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THE CONTENTS AND IONIC RATIOS OF THE SELECTED COMPONENTS OF BEAN IN THE BACKGROUND OF FERTILISATION WITH MICROELEMENTS

ZAWARTOŚĆ WYBRANYCH MAKROSKŁADNIKÓW I ICH STOSUNKI JONOWE W FASOLI NA TLE NAWOŻENIA MIKROELEMENTAMI

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ABSTRACT

As the studies revealed, the microelement fertilisation generally diversified the contents of macro-components in vegetative and generative parts of the “Aura” cultivar bean with the exception of the content of phosphorus, calcium and sodium in bean seeds. Amongst the applied microelements, zinc was the one which modified the contents of macro-elements to the most degree. There was observed a significant influence of this micro-element on the content of potassium and magnesium in bean seeds, and of nitrogen, magnesium and sodium in straw. In turn, molybdenum had no effect on the content of any of the tested components in bean seeds. Manganese fertilisation resulted in the largest increase in nitrogen and magnesium contents in bean seeds and straw. Variations in the contents of the individual macro-elements in bean under the effect of microelement fertilisation generally resulted in higher sums of the equivalent contents of cations with reference to the control object.

Key words: bean, microelements, fertilization, content of macroelements, ionic ratios

STRESZCZENIE

Jak wykazały badania przeprowadzone na podstawie trzyletniego doświadczenia mikropoletkowego, nawożenie mikroelementami na ogół istotnie różnicowało zawartość makroskładników w częściach wegetatywnych i generatywnych fasoli odmiany ‘Aura’. Spośród stosowanych mikroelementów, cynk był pierwiastkiem, który w największym stopniu modyfikował zawartość makropierwiastków. Wykazano istotne oddziaływanie tego mikroelementu na zawartość potasu i magnezu w nasionach fasoli oraz azotu, wapnia, magnezu i sodu w słomie. Molibden z kolei nie wpływał na kształtowanie zawartości żadnego z badanych składników w nasionach fasoli. Nawożenie manganem powodowało największy przyrost zawartości azotu oraz magnezu w nasionach i słomie fasoli. Konsekwencją zmian zawartości poszczególnych makroelementów w fasoli pod wpływem nawożenia mikrolementami były na ogół istotnie wyższe w stosunku do obiektu kontrolnego sumy równoważnikowych zawartości kationów.

Słowa kluczowe: fasola, mikroelementy, nawożenie mikroelementami, zawartość makroelementów, stosunki jonowe

STRESZCZENIE ROZSZERZONE

W latach 2003-05 przeprowadzono jednoczynnikowe ścisłe doświadczenie mikropoletkowe, założone metodą losowanych podbloków w układzie split-plot w trzech powtórzeniach w Stacji Badawczej w Wierzchucinku należącej do Uniwersytetu Technologiczno-Przyrodniczego w Bydgoszczy. Doświadczenie realizowano na glebie płowej właściwej, pod względem rolniczej przydatności należącej do kompleksu żytniego dobrego. Gleba o klasie bonitacyjnej IIIb charakteryzowała się lekko kwaśnym odczynem (pH_{KCl} – 5,7), zawartością próchnicy -1,5%, średnią zasobnością przyswajalnych form potasu, fosforu, magnezu, cynku, manganu i boru oraz niską - miedzi. Powierzchnia poletek do zbioru wynosiła 3 m^2.

Badanym w doświadczeniu czynnikiem był rodzaj mikroelementów (n=5): Cu, Zn, Mn, B i Mo, zastosowanych w formie schelatowanej w dawce 200 $g \cdot ha^{-1}$ dla każdego z pierwiastków.

Wykazano, że nawożenie mikroelementami na ogół istotnie różnicowało zawartość makroskładników w częściach wegetatywnych i generatywnych fasoli odmiany 'Aura'. Spośród stosowanych mikroelementów, cynk był pierwiastkiem, który w największym stopniu modyfikował zawartość makropierwiastków. Wykazano istotnie dodatnie oddziaływanie tego mikroelementu na zawartość potasu i magnezu w nasionach fasoli oraz azotu, wapnia, magnezu i sodu w słomie. Nawożenie manganem powodowało największy przyrost zawartości azotu oraz magnezu w nasionach i słomie fasoli. Badania wykazały, że bor w dużym stopniu oddziaływał na zawartość potasu i fosforu w fasoli, jednak statystyczne potwierdzenie uzyskano tylko dla wpływu tego pierwiastka na zawartość potasu w nasionach oraz na zawartość fosforu w słomie. Molibden z kolei nie wpływał na kształtowanie zawartości żadnego z badanych składników w nasionach fasoli. Nalistne zastosowanie miedzi wpłynęło tylko na zmiany zawartości potasu w nasionach oraz azotu, fosforu i potasu w słomie fasoli zwyczajnej, nie wykazano natomiast oddziaływania tego pierwiastka na zawartość azotu w nasionach tej rośliny.

Konsekwencją zmian zawartości poszczególnych makroelementów w fasoli pod wpływem nawożenia mikrolementami były na ogół istotnie wyższe w stosunku do obiektu kontrolnego sumy równoważnikowych zawartości kationów oraz stosunku sumy kationów dwudodatnich (Ca^{2+} i Mg^{2+}) do jednododatnich (Na^{+} i K^{+}). Najwyższą wartość te wielkości osiągały, w przypadku nasion, a także i słomy, dla obiektów nawożonych manganem. Wartości stosunku sum zawartości kationów do zawartości azotu w nasionach fasoli nie były istotnie zróżnicowane nawożeniem mikroelementami.

Wykazane w przeprowadzonych badaniach zmiany zawartości makroskładników i ich proporcji jonowych pod wpływem zastosowanych w uprawie fasoli mikroelementów, dowodzą korzystnego oddziaływanie nawożenia tymi składnikami na wartość konsumpcyjną nasion fasoli.

INTRODUCTION

The condition necessary to obtain high and stable crops of plants is a balanced provision with nutrients dependent on soil fertility and on the applied fertilisation with macro- and microelements. Provided that the macro-components are used by plants to build tissues and assimilates, the role of the micro-components is to regulate biochemical processes taking part wen the plant grows. They are active substrates in cell metabolism as components of enzymes or play a role of their activators. Therefore, these elements increase the effectiveness of fertilising with macro-elements, determining higher crops and their high biological value [7, 11, 18]. The measure of fertilising usability of the fodder obtained from plants cultivated as forage crops and also of the nutritional value of these plants is the chemical composition of the constituents. A physiological role of basic nutritional components in plants is known as a rule, but mutual ionic ratios of the macro-components in plants fertilised with the individual microelements have been recognised to the less degree.

Table 1 The content of macrocomponents in the seeds of kidney bean (three-year means $g \cdot kg^{-1}$ d.m.)
Tabela 1 Zawartość makroskładników w nasionach fasoli (średnie z trzech lat, $g \cdot kg^{-1}$ s.m.)
(1) makroelementy, (2) obiekty nawozowe, (3) średnio, (4) NIR $_{0,05}$

Macroelements[1]	Fertilization objects[2]						Mean[3]	$LSD^4_{0,05}$
	0	Cu	Zn	Mn	B	Mo		
N	31,86	32.53	32.37	33.08	33.04	32.36	32.54	0,790
P	3,64	3,92	3,81	3,69	4,05	3,75	3,81	n.s.
K	14,76	15,42	15,30	15,29	15,41	15,07	15,21	0,423
Ca	0,94	0,99	0,95	0,89	0,92	0,89	0,93	n.s.
Mg	5,01	5,28	5,51	5,67	5,21	5,25	5,32	0,310
Na	0,11	0,10	0,11	0,10	0,10	0,10	0,10	n.s.

Amongst arable plants, papilionaceous plants play a significant role in farming and environment management and also in ecosystem functioning. This is due to their abilities to be used as food, nutrients and fertilisers. The bean, a distinctive plant amongst the legumes, is an important component of human diet. Bean seeds are a valuable source of high biological value plant protein and of relatively high contents of phosphorus and iron [8, 9, 12]. Of the papilionaceous, mostly the leguminous plants are used for consumption. Apart from that the plants are considered free from unreduced forms of nitrogen [12].

The aim of the research undertaken was to assess the effect of foliar fed common bean (Phaseolus vulgaris) with micro-elements on the content and equivalent doses of the selected macro-components in its seeds and straw.

MATERIAL AND METHODS

In the years 2003-05, at the University of Technology and Life Sciencies in Bydgoszcz, in the area of the Research Station at Wierzchucinek near Bydgoszcz, a strict one-factor mirco-plot experiment was carried out by using the method of randomised sub-blocks in split-splot system in three repetitions. The experiment was conducted in a typical fallow soil of size grading, characteristic of arable firm clayey sand belonging to a very good rye complex. The soil classified as 3b productivity class was characterised by light acid reaction (pH_{KCl} – 5,7), the content of humus - 1,5%, and mean abundance of assimilable forms of potassium, phosphorus, magnesium, zinc, manganese, and boron but low - copper.

The tested factor was a type of micro-elements (n=5): Cu, Zn, Mn, B and Mo, used as series of'Symfonia' fertilisers in dosage of 200 $g \cdot ha^{-1}$ for each element. The fertilisers of 'Symfonia' series contained micro-elements in a chelated form. The spray was made twice: at the beginning of forming flower buds and a week later. The applied fertilising components were diluted in a volume of water corresponding with a dosage of 300 $dm^3 \cdot ha^{-1}$. Triple superphosphate (30 kg $P \cdot ha^{-1}$) and potassium sulfate(VI) (110 kg $K \cdot ha^{-1}$) were used as the basic fertilisation. A common bean of 'Aura' cultivar was the cultivated plant. It is a lodge-resistant, early variety of high prolificacy. The bean was sown at the turn of I and II decade of May, with raw spacing of 15 cm. The plot harvest areas were 3 m^2.

In the collected specimens of bean seeds and straw, after their preliminary mineralisation, the following determinations were made: total nitrogen – by Kjeldahl's method, total phosphorus – by the method with ammonium molybdate and colorimeter DR-2000, potassium, calcium and sodium – by the method of flame photometry using photometer Phlavo 5. The results obtained were processed by using variance analysis for one-factor experiments. The lowest significant differences were calculated using Tukey's test at the significance level p=0,05.

RESULTS AND DISSCUSSION

Amongst macro-components determined in the common bean, nitrogen was quantitatively dominating (Table 1 and 2). Its mean amount in seeds and straw was for three years of the research, respectively: 32,54 $g \cdot kg^{-1}$ and 21,52 $g \cdot kg^{-1}$. Significantly lower concentration was observed for phosphorus, potassium, calcium and magnesium. Their mean contents in $g \cdot kg^{-1}$ were, respectively, in seeds: 3,81, 15,21, 0,93 and 5,32, in straw: 1,27, 17,58, 3,88 i 5,38. Sodium was the macro-component of the lowest mean concentration, on average in $g \cdot kg^{-1}$: 0,10 and 1,10. A decreasing series of the discussed elements in the tested bean did not depend on fertilisation with micro-elements, but was slightly different for seeds (N>K>Mg>P>Ca>Na) than for straw (N>K>Mg>Ca>P>Na).

The study carried out indicated that fertilisation with micro-elements generally differentiated significantly the content of micro-components in seeds and straw of the common bean, with the exception of the contents of phosphorus, calcium and sodium in seeds. Amongst the used microelements, zinc was the one that modified the contents of microelements to the most degree. The study demonstrated a positive effect of this component on the content of potassium and magnesium in bean seeds, and

Table2 The content of macrocomponents in the straw of kidney bean (three-year means, $g \cdot kg^{-1}$d.m.)
Tabela 2 Zawartość makroskładników w słomie fasoli (średnie z trzech lat, w $g \cdot kg^{-1}$s.m)
(1) makroelementy, (2) obiekty nawozowe, (3) średnio, (4) NIR $_{0,05}$

Macroelements[1]	Fertilization objects[2]						Mean[3]	LSD[4] $_{0,05}$
	0	Cu	Zn	Mn	B	Mo		
N	20.38	22.22	21.50	23.37	21.00	20.68	21.52	1.102
P	1,10	1,37	1,14	1,17	1,31	1,56	1,27	0,104
K	17,77	16,50	17,31	18,07	17,34	18,51	17,58	0,608
Ca	3,57	3,82	4,04	3,93	3,93	4,01	3,88	0,465
Mg	4,85	5,07	5,77	6,13	4,90	5,54	5,38	0,425
Na	1,04	1,10	1,17	1,05	1,17	1,09	1,10	0,075

on the content of nitrogen, calcium, magnesium and sodium in the bean straw. The differences with reference to the control in % were, respectively: 3,7, 10,0, 5,5, 13,2, 19,0, 12,5. The effect of zinc on the content of macro-elements in plant results from the fact that this component is a co-factor for many enzymes and its deficiency disorganises significantly the carbohydrate and protein metabolisms, the auxin and nucleic acid syntheses [3, 13, 15]. A positive effect of zinc on the nitrogen content is a consequence of the role that this element plays in the synthesis of tryptophan - the second (after methionine) limiting amino acid, and also of a function in oxidation processes in protein synthesis [3]. Fertilisation with manganese induced the largest increase in nitrogen and magnesium both in seeds and straw of the common bean. The respective differences with reference to the control unfertilised with micro-elements, in %, were as follows: 3,8 and 13,2 for seeds, 14,7 and 26,4 for straw. The impact of manganese on nitrogen assimitation and on protein biosynthesis in leguminous plants has been confirmed by many studies [5, 10]. This element as a component or an activator of e.g. nitrate(V) reductase, peptidase, arginase affects the process of reduction of nitrates(V), peptide and amide hydrolysis, urea hydrolysis, auxin oxidation, and many other biochemical processes taking place in a plant. Foliar spraying with copper solution significantly affected the changes in potassium contained in the common bean seeds and in nitrogen, phosphorus and potassium in the straw. Unlike the studies of Seliga [14] and Alaoni-Sousse [13] on the yellow lupine (Lupinus luteus), soya bean and horse bean, no effect of this element was demonstrated on the content of nitrogen in bean seeds. Even though the increase in nitrogen content for the objects fertilised with this constituent was found and amounted to on average 2,1% for three years, the difference was not statistically proved. However, a high increase in phosphorus content in the bean straw that was as much as 24,5% with reference to control is worth noticing. The content of phosphorus varied considerably after applying fertilisation with microelements. Apart from copper, significant phosphorus increases were also induced fertilisation with boron and molybdenum; the respective differences, in %, with reference to the control were: 19,1 and 41,8.

Boron is the element that to the most degree affected the content of potassium and phosphorus in the bean, however a statistical conformation was achieved only for the influence of this element on the content of potassium in bean seeds and on the content of phosphorus in straw.

Molybdenum is a constituent of nitrate(V) nitrogenase, the most important enzyme to bond atmospheric nitrogen by papilionaceous plants [1, 5, 6, 17, 19]. The research

Table 3 The sum of cations and the equivalent ionic ratios of macro-components in bean seeds (three year means)

Tabela 3 Równoważnikowa suma kationów i proporcje jonowe makroskładników w nasionach fasoli (średnie z trzech lat)

(1) suma kationów, (2) obiekty nawozowe, (3) średnio, (4) NIR $_{0,05}$, (5) suma kationów/N

	Fertilization objects 2						Mean 3	LSD $^{4}_{0,05}$
	0	Cu	Zn	Mn	B	Mo		
∑cat. (val·kg^{-1}) 1	0,848	0,889	0,904	0,913	0,880	0,873	0,887	0,024
Ca+Mg/K+Na	1,212	1,225	1,276	1,304	1,202	1,234	1,242	n.s.
∑cations/N 5	0,373	0,383	0,391	0,387	0,373	0,378	0,381	n.s.

Table 4 The equivalent sum of cations and the equivalent ionic ratios of macro-components in bean straw (three-year means)

Tabela 4 Równoważnikowa suma kationów i równoważnikowe proporcje jonowe makroskładników w słomie fasoli (średnie z trzech lat)

(1) suma kationów, (2) obiekty nawozowe, (3) średnio, (4) NIR $_{0,05}$, (5) suma kationów/N

	Fertilization objects						Mean	LSD$_{0,05}$
	0	Cu	Zn	Mn	B	Mo		
∑cat. (val·kg^{-1})	1,084	1,084	1,178	1,216	1,100	1,184	1,141	0,045
Ca+Mg/K+Na	1,164	1,303	1,380	1,390	1,221	1,269	1,288	0,105
∑cations/N	0,744	0,683	0,767	0,729	0,734	0,802	0,743	0,052

carried out, similarly to that by Kotecki and Janeczek [8], demonstrated no clear differences in nitrogen content under the effect of fertilisation with this element. Those authors emphasise that only when boron and molybdenum were applied together the nitrogen content in the bean seeds increased.

The consequences of changes in contents of the individual macroelements in the bean under the effect of microelement fertilisation were generally higher values of totals of equivalent contents in cations with reference to the control (Table 3 and 4). This parameter achieved its highest value both in seeds and straw for the objects fertilised with manganese.

The increase in quotient of the sums of divalent cations (Ca^{2+} and Mg^{2+}) to univalent ones ($K^{+}$and Na^{+}) was found with reference to the control under the effect of all the tested microelements with the exception of boron. Both in seeds and straw of the common bean, the highest increase in the discussed ratio was a result of using fertilisation with manganese. The differences in % with the reference to the object non fertilised were, respectively: 7,6 and 19,4. Proper proportions between the content of univalent and divalent cations in plant fertilisers are extremely important to maintain a correct metabolism in the organism of consumers. Arable plants, especially those of forage intention often demonstrate excessive concentration of potassium, which is not good for their consumers' health, especially for ruminants [4, 18]. Too narrow ratio Ca+Mg/K+Na usually shows an unsatisfactory level of magnesium in the fodder, which is usually accompanied by a high content of potassium [18]. The changes in the discussed proportion after applying most microelements reveal advantageous interaction of fertilisation with these components on the consuming value of bean seeds.

For bean seeds, the values of the ratio of equivalent contents of cations to the content of nitrogen ranged in narrow limits 0,373-0,391 and were not significantly differentiated under the effect of fertilisation with microelements. But for bean straw, only the use of molybdenum resulted in significant increase in this ratio with reference to the control.

CONCLUSIONS

1. Amongst the applied microelements, zinc was the one which modified the contents of macroelements in the common bean to the most degree. A significant positive effect of this component was proved on the contents of nitrogen and magnesium in the bean seeds, and also nitrogen, calcium, magnesium and sodium in the bean straw.
2. The highest increase in nitrogen and magnesium was found after using manganese.
3. The consequences of changes in contents of the individual macroelements in the bean under the effect of fertilisation with microelements were generally higher values of both equivalent sums of cations and the ratio of the sum of divalent cations (Ca^{2+} and Mg^{2+}) to the sum of univalent ones (K^{+} and Na^{+}) with reference to the control.

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