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Impact of zero tillage system on the nutrient content of grain and vegetative parts of cereals

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Abstract. Evaluating differences in mineral composition of cereal crops grown in zero and conventional tillage systems have been performed with the use of the results of the experiments carried out in experimental stations of IUNG-PIB in Jelcz-Laskowice, near Wrocław (years 2002–2009) and Baborówko near Poznań (2007–2009). The study covered results of various one-year experiments with: winter wheat (9 experiments), maize (4 exp.), spring barley (3 exp.), oats (3 exp.). Conventional tillage consisted of a group of post-harvest tillage operations to a depth of 10–15 cm, and then pre-plant plowing to a depth of 25 cm and sowing cultivation with an active harrow. Zero tillage was performed without using any mechanical tillage, with mulching of the soil surface with shredded straw. The plant samples were analyzed for contents of N and P by flow absorption spectrophotometry, K – by flame emission spectrometry and Ca, Mg, Cu, Mn and Zn by AAS. Also the mineral content of the so-called indicator parts collected during the growing season were evaluated acc. to Bergmann values, to determine if there were any shortages of elements in the earlier phases of development, which could affect the mineral composition of grain. In soil samples the content of available P and K were determined by Egner-Riehm method, Mg by Schachtschabel method and organic carbon by Tiurin method. The evaluation of the significance of differences between the studied farming systems in the mineral contents in grain and cereal biomass was based on the analysis of variance for two independent samples using the Tukey test ($P<0.05$).

Growing of cereals and maize in zero tillage systems, in the conditions of light soils, did not cause differences in the concentration of macro-and micronutrients in plants at the beginning of the vegetation, nor did it bring about any deterioration of grain quality in terms of content of the primary minerals, which is important in assessing its value as a feed or foodstuff.

key words: zero-tillage system, cereals, maize, nutrient content

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INTRODUCTION

The use of zero-tillage methods, consisting of direct sowing in a non plowed soil using a specialized drill, has many advantages, which may include prevention of soil erosion, reducing water losses and lower costs of production compared to traditional methods of using the plow. In the literature, it is reported that no-tillage methods affects yield differently. There are many factors that determine the effects of direct sowing, the most important are: the climate, the time elapsed since the beginning of a method of zero tillage in a given field, as well as soil type (Martinez et al., 2008). The benefits of zero tillage are typically achieved in a dry climate or in years with less rainfall (Arshad et al., 1999; Bonfil et al., 1999; De Vita et al., 2007). The impact of soil type on the effects of zero tillage is associated with the fact that changes in physical properties of soil in relation to conventional tillage, especially density and air-water relations, as well as chemical and biological properties occur faster and can reach deeper into the heavier soils rather than the lighter ones. In the climatic conditions of western and south-western Poland, zero tillage of light soil often produces worse results than traditional tillage (Korzeniowska and Stanisławska-Glubiak, 2009). Many authors have reported differences in the content and distribution of macronutrients in the soil, depending on farming practices (Franzluebbers et al., 1996; Martin-Rueda et al., 2007; Tarkalson et al., 2006). These differences could certainly have an impact not only on the rate of biomass production and crop yields, but also on the nutrient intake and content in a plant. At present, there is not too much information on the impact of zero tillage on the chemical composition of plants (Lavado et al., 2001; Stanisławska-Glubiak and Korzeniowska, 2009). This is particularly true of those parts which are intended for consumption by humans and animals. The aim of this study was to assess the content of basic minerals in the grain and vegetative parts of cereals from the fields cultivated by a zero tillage method in relation to the traditional tillage system.

MATERIALS AND METHODS

Evaluating differences in mineral composition of cereal crops grown in zero and conventional tillage systems have been performed with the use of the results of all the experiments which concerned the comparison effects of yielding of the zero tillage method to the traditional tillage cultivation of the soil. The experiments were carried out in experimental stations of IUNG-PIB in Jelcz-Laskowice, near Wrocław (years 2002–2009) and Baborówko near Poznań (2007–2009). Conventional tillage (CT) consisted of a group of post-harvest tillage operations to a depth of 10–15 cm, and then pre-sowing plowing to a depth of 25 cm and pre-sowing cultivation with an active harrow. Zero tillage (ZT) was performed without using any mechanical tillage, with mulching of the soil surface with shredded straw. Sowing seeds on ZT, after the eradication of weeds with herbicides, was carried out using the drill for direct sowing with disk coulters: Great Plain (Jelcz-Laskowice) or Kongskilde Demeter Classic 3000 (Baborówko).

For the comparison of the mineral composition of cereal at the ZT and CT, the results of various one-year experiments were used in a total number of: winter wheat – 9, maize – 4, spring barley – 3, oats – 3. These plants were grown in cereal crop rotations and the varieties were not identical in every year. The results for the concentration of macro-and micronutrients in the grain were selected from all the experiments for both tillage methods, with the exception of barley and oats, for which only the analyzes of the content of macroelements were performed. In addition to that, the content of analysed elements in the so-called indicator parts collected during the growing season were evaluated (Bergmann, 1992), to determine if there were any shortages of elements in the earlier phases of development, which could affect the mineral composition of grain. For cereals, the indicator part was the whole above-ground part of plant, and for maize – fully developed leaves, at the plant height of 40–60 cm.

Due to the fact that the patterns of individual experiments were varied, the number of samples where the mineral composition was assessed was not the same in each experiment. Only the objects with full mineral fertilization were chosen. Total number of samples of grain, and accordingly, the same number of trials of vegetative parts of plants, for each tillage system was: for winter wheat from Jelcz-Laskowice (winter wheat I): n = 12, for winter wheat from Baborówko (winter wheat II): n = 8, for maize: n = 12, for spring barley: n = 3, and for oats: n = 3. Winter wheat was divided into two sets, according to the location of the experiments, due to the relatively large difference in soil pH between the experimental points, and therefore to the difference in the nutrient availability to plants and their intake. In the ES in Jelcz-Laskowice there were acid soils, and in ES Baborówko – soils with a pH close to neutral (Table 1).

Other soil conditions in both places were similar. All the experiments were conducted on sandy soils with low organic carbon content, high phosphorus content and the average content of potassium and magnesium.

Fertilization of plants in each year of the study was adapted to the requirements of plants growing conditions that year which, to some extent, differentiated the doses of fertilizer between particular years (Table 2). In ES in Baborówko, a slightly higher level of nitrogen was used under the wheat than in ES Jelcz-Laskowice. Doses of P and K in both places were the result of the nutritional requirements of cultivated plants and fertility of soil found in a given year.

Table 2. The ranges of doses of fertilizer used in the study years.

Experimental Station/field	N	P	K
	kg ha^{-1}		
ES Jelcz-Laskowice			
Winter wheat I	100–110	25–30	70–85
Maize	100–120	30–50	50–80
Barley, oats	50–70	25	70
ES Baborówko			
Winter wheat II	120–160	15–20	50

Table 1. Selected physicochemical properties of topsoil (0–20 cm) in soils of field trials.

Experimental station/field	Soil textural group	pH (KCl)	C org. [%]	Content [mg kg^{-1}]		
				P	K	Mg
ES Jelcz-Laskowice						
Winter wheat I	pg	4.7–5.5	0.69–0.75	64–93	83–234	43–70
Maize	pg	4.2–5.2		48–87	162–232	31–76
Barley, Oats	pg	4.7–4.8	0.69–0.76	64–66	83–100	43–44
ES Baborówko						
Winter wheat II	pg, gp	6.2–6.4	0.60–0.80	67–92	84–116	66–97

pg – loamy sand, gp – sandy loam

The plant samples were analyzed for contents of N and P by flow absorption spectrophotometry, K – by flame emission spectrometry and Ca, Mg, Cu, Mn and Zn by AAS. Analyses of soil samples were carried out with the methods used in chemical and agricultural stations. The contents of available P and K were determined by Egner – Riehm method, Mg by Schachtschabel method and organic carbon by Tiurin method.

The evaluation of the significance of differences between the studied farming systems in the mineral contents in grain and cereal biomass was based on the analysis of variance for two independent samples using the Tukey test ($P < 0.05$).

RESULTS AND DISCUSSION

An analysis of the indicator parts of the tested plants, taken during the growing season, showed the same macronutrient content in the biomass, irrespective of tillage system (Table 3). According to the criteria of Bergmann (1992), this content was optimal. Only in the tissues of barley a nitrogen content in the zero tillage was higher than in the traditional one, but this was not reflected in the increased concentration of this constituent in grains. Macroelements content in grain was not in fact considerably varied depending on the tillage system (Table 3).

Zero tillage did not generally cause changes in the concentration of macroelements in grain in relation to the plants from the plots where the traditional method of cultivation was used. The exception was the grain of wheat grown in Baborówko (winter wheat II) in zero-tillage system, which had a significantly lower nitrogen content than in traditional cultivation. This could be due to the improved habitat conditions for wheat in ES Baborówko compared to ES Jelcz-Laskowice. Soil pH was here close to neutral, and therefore compliant with the requirements of this species, and the level of nitrogen fertilization was higher than in experiments in Jelcz-Laskowice. The positive effects of zero tillage are revealed generally in poorer growing conditions, especially under insufficient rainfall. In the studies of De Vita et al. (2007) differences in the concentration of nitrogen in wheat grain between zero and traditional cultivation occurred at the site with a lower amount of precipitation during the growing season, while at the site with the higher amount of precipitation, such differences were not found. In good moisture conditions, Lavado et al. (2001) also did not observe differences between crops in the content of macroelements neither in grain, nor in wheat leaves. Only the roots contained more phosphorus in the zero tillage system. Małecka and Blecharczyk (2008) in the studies with spring barley found that at the zero tillage, nitrogen intake of grain was significantly lower than in conventional tillage, with tillage system having a much lower effect on this difference than mulching and the dose of nitrogen fertilization.

Of all the microelements analyzed in this study, only copper in the grain of wheat grown on acid soils showed a higher content at zero tillage than at the conventional one (Table 4). In the indicator parts, though, there was a higher concentration of manganese. The probable cause of these differences was the higher content of Cu and Mn in the soil of the zero cultivation than on those with the traditional cultivation, as reported in some papers (Rahman et al., 2008; De Santiago et al., 2008).

Table 3. Content of basic macroelements in grain and vegetative parts of cereal in the traditional system (CT) and zero tillage (ZT).

Plant and tillage system	Grain					Indicator parts				
	Content [g kg^{-1}]									
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Winter wheat I (mean from 2002–2004 i 2007–2009; n=12)										
CT	20.6 a	3.2 a	3.8 a	0.43 a	1.22 a	30.7 a	4.0 a	35.2 a	3.3 a	1.1 a
ZT	19.5 a	3.3 a	4.0 a	0.51 a	1.28 a	29.7 a	4.1 a	32.3 a	2.9 a	1.1 a
Winter wheat II (mean from 2007–2009; n=8)										
CT	21.1 a	3.2 a	3.9 a	0.53 a	1.25 a	32.8 a	3.8 a	27.9 a	3.6 a	1.3 a
ZT	18.5 b	3.1 a	4.0 a	0.48 a	1.22 a	32.9 a	3.8 a	28.9 a	3.2 a	1.2 a
Spring barley (mean from 2002–2004; n=3)										
CT	21.4 a	3.3 a	4.7 a	0.51 a	1.17 a	25.4 b	3.7 a	35.0 a	3.8 a	0.9 a
ZT	22.7 a	3.3 a	4.9 a	0.49 a	1.13 a	35.0 a	4.1 a	38.5 a	5.2 a	1.3 a
Owies (mean from 2002–2004; n=3)										
CT	20.7 a	3.2 a	4.4 a	0.69 a	1.16 a	24.5 a	4.3 a	34.7 a	4.1 a	1.0 a
ZT	20.1 a	3.3 a	4.6 a	0.65 a	1.17 a	29.0 a	4.9 a	41.9 a	4.1 a	1.2 a
Maize (mean from 2004–2009; n=12)										
CT	14.3 a	3.1 a	3.5 a	0.19 a	1.21 a	37.6 a	3.8 a	47.9 a	6.4 a	2.4 a
ZT	14.7 a	3.4 a	3.9 a	0.17 a	1.27 a	36.5 a	3.9 a	43.3 a	6.0 a	2.5 a

Identical letters (a comparison between the CT and ZT separately in each column) show no significant difference by Tukey test ($P < 0.05$).

Table 4. Contents of selected microelements in vegetative parts and grain of cereal in the traditional system (CT) and zero tillage (ZT).

Plant and tillage system	Grain			Indicator parts		
	Content [mg kg^{-1}]					
	Cu	Mn	Zn	Cu	Mn	Zn
Winter wheat – Jelcz-Laskowice (mean from 2002–2004 i 2007–2009; n=12)						
CT	2.34 b	32.6 a	30.7 a	4.09 a	36.5 b	24.8 a
ZT	2.82 a	36.6 a	32.9 a	4.04a	50.8 a	26.9 a
Winter wheat – Baborówko (mean from 2007–2009; n=8)						
CT	2.09 a	21.9 a	19.8 a	3.43 a	28.0 a	23.4 a
ZT	2.25 a	24.3 a	19.1 a	3.50 a	29.5 a	23.3 a
Maize (mean from 2004–2009; n=12)						
CT	1.51 a	6.17 a	19.0 a	6.47 a	58.4 a	35.3 a
ZT	1.23 a	5.83a	19.2 a	6.65 a	72.4 a	42.8 a

Identical letters (a comparison between the CT and ZT separately in each column) show no significant difference by Tukey test ($P < 0.05$).

In the present study conducted in the conditions of light sandy soils, it was found that tillage system did not significantly affect the nutrient content of cereal grains and corn. Similar results of no difference between zero and traditional cultivation in terms of the concentration of nitrogen in the grain of corn grown on loamy sand were obtained by Mehdi et al. (1999). Other authors, in experiments on heavy clay soils (Iqbal et al., 2005) and on loam (Campbell et al., 1998), also found the same nitrogen content in wheat grain straw and roots in conditions of traditional and zero-tillage systems.

CONCLUSION

Growing of cereals and maize in zero tillage systems, in the conditions of light soils, did not cause differences in the concentration of macro- and micronutrients in plants at the beginning of the vegetation, nor did it bring about any deterioration of grain quality in terms of content of the primary minerals, which is important in assessing its value as a feed or foodstuff.

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