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THE EFFECT OF FERTILIZATION WITH BORON, MAGNESIUM AND SULPHUR ON GROWTH, SEED YIELD AND OIL CONTENT IN PURPLE VIPER'S BUGLOSS (*Echium plantagineum* L.)

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Abstract. Oil in *Echium plantagineum* (purple viper's bugloss) seeds is rich in polyunsaturated fatty acids including the rarely occurring γ-linolenic acid and stearidonic acid. Therefore, the oil is used in pharmacy and food industry. Boron, magnesium and sulphur play an important role in physiological processes of plants. Polish soils, however, in majority are deficient in these elements. The aim of the experiment was to compare the effects of two methods of fertilization (into soil and foliar one) with boron, magnesium and sulphur on growth and seed yields of purple viper's bugloss. The study was carried out on silt - loam soil characterized by the mean content of magnesium and sulphur and a low content of boron. Afore-named elements, irrespectively of the application method, brought about a significant increase in the height of plants, their vegetative mass, and induced better development of seeds. As a result, yields of seeds on plots with boron, magnesium and sulphur fertilization were significantly higher in comparison with the control (it should be stressed that impact of boron was the greatest). Fertilization had a positive effect on the fat content in seeds too, resulting in an increase by 0.2%-1.6% (boron was the most effective in this respect too). Results of the present study showed that application of fertilization with boron, magnesium and sulphur had a significant effect on the yield and oil content in purple viper's bugloss seeds.

Key words: foliar and soil application, medicinal plant, oil content, purple viper's bugloss, yield seed, stearidonic acid

INTRODUCTION

The genus *Echium* comprises 30 species that are primarily native to the Mediterranean [Guil-Guerrero *et al*. 2000]. Two of the most common species in Poland are *Echium vulgare* and *Echium planatagineum* [Chwil and Weryszko-Chmielewska 2011]. Agronomic interest in purple viper's bugloss (*Echium plantagineum* L.) as an

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oilseed crop is caused by its oil containing specific fatty acids. Oil obtained from seeds of this species is characterized by a high percentage of polyunsaturated fatty acids, including the following rare acids: γ-linolenic acid (C18:3 Ω6) and stearidonic acid (C18:4 Ω3). Stearidonic acid is very uncommon in higher plants, but very important in human nutrition because SDA is an intermediate in the biosynthesis of eicosapentanoic (EPA) and docosahexaenoic (DHA) acids. Both of these omega-3 fatty acids, are required in human diet for the proper functioning of cell membrane and good health [Clough 1993]. Echium seed oil has a unique ratio of omega-3 to omega-6 fatty acids not present in any other plant. This oil currently finds application in the food industry as a bioactive component of food formulations and functional food reducing the risk of incidence of diseases of affluence. It is also used in the prevention and treatment of heart and cardiovascular diseases, and it is a component of protective and anti-aging cosmetics [Mir 2008]. Purple viper's bugloss is grown commercially in Poland and Europe [Coupland 2008].

Both macro and micronutrient availability is influenced by chemical and physical properties of the soil. The soil nutrient content may not always be sufficient to fulfil crop requirements. Boron plays an important role in metabolic processes of plants influencing growth and productivity of many crops. Boron takes part in such processes as: calcium utilization, cell division, water relations, flowering and fruiting, and serves as a catalyst in certain reactions. A steady supply of boron during the peak of vegetative growth, flowering, and seed development stages is essential for optimum seed yield [Blevins and Lukaszewski 1998].

Soils of many regions of the world (including Poland) are characterized by a low content of sulphur, which is insufficient to ensure normal growth and development of plants. This can be attributed mainly to the significant reduction of industrial emission and to the decreasing deposition of this element coupled with the simultaneous increase in the application of mineral fertilizers with low sulphur content [Klikocka 2005]. Sulphur plays a pivotal role in various plant growth and development processes. The role of sulphur in plants is to help in the formation of plant proteins, and it is essential in the formation of chlorophyll. Sulphur is also involved in the synthesis of fatty acids and other metabolites [Scherer 2001]. Sulphur deficiency in the soil may not only reduce the yield, but also the quality of the produce [Kozłowska-Strawska and Kaczor 2009].

Magnesium is the main component of chlorophyll and is responsible for a number of functions in plants as an activator of the enzymatic systems that regulate processes of photosynthesis, energy transformations, and synthesis of carbohydrates, proteins and fats. Magnesium deficiency during plant growth causes a decrease in the yield and its quality [Gerendás and Führs 2013].

Foliar application of macro and micronutrients has advantages over soil application because of high effectiveness, rapid plant response, convenience and elimination of toxicity symptoms brought about by excessive soil accumulation of such nutrients [Kwiatkowski 2012].

The role of boron, magnesium and sulphur in purple viper's bugloss yield is insufficiently presented in scientific literature. The aim of the experiment was to compare the effects of two methods of fertilization (into soil and foliar one) with these elements on the growth and seed yields of purple viper's bugloss.

MATERIAL AND METHODS

A field experiment was conducted in 2009 and 2010 at the Experimental Farm of the University of Life Sciences in Lublin (51°14′ N; 22°34′ E), Poland. The soil was of silt – loam texture, with a medium organic matter content (1.87%) and was slightly alkaline (pH 7.6). The plough layer was characterized by a medium content of phosphorus (77 mg·kg^{-1} of soil), potassium (104 mg·kg^{-1} of soil) and magnesium (67 mg·kg^{-1} of soil), a very low content of boron (0.6 mg·kg^{-1} of soil) and a medium content of sulphur (S-SO_4 23,5 mg·kg^{-1} of soil).

The experiment included two methods of boron, magnesium and sulphur application into soil (before sowing seeds) and foliar (in two equal doses during stem formation and at the budding stage) (Table 1). The control plots were the ones with only basic fertilization. The basic fertilization was as follows: N – 60; P – 17.5; K – 66.4 kg of nutrient per ha. Before sowing the seeds, phosphorus and potassium fertilization was carried out in the form of triple superphosphate and potassium chloride, whereas pre-sowing nitrogen fertilization was applied in the form of ammonium nitrate (taking into account the amount of nitrogen incorporated together with magnesium nitrate and ammonium sulphate).

Table 1. Application method and doses of nutrients used in the experiment
Tabela 1. Sposób stosowania i dawki składników pokarmowych zastosowanych w doświadczeniu

Applied nutrient Składnik pokarmowy	Application method Sposób stosowania	Dose of nutrient Dawka składnika kg·ha^{-1}	Source of nutrient Źródło składnika
Boron Bor	soil – doglebowo	3.0	Foliarel ®
	foliar – dolistnie	0.3	Foliarel ®
Magnesium Magnez	soil – doglebowo	20.0	$Mg(NO_3)_2 \cdot 6H_2O$
	foliar – dolistnie	3.0	Hydromag 500
Sulphur Siarka	soil – doglebowo	10.0	$(NH_4)_2SO_4$
	foliar – dolistnie	5.0	Dolosul ® 80 WG
Control Obiekt kontrolny	without B, Mg, S fertilization – bez nawożenia B, Mg, S		

This study was conducted in randomized complete block design with four replications. Plot size and row spacing were 2.0 × 5.0 = 10.0 m^2 and 40 cm, respectively. Purple viper's bugloss cv. 'Blue Bedder' was used as the seed material. The seeds were provided by the Department of Botany, the Faculty of Horticulture and Landscape Architecture of the University of Life Sciences in Lublin. Sowing was conducted in late April, while the sowing rate was 4 kg·ha^{-1} of seeds. During plant growth, all necessary treatments were performed (weeding, interrow tillage). In the study, plant height (cm), number of branches (branch per plant) and mass of the aboveground parts (g·plant^{-1}) were calculated for randomly chosen 10 plants. Harvest was carried out at end of August in both years. Harvested plants were dried throughout 6-7 days on the field. They were threshed and the seed yields were calculated per plots. The seeds obtained from the experimental field were properly grounded and the oil was extracted by n-hexane in a Soxhlet extractor for four hours. Recovered crude oils were dried out in a rotator at 35°C. The oil content was calculated based on the dry mass [PN-EN ISO 659:2009].

The obtained results were elaborated statistically with the analysis of variance, while significance of differences was estimated with Tukey test on a significance level of 0.05. Calculations were carried out with the use of program ARStat from the Information Technology Centre of the University of Life Sciences in Lublin.

Climatic conditions for the years 2009-2010 and for the long term period (1951--2008) are given in Table 2.

Table 2. Chosen meteorological data in the experimental years (2009-2010) and long-term means (1951-2008) according to the Meteorological Station in Lublin
Tabela 2. Wybrane dane meteorologiczne w latach badań (2009-2010) i średnie wieloletnie (1951-2008) wg Stacji Meteorologicznej w Lublinie

Month Miesiąc	Rainfall – Opady, mm			Temperature – Temperatura, °C		
	2009	2010	long-term wielolecie	2009	2010	long-term wielolecie
April – kwiecień	3.0	20.5	40.6	11.4	9.4	8.5
May – maj	71.1	106.7	58.3	13.6	14.5	13.0
June – czerwiec	125.5	65.6	65.8	16.5	18.0	16.5
July – lipiec	57.1	101.0	78.0	19.9	21.6	18.9
August – sierpień	54.7	72.8	69.7	19.0	20.2	17.3
Total / Mean Suma / Średnia	311.4	366.7	312.4	16.1	16.8	14.8

RESULTS AND DISCUSSION

Effect of fertilization with boron, magnesium and sulphur on the air-dry mass of the aboveground parts of purple viper's bugloss plants, appeared to be statistically significant only when fertilizers were applied into the soil (except sulphur which was equally effective in both methods of application) – Table 3. Only boron (applied into the soil) had a significant effect on plant height and the number of branches (Table 3 and 4). The investigated morphological traits were significantly modified by weather factors during the study period. In the year 2010, in which there was much more rainfall, the plants were higher and produced more branches and, as a result of that, their vegetative matter was significantly higher than in 2009.

In the available literature, there is lack of data on responses of viper's bugloss to fertilization with boron. In the study on soybean conducted by Devi *et al.* [2012], soil application of boron beneficially affected plant height and the production of lateral branches as well as vegetative matter. Under the tropical climate conditions, Oyinlola *et al.* [2007] found an increase in sunflower plant height and yield as influenced by boron fertilization. However, other experiments showed that boron fertilization did not affect morphological traits and yield of coriander and poppy [Wójtowicz 2007, Nowak and Szempliński 2011].

Studies prove that sulphur fertilization has a positive effect on the growth and yield of many oilseed species. The study of Podleśna [2002] demonstrated a positive influence of sulphur on the growth and development of winter oilseed rape plants (higher stem, and siliques weight). In the case of white mustard sulphur did not differentiate significantly the number of siliques, but it caused a reduction in the plant height [Budzyński and Jankowski 2001].

Table 3. Height of purple viper's bugloss plants (cm) and air-dry mass of their aboveground parts ($g \cdot plant^{-1}$) depending on the applied nutrients
Tabela 3. Wysokość roślin (cm) oraz powietrznie sucha masa części wegetatywnych ($g \cdot roślina^{-1}$) żmijowca babkowatego zależności od zastosowanych składników pokarmowych

Applied nutrient Składnik pokarmowy		Height of plants Wysokość roślin			Mass of aboveground parts Masa części wegetatywnych		
		2009	2010	mean średnia	2009	2010	mean średnia
Application metod – Sposób stosowania							
Boron Bor	soil – doglebowo	92.2	102.5	97.4 a*	33.5	42.2	37.9ac
	foliar – dolistnie	88.5	99.2	93.9 ab	31.4	40.3	35.9cd
Magnesium Magnez	soil – doglebowo	91.0	97.5	94.3 ab	34.3	43.0	38.7ab
	foliar – dolistnie	89.1	96.2	92.7 b	32.2	41.5	36.9bc
Sulphur Siarka	soil – doglebowo	89.6	96.7	93.2 b	35.8	43.8	39.8a
	foliar – dolistnie	89.2	96.5	92.9 b	33.5	42.3	37.9ac
Control – Obiekt kontrolny		88.5	96.3	92.4 b	29.8	38.5	34.2d
Mean – Średnia		89.7	97.8	93.8	32.9	41.7	37.3
LSD (5%) – NIR (5%)							
nutrient – składnik pokarmowy (A)				3.76			2.65
year – lata (B)				6.65			7.84
interaction (A × B) – interakcja (A × B)				9.73			8.68

* values designated with the same letters within columns do not differ significantly at $p \leq 0.05$ – wartości oznaczone tymi samymi literami w obrębie kolumn nie różnią się istotnie ($p \leq 0,05$)

Table 4. Number of branches ($branch \cdot plant^{-1}$) of purple viper's bugloss depending on the applied nutrients
Tabela 4. Liczba rozgałęzień bocznych ($sztuka \cdot roślina^{-1}$) żmijowca babkowatego w zależności od zastosowanych składników pokarmowych

Applied nutrient Składnik pokarmowy		Number of branches – Liczba rozgałęzień bocznych					
		total – ogółem			first tier – I rzędu		
		2009	2010	mean średnia	2009	2010	mean średnia
Application metod – Sposób stosowania							
Boron Bor	soil – doglebowo	49.0	61.9	55.5*a	16.0	21.5	18.8a
	foliar – dolistnie	44.1	58.0	51.1b	14.6	20.3	17.5b
Magnesium Magnez	soil – doglebowo	46.4	60.5	53.5ab	14.9	21.6	18.3ab
	foliar – dolistnie	43.2	57.2	50.2bc	14.6	20.5	17.6b
Sulphur Siarka	soil – doglebowo	45.8	58.2	52.0abc	15.6	20.7	18.1ab
	foliar – dolistnie	42.4	56.9	49.7bc	14.5	20.6	17.6b
Control – Obiekt kontrolny		42.0	56.4	49.2bc	14.8	20.0	17.4b
Mean – Średnia		44.7	58.4	51.6	51.6	20.7	17.9
LSD (5%) – NIR (5%)							
nutrient – składnik pokarmowy (A)				4.21			1.15
year – lata (B)				10.57			3.52
interaction (A × B) – interakcja (A × B)				12.36			5.23

* see Table 3 – patrz tabela 3

On all plots, seeds were better developed under the influence of boron, magnesium and sulphur fertilization and had a higher weight of one thousand seeds compared to the control. However, fertilization method was not found to have a significant effect on this trait.

There were significant differences between the seed yield values of purple viper's bugloss in the experimental years (Table 5). Seed yield was recorded as 923.1 kg·ha^{-1} in 2009, while its average value was 986.7 kg·ha^{-1} in 2010. Seed yield of purple viper's bugloss depends greatly on climatic conditions. In the northern territories of USA yields did not exceed 500 kg·ha^{-1} [Berti *et al*. 2007], while in Egypt on fairly fertilized plots the yield reached 1900 kg·ha^{-1} [Hendawy and El-Gengaihi 2010]. In the experiments carried out in Poland [Król 2008] yields amounted to 700-1000 kg·ha^{-1} and were comparable with those obtained in the discussed experiment (818.8-1040.3 kg·ha^{-1}) (Table 5).

Table 5. Weight of 1000 seeds (g) and seed yield (kg·ha^{-1}) of purple viper's bugloss depending on the applied nutrients
Tabela 5. Masa tysiąca nasion (g) oraz plon nasion (kg·ha^{-1}) żmijowca babkowatego w zależności od zastosowanych składników pokarmowych

Applied nutrient Składnik pokarmowy		1000 seed weight – Masa tysiąca nasion			Seed yield – Plon nasion		
		2009	2010	mean średnia	2009	2010	mean średnia
Application metod – Sposób stosowania							
Boron Bor	soil – doglebowo	3.92	3.67	3.79 a*	961.0	1003.4	982.2 ab
	foliar – dolistnie	4.01	3.74	3.88 a	986.7	1040.3	1013.5 a
Magnesium Magnez	soil – doglebowo	3.90	3.57	3.74 a	951.0	978.5	964.8 ab
	foliar – dolistnie	3.99	3.65	3.82 a	942.5	1000.3	971.4 ab
Sulphur Siarka	soil – doglebowo	3.87	3.59	3.73a	903.0	960.3	931.7 b
	foliar – dolistnie	3.92	3.63	3.78 a	898.6	1030.5	964.6 ab
Control – Obiekt kontrolny		3.60	3.22	3.41 b	818.8	893.3	856.1 c
Mean – Średnia		3.89	3.58	3.73	923.1	986.7	954.9
LSD (5%) – NIR (5%)							
nutrient – składnik pokarmowy (A)				0.31			67.79
year – lata (B)				0.28			ns – ni
interaction (A × B) – interakcja (A × B)				0.41			75.82

* see Table 3 – patrz tabela 3
ns – ni – non-significant differences – różnice statystycznie nieistotne

On plots where fertilization with boron, magnesium and sulphur was used, the seed yield of purple viper's bugloss was significantly higher than on the control plot (Table 5). Comparing the effect of individual elements, it was found that in both years of the study boron was the most effective (in particular, in the case of foliar application). The effect of sulphur was largely dependent on humidity conditions in the growing season. In 2009, which was quite dry, the method of application did not have a significant influence, but in 2010 which was abundant in rainfall, foliar application resulted in a higher increase in the seed yield. This was probably caused by the fungicidal action of sulphur in the growing season in 2010, which was favourable for the infection of plants by fungal pathogens. Grzebisz *et al*. [2010] reported that sulphur compounds reduce activity of fungal diseases. No significant differences were found in the present experiment in the seed yield depending on the method of fertilization, though foliar application of these nutrients was found to have a slightly greater stimulating effect.

The seed yield-increasing effect of boron has been demonstrated in the case of many oilseed species. Positive results have been obtained in experiments with soybean [Devi *et al*. 2012], sunflower [Oyinlola *et al*. 2007], and poppy [Wójtowicz 2007]. As reported by Bowszys and Krauze [2000], the productive effect of boron is dependent on weather conditions in the growing season. Rainfall deficiency impeded boron uptake from the soil, and in such case foliar fertilization produced better effects. No such relationship was found in our experiment, in spite of a large difference in the amount of rainfall in the growing seasons of 2009 and 2010.

According to Sepehre *et al*. [2002], magnesium fertilization significantly affects the one thousand seed weight and the yield of sunflower. On the other hand, Szczebiot [2002] obtained results showing that there was no response of camelina and crambe to magnesium application.

The yield-increasing effect of sulphur depends on the availability of this nutrient in the soil, but also on the sulphur requirement of a given plant species. An increase in the seed yield of oilseed crops as influenced by sulphur fertilization has been found in many studies [Budzyński and Jankowski 2001, Sepehre *et al*. 2002]. In experiments with poppy, the application of sulphur contributed to a slight decrease in the number of capsules per plant but, at the same time, one thousand seed weight increased and, as a consequence, a higher seed yield was obtained [Richter *et al*. 2009]. There are also reports saying that sulphur does not have any yield-increasing effect [Sepehre *et al*. 2002] or that it may reduce the seed yield [Wielebski and Muśnicki 1998].

Foliar application of nutrients is generally considered to be more effective compared to soil application. However, the study of Malhi et al. [2003] did not find significant differences in the oilseed rape yield depending on the method of boron application. Also Krauze and Bowszys [2000] received a higher seed yield of this species fertilized with sulphur before sowing, compared to foliar fertilization.

Fertilization with boron resulted in a significant increase in the seed oil content (on average by 1.2%). In the case of other elements, the observed increasing trend proved to be statistically insignificant (Table 6). The studies on the effect of boron fertilization on oil content in seeds of other species are varied. An increase in oil percentage was obtained in the experiments with sunflower [Oyinlola *et al*. 2007], whereas Devi *et al*. [2012] and Malhi *et al*. [2003] did not find boron to have an effect on oil accumulation in soybean and oilseed rape seeds, while Ceyhan *et al*. [2008] recorded a decrease in the oil content in sunflower seeds. Gerendás and Führs reported [2013] that the influence of magnesium on the accumulation of oil is dependent on plant species and method of application. According to Jahangir *et al*. [2005] magnesium fertilization causes an increase in the oil content in Indian mustard. A similar increase was also recorded by Sepehre *et al*. [2002] in sunflower seeds.

In numerous studies on oilseed crops [Ahmad and Abdin 2000] it has been demonstrated that sulphur application generally causes an increase in the oil content. Nevertheless, some publications report that there is no such effect [McGrath and Zhao 1996, Sepehre *et al*, 2002, Devi *et al*. 2012], or even that there is a negative influence of this nutrient on oil accumulation [Szulc *et al*. 2001].

In literature [Guil-Guerrero 2000, Król and Kowalski 2004), oil content in seeds of purple viper's bugloss is within the range of 20-25%. The content found in the presented experiment (Table 6) did not differ from the literature data.

Oil yield per unit of area is a resultant of the seed yield and oil content. In the experiment, oil yield per unit of area was higher on all fertilized plots than the one in the control (Table 6). The greatest differences were recorded under the influence of boron fertilization. Higher seed yield in 2010 did not have a significant effect on increasing oil yield in this year due to the lower percentage of oil compared to 2009.

Table 6. Oil content in seeds (%) and oil yield ($kg \cdot ha^{-1}$) of purple viper's bugloss depending on the applied nutrients
Tabela 6. Zawartość oleju w nasionach (%) oraz teoretyczny plon oleju ($kg \cdot ha^{-1}$) żmijowca babkowatego w zależności od zastosowanych składników pokarmowych

Applied nutrient Składnik pokarmowy		Oil content – Zawartość oleju			Oil yield – Plon oleju		
		2009	2010	mean średnia	2009	2010	mean średnia
Application metod – Sposób stosowania							
Boron Bor	soil – doglebowo	22.3	21.5	21.9ab	214.3	215.7	215.0ab
	foliar – dolistnie	22.6	21.7	22.2a	223.0	225.7	224.4a
Magnesium Magnez	soil – doglebowo	21.8	20.9	21. 4ac	207.3	204.5	205.9ab
	foliar – dolistnie	21.5	21.4	21.5ac	202.6	214.1	208.4ab
Sulphur Siarka	soil – doglebowo	21.2	20.6	20.9bc	191.4	197.8	194.6abc
	foliar – dolistnie	21.4	20.3	20.8bc	192.3	209.2	192.3bc
Control – Obiekt kontrolny		21.0	20.1	20.6bc	171.0	179.6	175.3c
Mean – Średnia		21.7	20.9	21.3	21.3	206.2	202.3
LSD (5%) – NIR (5%)							
nutrient – składnik pokarmowy (A)				1.22			30.10
year – lata (B)				ns – ni			ns – ni
interaction (A × B) – interakcja (A × B)				1.54			40.53

* see Table 3 – patrz tabela 3
ns – ni – non-significant differences – różnice statystycznie nieistotne

CONCLUSIONS

1. Results of the present study showed that application of fertilization with boron, magnesium and sulphur caused an increase in the air-dry mass of the aboveground parts of purple viper's bugloss plants. Boron, magnesium and sulphur fertilization (regardless of the method of application) resulted in better seed development and, as a result, in a higher yield compared to the control treatment. Comparing the yield-increasing effect of the elements studied, boron was the most effective.

2. Among the elements studied in the present experiment, only boron had a significant effect on an increase in the oil content in purple viper's bugloss seeds. However, a significant increase in the oil yield was obtained under the influence of fertilization with boron and magnesium (regardless of the method of application).

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WPŁYW NAWOŻENIA BOREM, MAGNEZEM I SIARKĄ NA WZROST ROŚLIN, PLON NASION I ZAWARTOŚĆ OLEJU ŻMIJOWCA BABKOWATEGO (*Echium plantagineum* L.)

Streszczenie. Olej z nasion żmijowca babkowatego charakteryzuje się wysokim udziałem (ponad 80%) wielonienasyconych kwasów tłuszczowych, w tym rzadko spotykanymi kwasami: γ-linolenowym oraz stearidonowym. Znajduje zastosowanie w przemyśle spożywczym i farmaceutycznym. Bor, magnez i siarka pełnią w roślinach szereg ważnych funkcji fizjologicznych. Duży odsetek gleb w Polsce charakteryzuje niska zasobność w przyswajalne formy tych pierwiastków. Celem eksperymentu było porównanie wpływu dwóch metod nawożenia (doglebowego i dolistnego) borem, magnezem i siarką na wzrost i plonowanie żmijowca babkowatego. Badania przeprowadzono na glebie pylastej charakteryzującej się średnią zawartością magnezu i siarki oraz niską boru. Nawożenie tymi pierwiastkami (niezależnie od metody aplikacji) spowodowało niewielki wzrost wysokości roślin oraz liczby rozgałęzień bocznych, a w konsekwencji także zwiększenie masy wegetatywnej. W obiektach nawożonych borem, magnezem i siarką nasiona były lepiej wykształcone i uzyskano wyższe plony w porównaniu z kontrolą. Porównując plonotwórcze efekty badanych pierwiastków, stwierdzono, iż najbardziej efektywny (niezależnie od sposobu stosowania) był bor. Nawożenie pozytywnie wpłynęło na zawartość tłuszczu w nasionach, zwiększając jego zawartość od 0,2 do 1,6% (najkorzystniej oddziaływał bor). Wyniki badania wykazały że dodatkowe nawożenie borem magnezem i siarką miało istotny wpływ na plonowanie oraz zawartość oleju w nasionach żmijowca babkowatego.

Słowa kluczowe: aplikacja dolistna i doglebowa, plon nasion, roślina lecznicza, zawartość oleju, kwas stearidonowy, żmijowiec babkowaty

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