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INFLUENCE OF THE SOIL CONDITIONER UGmax ON NITROGEN, PHOSPHORUS AND MAGNESIUM CONTENTS IN POTATO TUBERS

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Abstract. The purpose of this study was to determine the effect of the soil conditioner UGmax on nitrogen, phosphorus and magnesium contents in potato tubers. A field experiment was carried out at the Zawady Experimental Farm in 2008-2010. The trial was set up as a split-plot design with three replications; the soil was classified as the very good rye complex of soil quality. The following factors were examined: factor I: table potato cultivars (Satina and Tajfun), and factor II: timing and method of UGmax application: 1 – control – no UGmax, 2 – 1.0 $dm^3 \cdot ha^{-1}$ – applied once before planting of potato tubers, 3 – 1.0 $dm^3 \cdot ha^{-1}$ – split application: ½ pre-plant and ½ foliar application, 2.0 $dm^3 \cdot ha^{-1}$ – split application: ½ pre-plant and ½ foliar application, 4 – 1.0 $dm^3 \cdot ha^{-1}$ – split foliar applications at two dates. UGmax significantly increased nitrogen content in potato tubers compared with the control. Split application of UGmax at the rate of 2.0 $dm^3 \cdot ha^{-1}$ (pre--plant spraying followed by two foliar applications) was the best method of application. Moreover, the weather conditions in the study years and potato cultivars had a significant effect on nitrogen content in tubers. Satina accumulated more nitrogen than Tajfun. By contrast, neither UGmax application, cultivars nor weather conditions influenced phosphorus or magnesium contents in potato tubers.

Key words: magnesium, nitrogen, phosphorus, potato, soil conditioner UGmax

INTRODUCTION

Potato tubers play an important role in human diet due to high consumption in many countries [Leszczyński 2012, Ezekiel *et al*. 2013, Zgórska 2013]. Potato consumption in Poland belongs to the highest in the EU countries and in 2010 it amounted to 112 kg yearly per capita [Dzwonkowski *et al*. 2012]. Cereal products (110 kg) and vegetables (110 kg) are consumed in similar amounts, then meat and giblets (75 kg) and fruits (51 kg) [Świetlik *et al*. 2011]. Apart from carbohydrates, protein and vitamins, potato tubers

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contain 1-1.2% mineral components in the fresh mass, among which nitrogen, potassium, phosphorus, magnesium and calcium predominate. These components perform structural and physiological functions. They show the base-forming effect, their presence in food neutralizes the acidifying effect of cereal products, meat and fish [Kolasa 1993, Rivero *et al*. 2003, Zarzecka 2009]. Their taking up by plants is higher in conditions of good soil moisture, which provides the proper course of processes of mineralization and humification and in the presence of microbiological biopreparations, such as effective microorganisms or soil conditioners.

In recent years the application of microbiological preparations in crop production has become a new area of interest [Trawczyński and Bogdanowicz 2007, Stępień and Adamiak 2009, Sosnowski 2012a, Zarzecka and Gugała 2013]. Their introducing into the soil supports mineralization of organic substance and the availability of mineral components, improves soil fertility by the effect on physical and chemical properties, increases plant health and allows for obtaining higher yields of better quality [Emitazi *et al*. 2004, Trawczyński and Bogdanowicz 2007, Boligłowa and Gleń 2008, Jakubas *et al*. 2010, Zarzecka *et al*. 2011, Piotrowska *et al*. 2012]. Preparations arousing interest in Poland include the soil conditioner UGmax, which contains lactic acid bacteria, photosynthesis bacteria, *Azotobacter*, *Pseudomonas* and *Actinobacteria*, yeasts and potassium, nitrogen, sulphur, phosphorus, sodium, magnesium, zinc and manganese [Trawczyński 2007, Sosnowski 2012b]. In the available literature there are only few publications concerning the effect of the soil conditioner UGmax on the chemical composition of field crops. It was assumed that the soil conditioner UGmax applied in potato cultivation will cause favourable changes in the content of determined macroelements, since an increase in their content improves the nutritional value of tubers. Therefore the aim of this study was to estimate the effect of the soil conditioner UGmax on the contents of nitrogen, phosphorus and magnesium in table potato tubers.

MATERIAL AND METHODS

The research material was potato tubers derived from the field experiment carried out in the soil of the very good rye complex in 2008-2010 at the Zawady Experimental Farm of Siedlce University of Natural Sciences and Humanities (52º03' N; 22º33' E). Some chemical properties before the establishment of the experiment were presented in Table 1.

Table 1. Chemical composition of the soil in the experiment
Tabela 1. Skład chemiczny gleby w doświadczeniu

Year Rok	pH 1 mol KCl dm^3	Organic matter Materia organiczna $g \cdot kg^{-1}$	Available forms of nutrients, $mg \cdot kg^{-1}$ of soil Przyswajalne formy składników pokarmowych $mg \cdot kg^{-1}$ gleby						
			P	K	Mg	Fe	Mn	Zn	Cu
2008	4.99	15.40	90.64	124.50	41.00	655.00	91.00	7.60	1.40
2009	4.81	16.80	76.12	174.30	34.00	920.00	106.00	6.90	1.40
2010	5.91	18.10	73.48	112.10	45.00	570.00	80.10	7.30	2.20

The soil was characterized by a high to very high abundance in available phosphorus, moderate to high abundance in potassium and low in magnesium. The experiment was set up with the split-plot design in three replications. The first factor was two mid-early cultivars of table potato – Satina and Tajfun, the second factor was the dose and application time of the Soil conditioner UGmax (Table 2). The soil conditioner UGmax contained the following macroelements and microelements: N – 1200, P_2O_5 – 500, K_2O – 3500, Mg – 100, Na – 200, Mn – 0.3 mg·dm^3 and microorganisms: lactic acid bacteria, photosynthetic bacteria, *Azotobacter*, *Pseudomonas*, *Actinobacteria*, yeast. In the autumn each year natural fertilizers were applied – farmyard manure at the rate of 25.0 t·ha^{-1} as well as mineral – phosphorus at a rate of 44.0 kg P·ha^{-1} (triple superphosphate 46%) and potassium at a rate of 124.5 kg K·ha^{-1} (potash salt 60%), and in spring fertilization with nitrogen (ammonium nitrate 34%) at a rate of 100 kg N per 1 ha. Potato tubers were planted by hand, from 10th to 20th of April, in a row space of 67 × 37 cm. Harvest was performed on the first ten days of September, in technological maturity of tubers. The content of nitrogen was determined with the Kjeldahl method, phosphorus with the molybdenum blue colorimetric method and magnesium with the Atomic Absorption Spectrophotometry (AAS) [Ostrowska *et al*. 1991]. The results of the study were subjected to statistical analysis using the analysis of variance, and the significance of differences was assessed using Tukey's test.

Table 2. Rates and time of UGmax application
Tabela 2. Dawki i terminy aplikacji UGmax

Treatment Obiekt	Total rate Dawka całkowita dm^3·ha^{-1}	Application time – Czas aplikacji		
		before tuber planting przed sadzeniem bulw	10-15 cm plant height wysokość roślin 10-15 cm	start of flowering początek kwitnienia
1	–	–	–	–
2	1.0	1.0	–	–
3	1.0	0.5	0.25	0.25
4	2.0	1.0	0.5	0.5
5	1.0	–	0.5	0.5

Climatic conditions prevailing during the study were presented in Table 3. In 2008 the rainfall was higher than in the long-term period by 96.2 mm, but it was well distributed in individual months of growth; whereas air temperatures were similar to the means from the long-term period. This was the season which favoured the growth and development of potato plants. In 2009 rainfall was unevenly distributed, and the mean air temperature was higher than in 1987-2000. The year 2010 was warmer than the previous seasons, and the rainfall was very high, exceeding the mean total from the long-term period by as much as 184.5 mm.

RESULTS AND DISCUSSION

In the present study, it was found that the total nitrogen content in potato tubers stayed in the range 20.06-22.86 g·kg^{-1} of dry matter and depended significantly on the weather conditions in the growth period, the cultivar and the rate and time of the soil conditioner UGmax application (Tables 4, 5, 6). The content of this component in

potato tubers was similar to the values obtained by other authors [Zarzecka *et al*. 2009, Wierzbicka and Trawczyński 2011, Šreck *et al*. 2012]. Nitrogen concentration in potato tubers was determined by the weather conditions (Tables 3, 5, 6).

Table 3. Rainfall and air temperatures in the 2008-2010 potato growing seasons according to the Zawady Meteorological Station

Tabela 3. Opady i temperatura powietrza w latach 2008-2010 podczas wegetacji ziemniaka według Stacji Meteorologicznej Zawady

Month Miesiąc	Rainfall – Opady, mm				Temperatures – Temperatura,ºC			
	monthly mean – średnia miesięczna				monthly mean – średnia miesięczna			
	1987-2000	2008	2009	2010	1987-2000	2008	2009	2010
April – kwiecień	38.6	28.2	8.1	10.7	7.8	9.1	10.3	8.9
May – maj	44.1	85.6	68.9	93.2	12.5	12.7	12.9	14.0
June – czerwiec	52.4	49.0	145.2	62.6	17.2	17.4	15.7	17.4
July – lipiec	49.8	69.8	26.4	77.0	19.2	18.4	19.4	21.6
August – sierpień	43.0	75.4	80.9	106.3	18.5	18.5	17.7	19.8
September – wrzesień	47.3	63.4	24.9	109.9	13.1	12.2	14.6	11.8
April-September kwiecień – wrzesień	sum				mean			
	275.2	371.4	354.4	459.7	14.7	14.7	15.1	15.6

Table 4. Content of nitrogen, phosphorus and magnesium in potato tubers, $g \cdot kg^{-1}$ DM (mean of 2008-2010)

Tabela 4. Zawartość azotu, fosforu i magnezu w bulwach ziemniaka, $g \cdot kg^{-1}$ s.m. (średnie z lat 2008-2010)

Treatment* Obiekt	N			P			Mg		
	cultivar odmiana		mean średnia	cultivar odmiana		mean średnia	cultivar odmiana		mean średnia
	Satina	Tajfun		Satina	Tajfun		Satina	Tajfun	
1	20.96	20.23	20.60	2.59	2.53	2.56	1.26	1.28	1.27
2	21.94	20.54	21.24	2.51	2.49	2.50	1.33	1.30	1.32
3	22.47	20.84	21.66	2.50	2.47	2.49	1.34	1.32	1.33
4	22.86	21.18	22.02	2.48	2.45	2.46	1.37	1.33	1.35
5	21.89	20.48	21.18	2.51	2.49	2.50	1.34	1.30	1.32
Mean – Średnia	22.02	20.65	21.34	2.52	2.49	2.50	1.33	1.31	1.32
Means for treatments 2-5 Średnie dla obiektów 2-5	22.29	20.76	21.53	2.50	2.48	2.49	1.35	1.31	1.33
$LSD_{0.05}$ – $NIR_{0.05}$ between – pomiędzy:									
cultivars (I) – odmiana (I)			0.26			ns – ni			ns – ni
UGmax application (II) – aplikacja UGmax			0.43			ns – ni			ns – ni
interaction I x II – interakcja I x II			0.43			ns – ni			ns – ni

ns – ni – non-significant differences – różnice nieistotne

* 1, 2…5 – as in Table 2 – tabela 2

The largest amounts of this component were found in 2009 where air temperatures were higher than the long-term mean, and rainfall was unevenly distributed in individual months of that growing season. It should be assumed that extreme moisture and thermal conditions in the months of tuber formation (June and July) created favourable conditions for nitrogen uptake. Tubers harvested in 2010, which characterized by the highest rainfall and air temperatures, contained the least nitrogen.

Similar results were obtained by Mazurczyk and Lis [2001]. Also Kołodziejczyk and Szmigiel [2005] observed the smallest content of nitrogen in tubers harvested in the year when the rainfall was the highest. Significant interaction was found of the year of the study with the rates and times of the soil conditioner UGmax application (Table 5). In all the years of the study significantly higher amounts of this component were accumulated in tubers collected from treatments 3 and 4, where UGmax was applied before planting and two foliar application at rates 1.0 and 2.0 $dm^3 \cdot ha^{-1}$. In contrast, no interaction of cultivars with the weather conditions in the years of the study was observed.

Table 5. Content of nitrogen in potato tubers depending on cultivar and years, $g \cdot kg^{-1}$ DM (mean of cultivar)

Tabela 5. Zawartość azotu w bulwach ziemniaka w zależności od odmiany i lat, $g \cdot kg^{-1}$ s.m. (średnie z odmian)

Treatment* – Obiekt	Year – Rok			Mean Średnia
	2008	2009	2010	
1	20.51	21.23	20.06	20.60
2	21.25	21.92	20.54	21.24
3	21.80	22.06	21.09	21.66
4	22.69	22.16	21.20	22.02
5	21.32	21.85	20.48	21.18
Mean – Średnia	21.51	21.84	20.67	21.34
$LSD_{0.05}$ – $NIR_{0.05}$ between – pomiędzy:				
UGmax application (II) – aplikacja UGmax (II)				0.43
years (III) – lata (III)				0.41
interaction II x III – interakcja II x III				0.75

* 1, 2…5 – as in Table 2 – tabela 2

In the present study, the significantly highest content of nitrogen was found in tubers from the treatments treated with UGmax as compared with the control. In the study by Wierzbicka and Trawczyński [2011] it was proved that the use of effective microorganisms also contributed to an increase in total nitrogen content in tubers on average by 1.2 $g \cdot kg^{-1}$. Trawczyński and Bogdanowicz [2007] in turn did not observe the effect of soil microorganisms contained in the soil conditioner on the content of nitrogen, phosphorus and potassium. Of the grown cultivars, Satina accumulated significantly more nitrogen as compared with Tajfun. The effect of the varietal factor on nitrogen content in tubers is confirmed by the study of Rivero *et al*. [2003], Kołodziejczyk and Szmigiel [2005], Wichrowska *et al*. [2009]. In the present study, a significant interaction of methods of UGmax application with the cultivars was found. This indicates a diversified response of cultivars to the soil conditioner UGmax. Under the influence of the soil conditioner UGmax, the nitrogen content in tubers of the cultivar Satina increased on average by 1.23 $g \cdot kg^{-1}$, whereas in the cultivar Tajfun by 0.53 $g \cdot kg^{-1}$; and these changes were proved statistically. The most nitrogen was accumulated by tubers of the cultivar Satina at the soil and foliar application of UGmax (treatments 3, 4), and the least by the cultivar Tajfun harvested from the control (treatment 1).

Phosphorus content in tubers ranged from 2.45 to 2.59 $g \cdot kg^{-1}$ DM (Table 4, 6) and was comparable with the content reported by other authors [Kołodziejczyk and Szmigiel

2005, Zarzecka and Gugała 2010, Šreck *et al*. 2012]. In the present study, no effect of the weather conditions during the growing period and the cultivars on phosphorus accumulation in potato tubers was observed. The soil conditioner UGmax applied in the experiment did not change significantly phosphorus content in tubers, which may have resulted from a high and very high content of this component in the soil, but a tendency was observed to decrease it in relations to the control. In the study by Trawczyński and Bogdanowicz [2007] no effect of microorganisms contained in the soil conditioner on phosphorus was found. Also Wierzbicka and Trawczyński [2011] did not observe changes in phosphorus concentration in potato after the application of soil microorganisms, but they proved a significant effect of the varietal factor.

Table 6. Effect of years on the nitrogen, phosphorus and magnesium contents in potato tubers, $g \cdot kg^{-1}$ DM

Tabela 6. Wpływ lat na zawartość azotu, fosforu i magnezu w bulwach ziemniaka, $g \cdot kg^{-1}$ s.m.

Year Rok	Content – Zawartość		
	N	P	Mg
2008	21.51	2.63	1.30
2009	21.84	2.43	1.36
2010	20.67	2.45	1.29
$LSD_{0.05}$ – $NIR_{0,05}$	0.41	ns – ni	ns – ni

ns – ni – non-significant differences – różnice nieistotne

Magnesium content in tubers was on average in the experiment 1.32 $g \cdot kg^{-1}$ DM and it ranged from 1.26 to 1.37 $g \cdot kg^{-1}$ DM (Tables 4, 6). The content of this component stayed at the level similar to the literature data [Wierzbicka and Trawczyński 2011]. In the present study, the weather conditions of the growing seasons, cultivars and different times and rates of UGmax application did not affect magnesium content in potato tubers. Only a tendency was observed to increase in its content after the application of the soil conditioner UGmax with reference to the control on average by 0.06 $g \cdot kg^{-1}$ DM. Also Wierzbicka and Trawczyński [2011] did not observe the effect of soil microorganisms on magnesium accumulation in tubers. Other authors reported the effect of fertilization [Kołodziejczyk and Szmigiel 2005, Šreck *et al*. 2012] and cultivars [Kołodziejczyk and Szmigiel 2005, Ekin 2011, Wierzbicka and Trawczyński 2011] on the magnesium content in potato tubers. According to Wichrowska et al. [2009], higher content of macroelements in potato tubers may result from better conditions of plant development, and particularly the access to nutrients, light and water. In the earlier studies of the present authors [Zarzecka *et al*. 2011, Zarzecka and Gugała 2013] it was proved that the soil conditioner UGmax increased potato yields and improved the quantitative parameters of yield and tuber health.

CONCLUSIONS

1. The soil conditioner UGmax affected the increase in total nitrogen content in potato tubers, but it did not cause changes in the content of phosphorus and magnesium. The most effective application method of the of soil conditioner UGmax was its triple application at a rate of 2.0 $dm^3 \cdot ha^{-1}$.

2. Studied cultivars differed in nitrogen content in tubers – Satina accumulated more of it than Tajfun; no differences were found in phosphorus and magnesium concentrations.

3. Weather conditions in the warm and humid season of 2009 created the most favourable conditions for nitrogen uptake. Potato tubers accumulated the most nitrogen with pre-plant the soil conditioner application and two foliar applications.

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WPŁYW UŻYŹNIACZA GLEBOWEGO UGmax NA ZAWARTOŚĆ N, P I MG W BULWACH ZIEMNIAKA

Streszczenie. W ostatnich latach wzrasta zainteresowanie preparatami mikrobiologicznymi, które oddziałują na właściwości fizyczne i chemiczne gleby oraz na plony i cechy jakościowe roślin. Celem badań było określenie wpływu użyźniacza glebowego UGmax na zawartość azotu, fosforu i magnezu w bulwach ziemniaka. Doświadczenie polowe przeprowadzono w Rolniczej Stacji Doświadczalnej Zawady, na glebie kompleksu żytniego bardzo dobrego w latach 2008-2010. Eksperyment założono metodą losowanych podbloków w trzech powtórzeniach. Badanymi czynnikami były: I czynnik: odmiana ziemniaka jadalnego (Satina i Tajfun), II czynnik: dawka i termin aplikacji użyźniacza UGmax: 1 – obiekt kontrolny – bez użyźniacza, 2 – 1,0 $dm^3 \cdot ha^{-1}$ – w całości przed sadzeniem ziemniaków, 3 – 1,0 $dm^3 \cdot ha^{-1}$ – ½ przed sadzeniem + ½ dolistnie w dwóch terminach, 4 – 2,0 $dm^3 \cdot ha^{-1}$ – ½ przed sadzeniem + ½ dolistnie w dwóch terminach, 5 – 1,0 $dm^3 \cdot ha^{-1}$ – dolistnie w dwóch terminach. Użyźniacz Glebowy UGmax istotnie zwiększał zawartość azotu w bulwach ziemniaka w porównaniu z obiektem kontrolnym. Najbardziej korzystnym sposobem aplikacji UGmax było opryskiwanie w dawce 2,0 $dm^3 \cdot ha^{-1}$ przed sadzeniem bulw i dwukrotnie dolistnie. Wykazano także istotny wpływ warunków pogodowych w czasie wegetacji i odmian ziemniaka na kumulację azotu w bulwach.

Z uprawianych odmian Satina gromadziła istotnie większą ilość azotu niż odmiana Tajfun. Natomiast nie stwierdzono wpływu aplikacji UGmax, odmian i warunków pogodowych podczas wegetacji na zawartość fosforu i magnezu w bulwach ziemniaka.

Słowa kluczowe: azot, fosfor, magnez, użyźniacz glebowy UGmax, ziemniak

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