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ORIGINAL PAPER

EFFECT OF FOLIAR FERTILIZATION ON THE CHLOROPHYLL CONTENT IN LEAVES AND THE CHEMICAL COMPOSITION OF FABA BEAN SEEDS (*VICIA FABA* L. (PARTIM))*

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Abstract

Foliar fertilization allows supplementation of nutrients during their highest demand by agricultural crops. During the growing period, the state of plant nutrition can be assessed based on the chlorophyll content in leaves, and such analyses can be made using the chlorophyll gauge. The measurement of the so-called leaf greenness index (SPAD) obtained in this way allows determination of the optimal fertilization doses in order to increase or improve the quality characteristics of the yield. A controlled field experiment was conducted at the Experimental Station of Cultivar Assessment in Przecław in 2011 - 2013. The aim of this study was to estimate the response of two faba bean morphotypes (Amulet and Granit) to foliar fertilization with a multicomponent fertilizer (Basfoliar 6-12-6). The foliar fertilization was applied twice, i.e.: at the budding stage (BBCH 55) and after flowering (BBCH 69). Foliar fertilization did not significantly modify the chlorophyll content in leaves as compared with the control. Intervarietal differences in the SPAD index were not proven either. The mean measurement of the so-called leaf greenness measured at the first flat pod stage (BBCH 70) amounted to 40 SPAD units. Seeds of the cultivar Amulet contained significantly more total protein, ash and fibre but less raw fat than the seeds of the cultivar Grant. Foliar fertilization resulted in a significant increase in raw fat content in the seeds, but only in the cultivar Amulet. The foliar fertilizer increased the content of potassium (K) and zinc (Zn) in seeds. Seeds of the cultivar Amulet as compared with Granit contained significantly more magnesium (Mg), iron (Fe) and manganese (Mn) but less phosphorus (P).

Keywords: traditional cultivar, self-completing cultivar, SPAD index, macroelements, microelements.

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INTRODUCTION

In Poland animal feeding is largely based on imported soybean meal. Since a considerable amount of this meal derives from genetically modified crops, action has been undertaken aiming at increasing the domestic production of legumes (Jerzak et al. 2012). Polish plant production has good cultivars of all legume species, and increasing their cultivation is possible in nearly all areas of the country. Also the production profitability of legumes has increased, thanks to subsidies introduced for their cultivation. Due to a considerable differentiation of legume morphotypes and unstable yields in years, it is necessary to conduct research over their agricultural requirements under different habitat conditions (Podleśny 2005, Podleśny, Księżak 2009, Prusiński 2007*b*, *c*, Czerwińska-Kayzer, Florek 2012). Of the domestic legumes, faba bean is characterized by high yielding potential and a good nutrition value of seeds with a reduced content of non-nutritional substances. However, there is small interest in faba bean cultivation. This also refers to the scope of scientific research, which is reflected in the decreasing number of relevant scientific publications (Kulig, Zając 2007).

Many authors (Elsheikh et al. 1999, Osman et al. 2010, Rugheim, Abdelgani 2012) point to a significant effect of proper cultivation technology, including fertilization, on the faba bean seeds quality. Kocoń (2003, 2010) and Wojcieska and Kocoń (1997) report that in faba bean cultivation it is possible to apply foliar fertilization with nitrogen during the growth period. From many studies (Shaaban et al. 2006, Abou EL-Yazied, Mady 2012, Jasim et al. 2014, Salem et al. 2014) it follows that legumes also show a positive response to foliar fertilization with microelements. Microelements have a positive effect on nutrients taken up by plants, they enhance physiological processes and determine the quantity and quality of yield. Prusiński and Borowska (2003), however, draw attention to failures in foliar application of microelements in legumes, since costs of such treatment do not always compensate the subsequent slight increase in the seed yield. Semida et al. (2014) also report on a possibility of foliar application of other substances, e.g. α-tocopherol (αTOC), which affect plant metabolism and plays an essential role in smoothing biotic and abiotic stresses.

The leaves greenness index (SPAD) is used to diagnose the state of plant nutrition and to determine the fertilization requirements. Based on this measurement, one may assess the chlorophyll content in leaves, which consequently allows determination of proper doses of fertilizers (Machul 2001).

The aim of this study was to estimate the effect of foliar fertilization on the state of plant nutrition and the faba bean seed quality. In the working hypothesis it was assumed that the applied fertilizer would increase the chlorophyll content in leaves and differentiate the quality of faba bean seeds.
The experiment was conducted within the framework of our own research project grant obtained from the National Centre of Science, no. 030/B/P01/2011/40, N N310 003040.

MATERIALS AND METHODS

A controlled field experiment was carried out at the Experimental Station of Varietal Assessment in Przecław (50°11′ N, 21°29′ E, altitude of 185 m ASL) in 2011 - 2013. The experimental factors were: foliar fertilization (Basfoliar 6-12-6) and the control, and two cultivars: Amulet (traditional, low-tannin) and Granit (self-completing, high-tannin). The seed material originated from the company Plant Breeding Strzelce, IHAR Group. The experiment was conducted in medium-rich soil of very good wheat complex. The soil showed slightly acid reaction. The abundance of assimilable phosphorus and potassium was moderate and that of magnesium was high or very high. The content of microelements was medium or high. The analysis of a soil sample was made at the Regional Chemical and Agricultural Station in Rzeszów.

Agricultural treatments were performer according to the guidelines for faba bean cultivation and in accordance with the COBORU methodology. Potassium and phosphorus fertilization was applied in the autumn, in the form of granulated triple superphosphate and potash salt at doses of 30.52 kg ha^{-1} P and 99.6 kg ha^{-1} K. Ammonium nitrate 34% was used for the initial fertilization with nitrogen. Foliar fertilization with the fertilizer Basfoliar 6-12-6 was performed at the budding stage (BBCH 55) and after flowering (BBCH 69); each dose amounting to 10 dm^3 ha^{-1}. The amount of working fluid was 300 dm^3 ha^{-1}. The chemical composition of the foliar fertilizer is presented in Table 1.

Table 1

Chemical composition of the fertilizer - Basfoliar 6-12-6

Nutrients	Content (% by volume)	Content (% by weight)	Content (g dm^3)
N	7.200	6.000	72.00
P	6.278	7.969	62.78
K	5.976	4.980	59.76
Mg	0.007	0.006	0.072
Mn	0.012	0.010	0.120
Cu	0.012	0.010	0.120
Fe	0.012	0.010	0.120
B	0.012	0.010	0.120
Zn	0.060	0.050	0.600
Mo	0.005	0.005	0.060

Linurex 500 SC was applied immediately after sowing to control weeds. The secondary weed infestation was eliminated manually. The preparation Rovral Aquaflo 500SC (1.5 kg ha^{-1}) was used twice to prevent faba bean diseases. Pests were controlled twice using Karate Zone 050EC (0.15 dm^3 ha^{-1}) and once using the preparation Pirimor 500WG (0.3 kg ha^{-1}).

The weather conditions were changeable in the years of the study, which modified the course of plant growing and faba bean yielding. In March 2013, subzero mean monthly air temperature and intensive precipitation (including snow) were recorded, which delayed faba bean sowing until the 10th -20th April. In turn, in July 2011 and in May and June 2013, intensive rainfalls occurred. The warmest months throughout the study were August in 2011 and July in 2012 and 2013. The weather conditions data were derived from the records of the Experimental Station of Cultivar Assessment in Przecław.

Chlorophyll content in leaves was evaluated using the SPAD index on the scale from 0-99 (chlorophyll gauge SPAD 502P). Measurements were made on 30 top leaves in the phase of the first flat pod (BBCH 70) on each plot.

The basic chemical composition of the seeds (total protein, raw fat, ash and fibre) was determined using the apparatus Spektrometr FT, NIR MPA from Bruker. Macroelements and microelements were determined in the Laboratory of the Biological and Agricultural Faculty of the University of Rzeszów. Determinations of the contents of particular elements were performed using a flame absorption spectrophotometer Hitachi Z-2000 with the calibration curve method. For determination of Ca, Mg and K, an addition of lanthanum was applied (to a concentration of 0.1% in the solution).

Significance of differences between the values of analyzed parameters was evaluated with the Tukey's confidence half-intervals, at the significance level $\alpha = 0.05$. Calculations were made using the statistic software FR-ANALWAR-5.3.FR.

RESULTS AND DISCUSSION

The state of plant nutrition on the treatment with foliar fertilization was better as compared with the control. However, the obtained differences in SPAD units were not confirmed statistically (Figure 1). The SPAD index me-

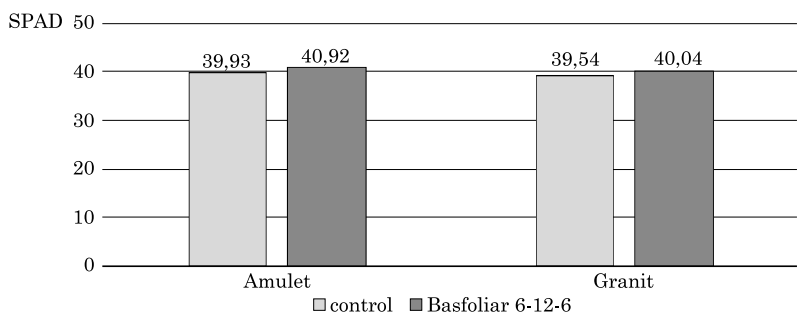

Fig.1. Influence of foliar fertilization on the SPAD index (non-significant differences)

asured at the first flat pod stage amounted on average to 40 units. Prusiński et al. (2008) reported that different doses and forms of mineral nitrogen applied in faba bean cultivation did not significantly modify chlorophyll content in the leaves. In the experiment conducted by those authors, a measurement of SPAD index made at the end of plant flowering stage amounted to 45 units. According to Prusiński (2007*a*), in faba bean the factor differentiating the chlorophyll content is primarily the plant developmental stage. Księżak (2007) observes that the greatest accumulation of nitrogen in faba bean plants occurs from the end of flowering to the pod maturity. Additionally, he confirmed that nitrogen accumulation in plants was varied in cultivars.

Kocoń (2010) explains that it is more beneficial to supply nitrogen to faba bean plants in the form of foliar fertilization than to the soil. Urea used in this form effects the increase in photosynthesis intensity, and this in turn results in higher nitrogen accumulation. Neuhaus et al. (2014) indicated that foliar fertilization of faba bean plants with magnesium resulted in a higher chlorophyll concentration in leaves. As a result, the intensity of photosynthesis was enhanced and consequently, the supply of assimilates increased.

Foliar fertilization effected a significant rise in raw fat content in seeds of the cultivar Amulet. This relationship was not confirmed for the cultivar Granit.

Seeds of the cultivar Amulet contained significantly more total protein, ash and fibre but less raw fat than seeds of the cultivar Granit (Table 2).

Table 2

Content of the components in seeds of faba bean (g kg^{-1} d.m.)

Component	Cultivar (B)	Foliar fertilization (A)		Mean for B
		Basfoliar 6-12-6	control	
Total protein	Amulet	298.9	299.1	299.0
	Granit	284.5	284.9	284.7
	mean for A	291.7	292.0	291.9
	$LSD_{0.05}$ for A – n.s., for B – 3.65, for AxB – n.s.			
Crude fat	Amulet	10.2	8.4	9.3
	Granit	12.0	13.0	12.5
	mean for A	11.1	10.7	10.9
	$LSD_{0.05}$ for A – n.s., for B – 2.33, for AxB – 2.63			
Ash	Amulet	32.5	32.3	32.4
	Granit	29.3	29.2	29.3
	mean for A	30.9	30.8	30.9
	$LSD_{0.05}$ for A – n.s., for B – 2.89, for AxB – n.s.			
Fiber	Amulet	69.8	66.0	67.9
	Granit	64.5	64.0	64.3
	mean for A	67.2	65.0	66.1
	$LSD_{0.05}$ for A – n.s., for B – 3.04, for AxB – n.s.			

n.s. – non-significant differences

The experiment on the chemical composition of faba bean seeds conducted by Szpunar-Krok et al. (2009) indicated that the studied cultivars did not differ significantly in the content of protein, fat or ash. The above authors claimed that the seed yield of mixtures of naked oats with faba bean was balanced better in respect of nutrition than monoculture crops. Also Kulig et al. (2009) did not prove intervarietal differences in protein content in faba bean seeds. The mean protein content in their experiment stayed within the range 312 - 343 g kg^{-1} of seeds. Thus, they were higher values than those obtained in the present study. Stępnik and Lepiarczyk (2009) reported that the protein content in faba bean seeds was significantly modified by the climatic conditions. This is also confirmed by Musallam et al. (2004), who claim that an increase in the content of protein, ash and fibre in faba bean seeds is significantly affected by plant irrigation. In turn Alghamdi (2009) obtained a significantly higher protein content in faba bean seeds in conditions of water stress. Apart from that, he confirmed significant varietal differentiation in the chemical composition of faba bean.

El-Fouly et al. (1990) indicated benefits from the combined application of nitrogen (Urea) with microelements. In such cases, the use of applied mineral elements by plants increases.

In our study, foliar fertilization resulted in a significant increase in potassium content in seeds, as compared with the control. The foliar fertilizer also increased the concentrations of the other determined macroelements in seeds, but this was not confirmed statistically (Table 3).

Table 3

Content of macroelements in seeds of faba bean (g kg^{-1})

Component	Cultivar (B)	Foliar fertilization (A)		Mean for B
		Basfoliar 6-12-6	control	
P	Amulet	6.38	6.39	6.39
	Granit	6.59	6.51	6.55
	mean for A	6.49	6.45	6.47
	$LSD_{0.05}$ for A – n.s., for B – 0.145, for AxB – n.s.			
K	Amulet	11,0	10.3	10.6
	Granit	10.8	10.7	10.7
	mean for A	10.9	10.5	10.7
	$LSD_{0.05}$ for A – 0.36, for B – n.s., for AxB – n.s.			
Mg	Amulet	1.19	1.19	1.19
	Granit	1.09	1.01	1.05
	mean for A	1.14	1.10	1.12
	$LSD_{0.05}$ for A – n.s., for B – 0.115, for AxB – n.s.			
Ca	Amulet	0.69	0.68	0.69
	Granit	0.66	0.63	0.65
	mean for A	0.68	0.66	0.67
	$LSD_{0.05}$ for A – n.s., for B – n.s., for AxB – n.s.			

n.s. – non-significant differences

Seeds of the cultivar Amulet contained more manganese whereas seeds of the cultivar Granit contained more phosphorus. The calcium content was not modified by the experimental factors. Szpunar-Krok et al. (2009) did not confirm varietal differentiation in the content of macroelements in faba bean seeds. However, they determined similar mean contents of microelements (P, K, Mg) and a higher content of calcium (Ca). Neuhaus et al. (2014) proved that foliar fertilization with magnesium did not modify the content of this element in seeds, but it had a beneficial effect on the protein concentration.

The copper content in seeds was not dependent on the experimental factors (fertilization and cultivars). Foliar application of fertilizers resulted in an increase in the zinc content in seeds as compared with the control. Seeds of the cultivar Amulet contained more iron and manganese than those of the cultivar Granit (Table 4). Szpunar-Krok et al. (2009) obtained a higher con-

Table 4

Content of microelements in seeds of faba bean (mg kg^{-1})

Component	Cultivar (B)	Foliar fertilization (A)		Mean for B
		Basfoliar 6-12-6	control	
Fe	Amulet	41.5	40.0	40.8
	Granit	38.4	36.9	37.6
	mean for A	39.9	38.5	39.2
	$LSD_{0.05}$ for A – n.s., for B – 2.57, for AxB – n.s.			
Cu	Amulet	12.9	12.5	12.7
	Granit	13.5	13.2	13.3
	mean for A	13.2	12.9	13.0
	$LSD_{0.05}$ for A – n.s., for B – n.s., for AxB – n.s.			
Mn	Amulet	17.1	16.9	17,0
	Granit	16.1	15.9	16,0
	mean for A	16.6	16.4	16.5
	$LSD_{0.05}$ for A – n.s., for B – 0.96, for AxB – n.s.			
Zn	Amulet	31.5	30.9	31.2
	Granit	32.5	30.2	31.4
	mean for A	32.0	30.6	31.3
	$LSD_{0.05}$ for A – 1.32, for B – n.s., for AxB – n.s.			

n.s. – non-significant differences

tent of iron, manganese and zinc and a lower content of copper in faba bean seeds. Nevertheless, they did not indicate varietal differences in the content of microelements in seeds. El-Gizawy and Mehasen (2009) point up a crucial role of microelements in increasing both quantity and quality of faba bean seed yield. El-Fouly et al. (2010) add that foliar fertilization with microelements may eliminate the negative effect of soil salinity on the uptake of nutrients. They suggest that the foliar application of microelements may be recommended for improvement of plant tolerance to salinity.

CONCLUSIONS

1. The state of plant nutrition, evaluated with the SPAD index, was not significantly dependent on foliar fertilization.

2. Foliar fertilizer effected a significant increase in the raw fat content in seeds, but only in the cultivar Amulet.

3. Foliar fertilization resulted in a significant increase in the potassium (K) and zinc (Zn) content in seeds in comparison with seeds harvested from the control object.

4. Seeds of the cultivar Amulet contained more total protein, ash, fibre, magnesium, iron and manganese but less raw fat and phosphorus than seeds of the cultivar Granit.

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