5	14.0	3.4	1.31	0.086
Monoculture – conventional tillage	0–10	6.17	18.0	8.9	3.0	1.11	6.8	24.6	7.6	3.5	1.28	0.083
	10–20	6.42	19.0	11.5	2.4	1.14	6.9	24.3	6.6	3.5	1.28	0.084
	20–30	6.65	20.7	15.4	3.5	1.10	7.0	23.5	7.9	3.7	1.29	0.086
	mean	6.41	19.2	11.9	3.0	1.12	6.9	24.1	7.4	3.6	1.28	0.084
Crop rotation	0–10	6.63	21.3	11.5	3.2	1.10	6.7	21.0	7.4	3.3	1.19	0.080
	10–20	6.73	22.5	13.9	3.2	1.22	7.1	21.0	7.9	3.5	1.22	0.079
	20–30	6.81	21.0	16.2	3.4	1.05	7.1	21.8	8.3	3.6	1.17	0.079
	mean	6.72	21.6	13.9	3.3	1.12	7.0	21.3	7.9	3.5	1.19	0.079

low development of the root system with a concommittant depletion of some elements from the top layers.

Total soil N was found to vary little with different seedbed preparation methods although somewhat less total N was found under rotated maize. Likewise, there was little layer-to-layer variation of that nutrient. The content of P_2O_5 was higher after the trial was completed than before it was started. In the treatment which involved directly seeded and continuously grown maize the content of that nutrient was significantly higher at 0–20 cm than at 20–30 cm. No such differences were recorded in the remaining two treatments. When compared before and after the trial, the K_2O content of the 0–30 cm layer of the soil declined in the autumn of 2009. Likewise, the K_2O content of the soil cropped continuously to directly seeded maize was higher than that found in the two remaining treatments. Furthermore, in the former treatment the 0–10 cm soil layer was higher in K_2O than the soil layers of 10–20 and 20–30 cm. No such response was observed in the remaining two treatments which received plough-based cultivation. MgO content of the soil before and after the trial did not show any major changes. In the treatments which received plough-based tillage MgO content was similar across the soil profile, but it was higher by ca. 30% at the 0–10 and 10–20 cm soil depths than at the 20–30 cm depth. Increased levels of available forms of phosphorus, potassium and magnesium in the upper layers of directly seeded vs. conventionally managed soils were also recorded by Dzienia and Sosnowski (1991), Machul (1995), Radecki (1986). Conversely, Szymankiewicz (1987) states that tillage has no effect on the soil contents of potassium and magnesium. Furthermore, that investigator recorded that potassium and phosphorus contents declined with soil depth regardless of how the soil was managed. Increase in topsoil contents of nitrogen, phosphorus, potassium and carbon is, according to Pudełko et al. (1994) caused by reduced leaching and smaller erosion.

CONCLUSIONS

1. The highest grain yields, regardless of growing area, were obtained from maize grown under a three-year rotation scheme with organic fertilization. Under such a management the yields were higher by 10% compared to those from a treatment which combined maize monoculture and direct seeding. The grain yields recorded in Wielkopolska (Greater Poland) were higher by ca. 25% than those in the mid-eastern region.
2. In terms of cereal units, lower yields were obtained from the rotation scheme – spring barley, winter wheat – maize than from maize grown under monoculture, regardless of tillage method and growing area.
3. Direct seeding of continuously cropped maize increased grain moisture at harvest by ca. 2%, did not affect number of grains per cob, but decreased weight of 1000 grains
4. The contents of humus and P_2O_5 in the 0–30 cm soil layer were higher and that of K_2O was lower at the termination of the trial that at its commencement, but the content of MgO remained little changed.
5. The contents of humus and K_2O in the topsoil (0–10 cm) under continuously cropped and directly seeded maize were higher that in the 10–30 cm soil layer. Total N varied but little among seedbed preparation methods and also showed little variation across the soil profile.

REFERENCES

Alvarez R., Diaz R.A., Barbero N., Santanatoglia O.J, Blotta L., 1995. Soil organic carbon, microbial biomass and CO_2-C production from theree tillage systems. Soil Till. Res., 33: 17-28.

Blevins R.L., Smith M.S., Thomas G.W., Frye W.W., 1983. Influence of conservation tillage on soil properties. J. Soil Water Conserv., 38: 301-307.

Burgess S.M., Mehuys G.R., Madramootoo C.A., 1996. Tillage and crop residue effects on corn production in Quebec. Agron. J., 88: 792-976.

Cox W.J., Zobel R.W., van Es H.M., Otis D.J., 1990. Growth development and yield of maize under three tillage systems in the northeastern USA. Soil Till. Res., 18: 295-310.

Drury CF., Tan C., Welacky T.W., Oloya T.O., Hamill A.S., Weaver S.E., 1999. Red clover and tillage influence on soil temperature, water content and corn emergence. Agron. J., 91: 101-108.

Dubas A., 1980. The maize grown in monoculture and crop rotation. Pr. Kom. Nauk Roln. i Leś. PTPN, 59: 51-58. (in Polish)

Dubas A., Menzel L., 1999. Maize growthing in no-tillage system after different forecrop. Folia Univ. Agric. Stetin., 195, Agricultura, 74: 147-155. (in Polish)

Dubas A., Sulewska H., Menzel L., 2002. Weed infestation of maize grown in monoculture and no-tillage system. Progr. Plant Protect., 42(2), 604-606. (in Polish)

Dubas A., Szulc P., 2006. Long-term direct sowing effect on maize grown in monoculture. Fragm. Agron. 3: 27-35. (in Polish)

Dzienia S., Sosnowski A., 1991. Possibilities of application of direct sowing on the soil of good ryeland complex under climatic conditions of the Western Pomerania. Rocz. Nauk Rol., 109(2): 157-173. (in Polish)

Gregorich E.G., Reynolds W.D., Culley J.L.B., McGovern M.A,, Curnoe E.E., 1993. Changes in soil physical properties with depth in a conventional tilled soil after no-tillage. Soil Till. Res., 26: 289-299.

Gryffith D.R., Kladivko E.J., Mannering J.V., 1988. Long-term tillage and rotation effects on corn growth and yield on high and low organic matter, poorly drained soil. Agron. J., 80(4): 599-605.

Ismail I., Blevins R.L., Frye. W.W., 1994. Long-term no-tillage effects on soil properties and continuous corn yields. Soil Sci. Soc. Am. J., 58: 193-198.

Kapusta G., Krausz R.F., Matthews I.L., 1996. Corn yield is equal in conventional, reduced, and no-tillage after 20 years. Agron. J., 88: 812-816.

Kaspar T.C., Crosbie T.M., Cruse R.M., 1987. Growth and productivity of four corn hybrids as affected by tillage. Agron. J., 79(3): 477-481.

Machul M., 1993. Application potential of simplified tillage in the production of corn for grain under three-year monoculture. Pam. Puł., 102: 191-199. (in Polish)

Machul M., 1995. Effect of pre-sowing soil cultivation on the yields of maize grown on five-year monoculture. Pam. Puł., 106: 47-62. (in Polish)

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. Fragm. Agron., 95(3): 292-299. (in Polish)

Menzel L., Dubas A., 2003. Reaction of maize (*Zea mays* L.) grown in monoculture on tillage minimization. Pam. Puł., 133: 123-134. (in Polish)

Pabin J., Włodek S., Biskupski A., 2003. Effect of different tillage techniques on soil properties and crop yields. Pol. J. Soil Sci. Soil Technol., Vol. XXXVI/2: 187-194.

Pudełko J., Wright D.L., Wiatrak P., 1994. Using of restrictions in soil tillage in the United States AP. Post. Nauk Rol., 1: 153-162. (in Polish)

Radecki A., 1986. Studia nad możliwością siewu bezpośredniego na czarnych ziemiach właściwych. SGGW-AR Warszawa, Rozpr. Nauk. Monogr., 87 pp.

Radecki A., Opic J., 1991. The direct swing method in the light of home and foreign literature. Rocz. Nauk Rol., 109(2): 119-141. (in Polish)

Sekutowski T., Sadowski J., 2008. Influence of different tillage systems on maize field and degradation dynamics of rimsulfuron in soil. In: Problemy agrotechniki oraz wykorzystania kukurydzy i sorgo. UP Poznań, 100-103. (in Polish)

Śmierzchalski L., 1980. Actual trends of the soil tillage changes. Zesz. Probl. Post. Nauk Rol., 227: 131-229. (in Polish)

Szymankiewicz K., 1987. Badania nad sposobami uprawy roli pod kukurydzę w krótkotrwałej monokulturze. Rozpr. Nauk AR Lublin, 101, 69 pp.

Szymankiewicz K., 1988. Effect of a differentiated soil tillage on physical soil properties and yielding of maize in a short-term monoculture. Zesz. Probl. Post. Nauk Rol., 356: 223-229. (in Polish)