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The effect of foliar application of copper on content of this element in winter wheat grain

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Abstract: Copper is an essential element for plants, animals and people in small, but absolutely necessary quantities. Deficiency of this element in the diet causes many health problems at animals and people. The content of Cu in wheat grain in Poland has decreased by about 20% over the past 30 years, which adversely affects its nutritional value. The aim of the study was to examine the possibility of increasing the copper content in winter wheat grain by foliar application of this element. In 2003–2006, six one-year field trials were conducted with copper foliar fertilization of 10 varieties of winter wheat. Spraying with copper sulfate at a dose of 305 g ha^{-1} was performed in spring in full tillering stage. The average density of copper in the grain was at a very low level of 2,4–2,6 mg kg^{-1}. Such a content is not enough in terms of nutritional needs of livestock. Single copper spray did not cause a statistically significant increase in the content of this element in the grain of any of the tested varieties. At the same time, varieties that reacted with the highest, approximately a 20% increase in yield to the application of copper, showed a 11–12% decrease in Cu content of grain. This decline was most likely the dilution effect.

key words: wheat, copper content, foliar application, dilution effect

INTRODUCTION

Over 40% of people worldwide suffer from micronutrient deficits (so-called "hidden hunger"), which causes various health problems (Progress Report, 2000; Murphy et al., 2008). The large increase in the number of people suffering from the deficiency of micronutrients in the last 40 years coincides with the expansion of new highly yielding varieties of cereals, which are often characterized by a lower tolerance of their deficiency. While worldwide deficiencies concern primarily iron and zinc (White and Zasoski, 1999), the problem in Poland is primarily an insufficient quantity of copper in food and feed.

Copper is an essential element for plants, animals and people in small, but absolutely necessary quantities. An insufficient content of this element in the soil reduces the yield of crops, particularly cereals. Too low amount of Cu in the diet, relative to the demand, leads to various health problems in animals and humans. One of the most dangerous is the increased risk of cardiovascular failure, one of the most common causes of death in our time. Pietruszka et al. (1998) and Rutkowska et al. (1992) report that a very unfavourable phenomenon is that Poles consume in their diet by 30–40% less copper than stated by the required daily dose. In the light of the facts above, a disturbing trend is the decrease in Cu content in wheat grain in Poland over the past 30 years by at least 20%. The results of the research conducted on the basis of large collections of samples from the whole country show a clear decrease in the content of this element in the grain of 4,2–4,4 in the seventies (Kamińska et al., 1976; Czuba and Andruszczak, 1981) to 3,1–3,4 mg kg^{-1} in the years 2000–2001 (Report of the Ministry in 2002; Wróbel, 2000). This is largely connected with the introduction of new intensive varieties with higher nutritional requirements. In addition, Cu content in wheat grain in Poland is lower than in other countries, the latter being as follows: England – 3,9–5,4 (Fan et al., 2008), Iran – 5.5 (Karami et al., 2009), Canada – 4.1 (Gawelko et al., 2002), Sweden – 3.5–5.0 (Kirchmann et al., 2009), and the USA – 4.1 mg kg^{-1} (Murphy et al., 2008). Low copper content of Polish wheat grain raises concerns about its significant deterioration as a feedstuff, which may have a direct impact on the health of farm animals. Deficiencies of copper leads to anemia, reduce the growth and fertility, and disorders the nervous system.

It seems that the fertilization of wheat with copper, essential for good yields given the existing deficiencies in the soil, should also cause an increase in Cu content in grain.

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The aim of this study was to examine the possibility of increasing the copper content in winter wheat grain due to foliar fertilization with this element.

MATERIAL AND METHODS

In the period between 2003 and 2006 one-year field experiments, three at each experimental stations of IUNG in Jelcz-Laskowice and Osiny were carried out with copper foliar fertilization of 10 varieties of winter wheat. In Jelcz-Laskowice experiments were performed in the years 2003, 2004 and 2006, and in Osiny in 2004, 2005 and 2006. All the six experiments were performed as a 2-factorial (I – Cu fertilization, II – wheat varieties) split-plot design in 4 replications.

The experiments in Jelcz-Laskowice were located on podzolic soils rated as class IVa and IVb, in Osiny on the soils belonging to quality class IIIa and IIIb. Those soils were characterized by a slightly acidic pH, organic matter content of 11–12 g kg^{-1}, and a good supply of P, K, and Mg. Soils for the experiments were deliberately chosen having an average content of Cu as the researchers expected both positive and possibly negative reaction of some cultivars to fertilization with this element. Since the experimental soil in successive years of the study showed similar characteristics, their features are presented as an average of 3 years (Table 1).

Table 1. Physical and chemical properties of soil before the foundation of experience (average of 3 years).

Site	pH KCl	F_1 [%]	So [g·kg^{-1}]	P	K	Mg	Cu
				mg·kg^{-1}			
Jelcz-Laskowice	5.7	17	12	48 s	127 w	52 w	2.4 s
Osiny	5.6	17	11	51 s	120 s	62 w	3.2 s

So – organic substance, F_1 – fraction <0.02 mm, s – average content, w – high content

Spraying with copper sulphate at a dose of 305 g ha^{-1} were performed in spring in full tillering stage using a knapsack sprayer. The same NPK fertilization was used in all treatments in accordance with agrotechnical recommendations for winter wheat. The surface of the plot at harvest was 24 m^2 in Jelcz-Laskowice and 30 m^2 in Osiny.

Granulometric assays of soil were made using Casagrande's method as modified by Prószyński, pH in 1 mol KCl dm^{-3}, C_{org} by Tiurin's method, available forms of P and K by Egner-Riehm's method, Mg – by Schachtschabel's method, and Cu – in the extract 1 mol HCl dm^{-3}. Copper in the grain was determined by the ASA method after dry mineralization.

Program AWAR was used for the analysis of variance (Filipiak and Wilkos, 1995). Differences between means were evaluated using the Tukey test. Simple correlation calculations were made using Statgraphics.

RESULTS AND DISCUSSION

The copper content in grain of tested unfertilized wheat varieties ranged between 2,18–2,87 mg kg^{-1} and the average for all the varieties in Jelcz-Laskiowice was 2.59, and in Osiny 2,42 mg kg^{-1} (Table 2 and 3). The content is much lower than the average for Poland and it is insufficient in terms of nutritional needs of animals. Standard copper content in feed for farm animals according to Polish authors is 10 (Falkowski et al., 2000; Kruczyńska, 1985), and according to the American National Research Council it is 3–6 for pigs (U.S. NRC 1998), 6–8 for turkeys and chickens for fattening (U.S. NRC 1994), 10 for horses and cattle for slaughter (U.S. NRC 1989, 2000) and 12–16 mg kg^{-1} for dairy cows (U.S. NRC 2001).

Copper content in the experimental soils in Osiny while slightly higher than that in Jelcz-Laskowice had no beneficial effect on the content of Cu in wheat grain from the control treatments. On the contrary, the grain from Osiny was characterized by a slightly lower content of that element than the grain from Jelcz-Laskowice. Perhaps the reason behind that was twice as high yield in Osiny associated with the so-called dilution effect. However, it can be assumed that the higher Cu content in soil in Osiny was the cause of the smaller wheat response to fertilization with this element. In Jelcz-Laskowice as many as five wheat varieties responded by approximately 11–23% increases in yields, while only 2 varieties in Osiny responded with the increase at a level of 7,5–8,7% (Table 2 and 3).

Foliar application of copper in the experiments carried out in Jelcz-Laskowice did not cause any statistically significant increase in the content of this element in the grain in any of the tested cultivars (Table 2). For two cultivars:

Table 2. Yield and copper content in wheat grain grown in Jelcz-Laskowice (average of 3 years).

Cultivar	Cu content [mg kg^{-1}]			Grain yield [t ha^1]	
	0	+Cu	increase [%]	0	increase [%]
Jawa	2.64	2.51	-4.9	4.40	7.3
Kobra	2.75	2.44	-11.3*	3.73	22.8*
Korweta	2.55	2.42	-5.1	4.10	7.8
Kris	2.59	2.49	-3.9	4.77	-11.1*
Mewa	2.46	2.17	-11.8*	4.08	19.6*
Pegasoss	2.41	2.31	-4.1	4.03	12.2*
Sakwa	2.87	2.73	-4.9	4.77	11.7*
Soraja	2.48	2.68	8.1	4.31	3.2
Symfonia	2.57	2.74	6.6	4.83	-8.8*
Zyta	2.60	2.50	-3.8	4.08	11.3*
Mean	2.59	2.50	-3.5	4.31	7.6

* Statistically significant according to the Tukey test (α <0.05)

Kobra and Mewa a significant decrease (by 11–12%) was found whereas a downward trend, though statistically insignificant, was recorded for the six other varieties. At the same time, Mewa and Kobra reacted to Cu application with the biggest, almost 20–23% increase in yield.

In experiments in Osiny, fertilization with copper did not cause any significant changes to the content of this component in the grain (Table 3). It should be noted, however, that the increases in yields obtained as a result of application of Cu were significantly less frequent and smaller here than in Jelcz-Laskowice. This suggests that the decrease in Cu content in grain in Jelcz-Laskowice was also associated with the dilution effect.

Table 3. Yield and copper content in wheat grain grown in Osiny (average of 3 years).

Cultivar	Cu content [mg kg^{-1}]			Grain yield [t ha^{1}]	
	0	+Cu	increase [%]	0	increase [%]
Jawa	2.65	2.56	-3.4	8.00	1.1
Kobra	2.27	2.20	-3.1	7.62	8.7*
Korweta	2.58	2.70	4.7	7.62	-1.2
Kris	2.28	2.28	0.0	8.82	4.2
Mewa	2.25	2.31	2.7	7.83	3.3
Pegasoss	2.34	2.29	-2.1	8.21	3.3
Sakwa	2.58	2.74	6.2	8.66	4.7
Soraja	2.61	2.84	8.8	7.94	7.5*
Symfonia	2.50	2.60	4.0	7.91	3.5
Zyta	2.18	2.10	-3.7	7.65	5.1
Mean	2.42	2.46	1.6	8.03	4.0

* Statistically significant according to the Tukey test (α <0.05)

In the literature, both from the previous years and the latest, there is little data on changes in copper content in the grain under the influence of fertilization with this component to make up for its deficit. Most of the currently published work on copper is about contamination of plants with this element. A few authors who engaged in the research on copper fertilization of wheat, mostly provide its contents in the aerial parts at the early stages of development, or do not study the contents of Cu in plant tissues at all (Bobrzecka at al., 1992; Domska et al., 1994; Brennan and Bolland, 2003, 2004, 2006; Faber, 1992; Gałczyńska, 1972; Gupta and Kalra, 2006; Karamanos and Goh, 2004; Karamanos et al., 2004, Potarzycki, 2004 a; Potarzycki, 2004 b). Only Bobrzecka and Domska (1996) and Warechowska (2009) reported that foliar application of Cu resulted in an increase of Cu content in grain by respectively 8–30% and 14% compared to the control. The authors do not discuss in their work, however, yields of wheat, and therefore it is not known whether in the experiments conducted by them there were positive reactions to copper, reflected in increased yields.

Supposition, that the fall in Cu content in the grain due to its foliar application observed in our study was the result of the dilution effect is confirmed by (calculated for both sites together), the simple correlation coefficient between the increase in Cu content and the increase in grain yield due to application of copper, which was -0.595 (n = 20, α <0,01). This means that the increases in yields were accompanied by declines in Cu content in grain. Similar results were obtained by Owuoche et al. (1995) in studies on the effects of copper fertilization on the content of Cu in the grain of the Canadian wheat varieties.

On the basis of the obtained results it can be concluded that the increase in copper content in wheat grain using a single spray is very difficult. More often, there may be a decline in the Cu content associated with an increase in yields due to applications of copper causes the dilution effect.

CONCLUSIONS

1. In experiments conducted, the average density of copper in the grain was 2,4–2,6 mg kg^{-1}. It is not a sufficient content in terms of nutritional needs of livestock.
2. Single copper spraying of winter wheat at a dose of 305 g ha^{-1} did not cause a statistically significant increase in the content of this element in the grain in any of the 10 cultivars studied.
3. A significant 11–12% decrease in Cu content in grain was observed in varieties that responded to the application of copper with the highest, about a 20%, increase in yields. This decline was most likely the dilution effect.

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