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CONTENT OF MICROELEMENTS IN TUBERS OF POTATO TREATED WITH BIOSTIMULATORS

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Key words: potato cultivars, biostimulators, microelements content, microelements uptake.

Abstract

Three times every 10-14 days, starting from the BBCH 39 phase, four cultivars of edible potatoes were treated with the following bio-stimulants: Asahi SL, Bio-Algeen S90 or Kelpak SL. The control object was plants potato sprayed with distilled water. The large amount of precipitation in the first year of the research contributed to an increased content of Fe and Mn in the potato tubers. The tubers of potatoes treated with Kelpak SL had the highest content of Zn, Mn, Fe and Cu. The highest content of B was found after the potatoes were sprayed with Asahi SL. Compared to the control plants, Bio-Algeen S90 reduced the content of Zn, Mn, Fe and Cu. The content of microelements in the tubers was significantly dependent on the genotype. The highest concentration of Zn, Mn and B was found in the tubers of the cv. Volumia, the highest concentration of Fe and Cu – in the tubers of the cv. Sylvana, and the highest concentration of Ni – in the tubers of the cv. Satina. The uptake of microelements with the potato harvest depended more on the cultivar, in particular its yield, than on the biostimulators that were used.

ZAWARTOŚĆ MIKROELEMENTÓW W BULWACH ZIEMNIAKA TRAKTOWANEGO BIOSTYMULATORAMI

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Słowa kluczowe: ziemniak, odmiana, biostymulatory, zawartość i wynos mikroelementów.

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Abstrakt

Począwszy od fazy BBCH 39 rośliny ziemniaka trzykrotnie, co 10-14 dni, traktowano biostymulatorami: Asahi SL, Bio-Algeen S90 lub Kelpak SL. Obiektem kontrolnym były rośliny ziemniaka opryskiwane wodą destylowaną. Duża ilość opadów w pierwszym roku badań przyczyniła się do zwiększenia zawartości żelaza i manganu w bulwach ziemniaka. Bulwy roślin traktowanych preparatem Kelpak SL charakteryzowały się największą zawartością cynku, manganu, żelaza i miedzi. Natomiast najwięcej boru stwierdzono po opryskiwaniu Asahi SL. W porównaniu do roślin kontrolnych, Bio-Algeen S90 zmniejszył zawartość cynku, manganu, żelaza i miedzi w bulwach. Zawartość mikroelementów w bulwach była również istotnie różnicowana genotypem odmiany. Największą koncentrację Zn, Mn i B stwierdzono w bulwach odmiany Volumnia, Fe i Cu u Sylvana, natomiast Satina zawierała najwięcej Ni. Wynos mikroskładników z plonem bulw ziemniaka w większym stopniu zależał od odmiany, a zwłaszcza jej plonu, niż od stosowanych biostymulatorów.

Introduction

In 2013, the surface area of land on which potatoes were grown in Poland was equal to 337,000 ha, and the average yield was equal to 21.1 t ha^{-1} (*Statistical...* 2014). Potato tubers contain 1–1.2% of mineral components. Consumption of potatoes partly covers the demand for P, K, I, Fe and Cu (*The composition...* 2013).

Microelements control enzymatic processes, thus determining the chemical composition of tubers. The largest quantity of microelements (73–79%) comes from manure (KANIUCZAK et al. 2009). By stimulating living processes, growth regulators control the mineral management and increase the immunity of plants to stressful conditions, thus contributing to a higher quality and value of the yield (WIERZBOWSKA et al. 2010, GRZYŚ 2012). They influence the tubers yield, improve their biochemical parameters and increase their immunity to disadvantageous environmental conditions and pathogens (WIERZBOWSKA et al. 2015, SAWICKA and MIKOS-BIELAK 2002). An inexpensive source of natural growth regulators is algae extracts. They are used as biostimulators in agriculture and horticulture (PANDA et al. 2012). They can also reduce stress resulting from a shortage of nutrients, which enables reducing the doses of mineral fertilizers (PAPENFUS et al. 2013).

The purpose of the article is to study the impact of biostimulators on the content and uptake of microelements in potato tubers.

Materials and Methods

The micro-plot experiment in a system of randomly selected sub-blocks was established in four repetitions at the Experimental Facility in Tomaszkowo, which is owned by the University of Warmia and Mazury in Olsztyn. Potato was grown on arable land classified as R IVa, i.e. of medium and better quality, on brown soil which was dystric cambisol developed from loamy sand. The soil was characterized by pH in the range of 5.32 to 5.70 in a 1 mol KCl dm^{-3} extract; the content of available components was equal to 69–72 mg P kg^{-1}, 82–90 mg K kg^{-1}, 38–48 mg Mg kg^{-1}, 0.33–0.42 mg B kg^{-1} (in a hot water extract) and 0.90–1.05 mg Cu kg^{-1}, 4.50–5.59 mg Zn kg^{-1} and 110–139 mg Mn kg^{-1} in a 1 mol HCl dm^{-3} extract).

Four cultivars of edible potato was grown: the early cv. Volumia and the medium early Irga, Satina and Sylvana cultivars. The forecrop were cereals (oat in 2011 and triticale in 2012). In the autumn, manure was used in the quantity of 25 t ha^{-1}, and in the spring – mineral fertilizers in the following quantities: N – 40 (urea 46% N); P – 26,2 (superphosphate 17.45% P); K – 100 (potassium salt 50% K) kg ha^{-1}. The potato tubers were planted at intervals of 67.5 x 40 cm in late April. All the potato cultivars were harvested on the same days (6 September 2011 and 21 August 2012).

Starting from the BBCH 39 phase (complete coverage of the space between the rows), the plants potato were treated with biostimulators three times, at intervals of 10–14 days:

Asahi SL – 0,1% solution – contains phenols naturally occurring in plants: sodium ortho-nitrophenol, sodium para-nitrophenol, sodium 5-nitroguaiacol

Bio-Algeen S90 – 1,0% solution – extract from marine algae, contains amino acids, vitamins, alginic acid as well as macro- and micronutrients

Kelpak SL – 0,2% solution – extract from *Ecklonia maxima* (11 mg dm^{-3} auxins and 0.031 mg dm^{-3} cytokinins; the auxin to cytokinin ratio is 350:1

The control object was plants potato sprayed with distilled water. More information on the chemical compostion of used biostimulators is presented in an article by CWALINA-AMBROZIAK et al. (2015).

During the harvest, the yield of potato tubers was determined, and samples were taken for the purpose of chemical analysis. Dried and ground plant material was subject to wet mineralization in a mixture of nitric(V) and chloric(VII) acid (at a ratio of 4:1), with an addition of hydrochloric acid. The content of Cu, Zn, Mn, Fe and Ni was determined using the atomic absorption spectrophotometric method using an AA-6800 Shimadzu instrument. In order to determine the content of boron, the plant material was subject to dry mineralization (520°C) in the presence of calcium oxide, and the ash was dissolved in a 0.5 mol HCl dm^{-3}. The boron content was determined colorimetrically using azomethine-H (BENEDYCKA and RUSEK 1994).

The results of the tests were analysed statistically by way of variance analysis (STATISTICA 10 package), and the difference between the averages were compared using the Tukey's system at a significance level of $p = 0.05$.

Results and discussion

During nearly the entire period of vegetation of the potato, the temperature was higher than the multi-year average temperature. A significant excess of precipitation was observed in 2011: after a dry spring (April-May), there was an excess of precipitation in the summer, especially in July (269% of the multi-year average) and in August (120%). In 2012, after a dry April, the quantity of precipitation in May was slightly lower than the multi-year average for that month. On the other hand, in June and July, there was an excess of precipitation (130% and 160% of the multi-year average, respectively). The deficit of rain re-appeared in the late plant growing season.

The variance analysis demonstrated that the contents of Zn, Mn, Fe, Cu and Ni in potato tubers were significantly modified by the genotype of the cultivars and the bioregulators used (Table 1–3). The years of the study and of the interactions of the factors had a highly significant impact on the contents of the aforementioned microelements. The content of B was highly dependent on the characteristics of the studied cultivars and significantly dependent on the bioregulators used and the interaction between these factors and the years of the study.

Table1

Results of the variance analysis on the contents of microelements in the potato tubers

Factor	The significance of the impact					
	Zn	Mn	Fe	Cu	Ni	B
A – year	xx	xx	xx	xx	xx	ns
B – biostimulator	xx	xx	xx	xx	xx	x
C – cultivar	xx	xx	xx	xx	xx	xx
A x B	xx	xx	xx	xx	xx	x
A x C	xx	xx	xx	xx	xx	x
B x C	xx	xx	xx	xx	xx	ns
A x B x C	xx	xx	xx	xx	xx	ns
Significant at $\alpha \leq 0,05$ – x, $\alpha \leq 0,01$ – xx						

A x B; A x C; B x C; A x B x C – interaction; ns – non significat

In the first year of the study, the large amount of precipitation caused the potato tubers to contain 10% more Mn and nearly two times more Fe, while in the second year, the content of Zn, Ni and Cu was higher (by 4.8, 6.3, and 18.2%, respectively). No significant difference in the content of B was observed (Table 2). In the first year of the study, the tubers of the potatoes that were sprayed with Kelpak SL contained the largest quantity of iron (91.85 mg kg^{-1} DM). Compared to the control plants, Kelpak SL increased the content of Mn,

Table 2

Content of microelements in tubers of potatoes depending on the biostimulator used

Factor	Zn	Mn	Fe	Cu	Ni	B
	mg kg^{-1} DM					
2011						
Control	13.34	8.00	74.33	3.02	0.88	7.45
Asahi SL	14.91	8.02	73.42	3.34	1.16	8.01
Bio-Algeen S90	13.68	8.04	56.31	2.81	1.18	7.63
Kelpak SL	16.03	9.21	91.85	3.61	1.21	7.38
2012						
Control	14.84	8.01	43.25	3.79	1.10	7.48
Asahi SL	15.30	7.74	41.38	3.79	1.14	8.13
Bio-Algeen S90	14.48	7.01	34.04	3.77	1.18	7.70
Kelpak SL	16.14	7.43	39.45	3.74	1.32	7.36
Mean for year						
2011	14.49	8.31	73.98	3.19	1.11	7.62
2012	15.19	7.55	39.53	3.77	1.18	7.67
Mean of biostimulator						
Control	14.10	8.00	58.79	3.41	1.00	7.46
Asahi SL	15.11	7.88	57.40	3.56	1.15	8.07
Bio-Algeen S90	14.08	7.53	45.17	3.29	1.18	7.67
Kelpak SL	16.08	8.32	65.65	3.67	1.26	7.37
LSD $_{0.05}$ A	0.36	0.14	0.05	0.07	0.06	ns
B	0.68	0.26	0.18	0.13	0.12	0.02
A x B.	1.15	0.44	0.51	0.22	0.20	ns
A x C	1.15	0.44	3.20	0.22	0.20	0.03

A – year; B – biostimulator; C – cultivar; A x B; A x C; B x C; – interaction; ns – non significat

Cu, Fe, Zn and Ni (by 4.0, 7.8, 11.6, 14.1 and 27.9%, respectively), while reducing the content of B. Asahi SL, on the other hand, significantly increased the concentration of Ni (by 16.7%), B (by 8.1%) and Zn (by 7.2%) and also, to a lesser extent, of Cu. Bio-Algeen S90 had a negative impact on the concentration of Zn, Mn, Fe and Cu and a positive impact on the quantity of Ni and B. Significantly highest concentration of Fe and Cu was measured in tubers of the cv. Sylvana, and the highest concentration of Zn, Mn and B – in the tubers of the early cv. Volumia (Table 3). On the other hand, the lowest quantity of Zn and Mn was found in the tubers of the cv. Satina, and the lowest quantity of Cu and B – in the cv. Irga. Significantly largest content of Zn (19.36 mg kg^{-1} DM) was measured in the tubers of the cv. Volumia treated with Kelpak SL, and the smallest (11.32 mg kg^{-1} DM) – in the tubers of the cv. Satina from the control object. The highest content of Mn was measured in the tubers of the cv. Volumia from the control object and from the field treated with Kelpak SL. Moreover, the use of Kelpak SL resulted in the highest content of Fe

Table 3

Content of microelements in tubers of potatoes depending on the cultivar and the biostimulatort used

Factor	Cultivar	Zn	Mn	Fe	Cu	Ni	B
		mg kg^{-1} DM					
Control	Volumia	17.27	9.61	68.10	3.30	1.41	8.16
	Irga	14.55	7.19	52.60	3.17	0.85	6.23
	Satina	11.32	6.96	55.40	3.31	0.82	7.41
	Sylvana	13.25	8.23	59.07	3.85	0.87	8.04
Asahi SL	Volumia	16.88	8.27	36.90	3.26	1.36	8.60
	Irga	14.52	7.22	57.21	3.30	1.12	6.91
	Satina	12.14	6.93	60.09	3.15	0.83	8.60
	Sylvana	16.89	9.12	75.41	4.54	1.30	8.16
Bio-Algeen S90	Volumia	17.57	8.78	57.37	3.26	1.22	7.98
	Irga	14.85	7.35	31.67	3.01	1.36	6.98
	Satina	11.93	7.06	35.45	3.34	1.53	8.41
	Sylvana	11.99	6.91	56.20	3.56	0.61	7.29
Kelpak SL	Volumia	19.36	9.44	60.52	3.95	0.85	7.54
	Irga	15.90	7.80	48.60	3.15	1.35	6.79
	Satina	13.22	7.51	58.40	3.68	1.78	7.85
	Sylvana	15.86	8.52	95.07	3.91	1.07	7.29
Mean for cultivar	Volumia	17.77	9.03	55.72	3.44	1.21	8.07
	Irga	14.96	7.39	47.52	3.15	1.17	6.73
	Satina	12.15	7.11	52.34	3.37	1.24	8.07
	Sylvana	14.49	8.19	71.44	3.97	0.96	7.70
LSD $_{0.05}$ C		0.68	0.26	1.89	0.13	0.12	0.02
B x C		1.15	0.71	5.18	0.36	0.33	ns

Explanations as Table 1

(cv. Sylvana – 95.07 mg kg^{-1} DM) and Ni (cv. Satina – 1.78 mg kg^{-1} DM) and the smallest content of Cu (cv. Irga – 3.15 mg kg^{-1} DM). The use of Bio-Algeen S90 resulted in the lowest content of Fe in the tubers of the cv. Irga (31.67 mg kg^{-1} DM) and of Ni in the tubers of the cv. Satina (0.61 mg kg^{-1} DM). Asahi SL had a positive impact on the content of Cu in the tubers of the cv. Sylvana (4.57 mg kg^{-1} DM).

In the studies described here, the Fe:Mn ratio in potato tubers was at a level of 4.3–11.2:1. In the opinion of ROGÓŻ (2009), a Fe: Mn ratio higher than 2.5:1 indicates an excess of Fe, which is accompanied by a shortage of Mn. ROGÓŻ and TRĄBCZYŃSKA (2009) assume that Cu content below 5 mg Cu kg^{-1} DM indicates a shortage of this element in potato tubers. In the research conducted by WIERZBICKA and TRAWCZYŃSKI (2011), the average contents of micro-elements in the tubers of organic potatoes were equal to: Cu – 4.5; Fe – 46.9; Mn – 7.3; Zn – 12.4; B – 4.9 mg kg^{-1} DM.

The spatial distribution of minerals in potato tubers is not even (SUBRAMANIAN et al. 2011, PETRYK and BEDLA 2010, ŠREK et. al. 2012). The concentrations of most minerals were higher in the peel than inside the tuber. The potato peel contained about 17% of the total content of Zn and 55% of Fe. In the fresh tuber matter, the concentration of these elements was found to be higher in the stolon part of the tuber. The concentration of Cu decreases from the outside toward the centre of the tuber.

The cultivation system may affect the „mineral profile" of potato tubers (LOMBARDO et al. 2014). Early varieties from organic farms contained more P and quantities of Mg and Cu in comparison to ones from fields with traditional cultivation systems. On the other hand, more K, Ca, Fe, Na and Mn were found in tubers of potatoes grown in a conventional manner. Then, American research demonstrated that potatoes from organic farms contained more Mg and Cu and less Fe and Na, while the content of Ca, K and Zn was similar to that in tubers from conventionally cultivated fields (GRIFFITHS et al. 2012). In the opinion of ZARZECKA (2004), certain herbicides cause an increase in the Fe content and, to a lesser degree, also in the manganese content in potato tubers. Moreover, the concentration of these elements depends on the weather conditions: wet and cold weather is conducive to accumulation of Fe and Mn in the tubers. The genotype of the cultivar is an important factor that affects the content of metals in potato tubers (PROŚBA-BIAŁCZYK and MYDLARSKI 2000).

In the opinion of LIPIŃSKI et al. (2006), the concentration of Fe in wheat grains was also correlated with the quantity of clay particles in the soil, while a higher pH of the soil and higher content of humus resulted in a reduction of Fe content in the grains. On the other hand, the factors that reduced the content of Mn were increased quantity of particles larger than 0.02 mm, an increasing share of organic matter and high pH. In literature, there is the opinion that sulfur has an antagonistic action in relation to the availability and metabolism of Fe in crops (YOUSFI et al. 2007, KOZŁOWSKA-STRAWSKA 2010). In the opinion of KANIUCZAK et al. (2009), liming significantly reduced the contents of Mn and Zn, while increasing mineral fertilization with the NPK fertilizer increased the content of Mn in potato tubers.

Asahi SL mitigated the effects of stress caused by a shortage of water in maize (GRZYŚ 2012). Moreover, Asahi SL and 2-AE (2-aminoethanol – naturally occurring in plant cell) limited the effects of salt stress, which caused a reduction of the contents of K, Ca, Mg, Cu and Fe in the dry matter of the epigeal parts of maize. The preparations used resulted in a particular increase in the concentration of K, Ca and Mg, while reducing the accumulation of sodium in the epigeal parts of corn grown in salty conditions.

In the opinion of WESTERMANN (2005), the yield of potato tubes equal to 56 t ha^{-1} results in a uptake of about 2,000 g of Fe, 1,000 g of Mn, 200 g of B, 120 g of Zn and 100 g of Cu. In the studies described here, the uptake of Fe with

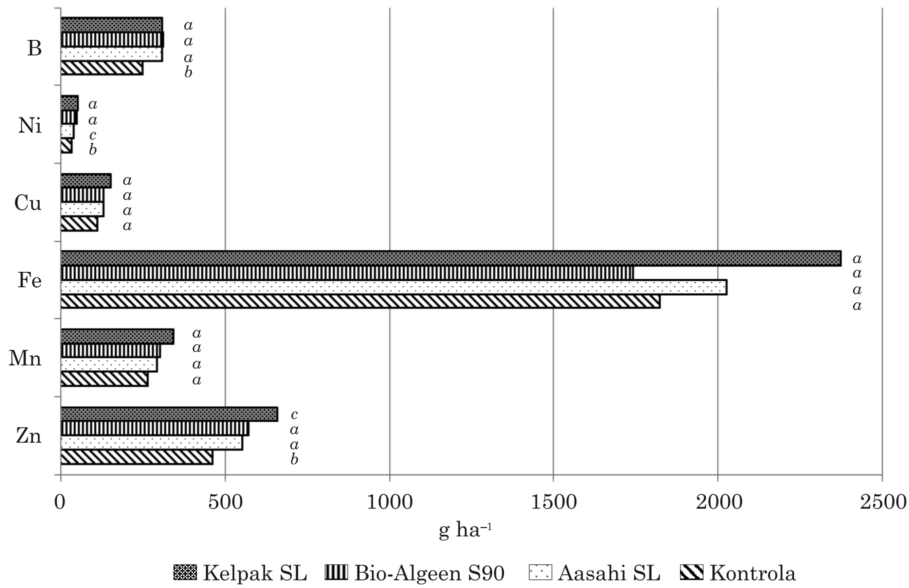

Fig. 1. The uptake of micro-elements with the potato tuber harvest depending on the biostimulator – averages of the two years (the data for individual elements marked with different letters are significantly different, at a level of $p \leq 0.05$)

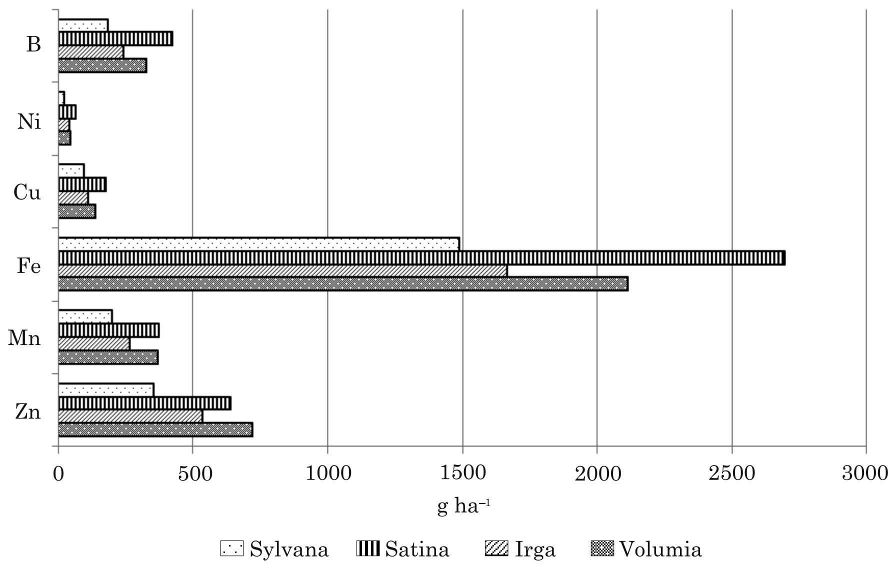

Fig. 2. The uptake of microelements with the potato tuber harvest depending on the cultivar – averages of the two years (Explanations as Figure 1)

the potato tuber harvest (WIERZBOWSKA et al. 2015) was at a level of 1,491–2,697 g ha^{-1}, while the uptake of Mn was only equal to 200–375 g ha^{-1} (Figure 1 and 2). On the other hand, the concentration of Zn in the harvested tubers was at a level of 355–720 g ha^{-1}, and the removal of B was at a level of 185–425 g ha^{-1}. The elements with the lowest concentration in the potato tubers were Cu (96–197 g ha^{-1}) and Ni (24–64 g ha^{-1}). Only in the case of Zn, Ni and B did the bioregulators significantly increase the removal of those metals compared to the control object. The smallest amount of microelements, mostly due to the smallest yield, was accumulated in the tubers of the cv. Sylvana.

Conclusion

The weather conditions, in particular the large amount of rain in the first year of the research, contributed to an increased content of Fe and Mn in the potato tubers. The tubers of potatoes treated with Kelpak SL had the highest content of Zn, Mn, Fe and Cu. The highest content of B was found after the potatoes were sprayed with Asahi SL. Compared to the control plants, Bio-Algeen S90 reduced the content of Zn, Mn, Fe and Cu in the tubers. The content of microelements in the tubers was also significantly different depending on the genotype of the cultivar. The highest concentration of Zn, Mn and B was found in the tubers of the cv. Volumia, the highest concentration of Fe and Cu – in the tubers of the cv. Sylvana, and the highest concentration of Ni – in the tubers of the cv. Satina. The uptake of microelements with the potato harvest depended more on the cultivar, in particular its yield, than on the biostimulators that were used.

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