AGRONOMY SCIENCE
wcześniej – formerly
Annales UMCS sectio E Agricultura

VOL. LXXIV (4) 2019

 http://dx.doi.org/10.24326/as.2019.4.2

[1]Department of Field Crops College of Agriculture, Al-Muthanna University, Iraq
[2]Department of Plant Protection, College of Agriculture, Misan University, Iraq
[3]Department of Plant Production Technology and Commodities Science,
University of Life Science in Lublin, Poland
e-mail: barbara.sawicka@up.lublin.pl

ALI HULAIL NOAEMA[1], ALI RAHEEM KAREEM ALHASANY[1],
DHURGAM SABEEH KAREEM ALTAI[2], BARBARA SAWICKA[3]

Effect of nano-boron spraying on the concentration of some nutrients in leaves and dry matter of two *Vicia faba* L. (Partim) cultivars

Wpływ stosowania nanoboru na stężenie niektórych składników pokarmowych w liściach i na zawartość suchej masy dwóch odmian *Vicia faba* L. (Partim)

Summary. The aim of this study was to determine the effect of spraying the nano-boron on the concentration of certain nutrients, chlorophyll in the leaves and dry matter of plants of two faba bean cultivars. The field experiment was carried out in one of the agricultural fields of Al-Muthanna Governorate in Iraq (30°12'N, 45°21'E) during the seasons 2016/2017–2018/2019. The experiment was carried out in a dependent, split-plot system, in triplicate, where the first-order factors were cultivars (‘Aquadlegi’, ‘Aquadols’), and the second-order factor was boron fertilization (5, 10 mg·dm^{-3} and control object without boron fertilization). Foliar fertilization with boron at a concentration of 10 mg·dm^{-3} increased the content of nitrogen, phosphorus, boron and chlorophyll in faba bean leaves and dry matter content of plants, as compared to the control object. The chlorophyll content in faba bean leaves was significantly increased only after using a double concentration of nano-boron in the sprayed solution compared to the control object. The ‘Aquadols’ cultivar was characterized by higher content of dry matter, nitrogen and chlorophyll in the leaves than the ‘Aquadlegi’ cultivar. Depending on results, we can recommend applying a twice supplementation of faba bean with nano-boron fertilizer at a concentration of 10 mg·dm^{-3} in a broad agricultural practice.

Key words: faba bean, nano-fertilizers, nutrients, chlorophyll, dry mass, cultivars

INTRODUCTION

Vicia faba L. is one of the most important legume species in the world. This is important, because its seeds have high protein content (28–38%), carbohydrates (40–46%), and they are important source of minerals, vitamins and fiber [Khalil et al. 2015]. Bean cultivation also contributes to the improvement of physical and chemical properties of soil due to its important role in stabilizing the atmospheric nitrogen, because its roots contain root warts that coexist with *Rhizobium* bacteria [Abbas 2012]. Nanotechnology is one of the recent applications that contribute to the increase in agricultural production on a large scale, it's one of the promising technologies in improving the quantity and quality of production as it helps to increase the absorption of water and nutrients , which contribute to improve the growth and increase plant's productivity [Ramadi et al. 2016]. In addition, the applications of nanotechnology in the agriculture contribute to reduce the economic cost by increasing the efficiency of fertilizers with low-cost material in addition to the resistance of the product to various environmental conditions [Singh and Prasad 2017]. Spraying of nutrients on the leaves is a positive fertilization method with the macro and micronutrients, in addition to being economical, easy and fast response of plant's ability to its nutrient requirements during different growth stages [Ali et al. 2014, Salem et al. 2014]. Foliar fertilization makes it possible to supplement nutrients during their greatest nutritional demand [Ramadi et al. 2016]. During the growing season, the nutritional status of plants can be assessed on the basis of the chlorophyll content in leaves, as well as using a chlorophyll meter. Obtained in this way, the so-called the green leaf indicator (SPAD) allows to determine the optimal doses of fertilization in order to increase or improve the quality characteristics of a crop. The role of boron is important in the creation of various molecular and condensed phases. Understanding the diversity of boron structures decreases the electronic structure of the isolated boron atom. In multi-atom networks, the addition of an electron first comes in an energetically more favorable configuration, which then goes to the most stable state. Therefore, the boron is clearly different from the acceptor and, however, the boron's elemental structures must be electron deficient. This is the reason why all forms of boron, both molecular and condensed phases, show very complex, focused structures. The B12 icosahedron with 12 boron atoms at the apex serves as the main structural unit. Because carbon nanosystems have been discovered, it has aroused interest in other materials, including boron itself, which may also exhibit nanostructures. Boron is a natural choice for the construction of nanosystems, e.g. nanowires, nanotubes, etc. The boron atom of a given icosahedron is bound to neighboring atoms and is usually connected to an atom from an adjacent icosahedron. This fact explains why the average number of atomic sites is high. Therefore, elemental boron has a lot of nanostructures and forms that can find applications in many techniques and technologies, among others, it is used as a fertilizer [Chkhartishvili 2011, Davarpanah et al. 2016]. Boron is one of the essential elements, which plays an important role in the process of the stage of holding fruits by stimulating many of the phylogenetic processes in plant growth and flowering stages, which helps growth the pollen tube, germinate the pollen and increase the fertilization [Shireen et al. 2018]. As the basis of the expansion and cultivation of faba bean and raise productivity is cultivation of high-yielding cultivars and the use of field methods with effective impact, this paper upon nutrition and knowledge of the ability of the class to absorb nutrients to obtain the potential energies is necessary, along with the knowledge about the extent of response of cultivars and adapting to local conditions [Hassani 2018]. The aim of this study was to determine the effect of nano-boron spraying on the concentration of certain nutrients in the leaves, chlorophyll in the leaves and dry matter of the plants of two faba bean cultivars.

MATERIALS AND METHODS

The field experiment was carried out in the agricultural field of Al-Muthanna Governorate (30°12'N, 45°21'E) during the agricultural season in the years 2016–2019 (Fig. 1).

Fig. 1. Governor Muthanna, Al Muthanna Province
Source: Governor Muthanna [2019]

The experiment was carried out in a dependent, split-plot system, in triplicate, where the first-order factors were early cultivars (‘Aquadlegi’, ‘Aquadols’), and the second-order factor was boron fertilization (5 mg·dm^{-3}, 10 mg·dm^{-3} and control object without boron fertilization). Nano Chelated Boron Fertilizer – is a fertilizer containing 9% chelated boron and absorbed at pH 3–11, completely soluble in water, synthesized by “advanced chelate technology”. Increasing the transfer of materials produced in photosynthesis to the place of consumption. It prevents pods from falling and increases their production. This nano-fertilizer was used as recommended by the manufacturer and experts when boron deficiency is observed in the plant.

The process of tillage and levelling was carried out. The experimental field was planned according to the design used, and then the soil of experiment was irrigated prior to the planting date for the purpose of calibration and to determine the level of seeds on the plot and the planting process was done after the seeds were soaked in water and planted on 16.10.2016, 18.10.2017 and 15.10.2018 [Gasim et al. 2015]. The field was divided into three replicates, leaving a distance of 1 m between each replication and another between experimental units. The experimental unit size was 2 × 3 m. Each experimental unit consisted of 4 furrows. The distance between furrows was 75 cm. Seeds of faba bean were planted at 20 cm between plants by placing two seeds in the hole and then making the seed thinning to one plant when the plant height reached 10–15 cm.

The plant was fertilized with nitrogen of 60 kg N · ha^{-1} (urea 46% N) twice: 15 days after planting and the second, one month after the first batch and the phosphate fertilization was 80 kg P_20_5 · ha^{-1} in the form of superphosphate fertilizer (21% P) in one batch before planting. Potassium fertilizer at 80 kg K_2O in the form of potassium sulfate 42% K – one batch before planting [Al-Rawi and Allah 2000, Abedi 2011]. Care and protection of plants was carried out as needed, and the harvest was completed in the last decade of March each year. The spraying of nano-boron was done twice. Foliar fertilizers were used in accordance with the recommendation of the producer: 2 times starting from the phase BBCH 39 (crop cover complete: about 90% of plants meet between rows) to BBCH 71 (75% of in the first fructification have reached full size (main stem). One spray was used 10 or 20 dm^3 · ha^{-1} NanoBoron, with a tank capacity of 400 dm^3 water · ha^{-1}. Clean water (400 dm^3 water · ha^{-1} water) was used in the control object without fertilization [Meier 2001].

The leaf greenness index (SPAD) is used to diagnose the nutritional status of plants and determine fertilizer requirements. Based on this measurement, it is possible to allow an assessment of the chlorophyll content in the leaves, which in turn enables the determination of the correct doses of fertilizers [Machul 2001]. Chlorophyll content in leaves was evaluated using the SPAD index on the scale 0–99 (chlorophyll gauge SPAD 502P). Measurements were made on 30 top leaves in the phase of the first flat pod (BBCH 71) on each plot.

During plant vegetation from each plot, leaves samples were taken for chemical analysis. The dry matter content of leaves was determined by a drying-weight method. Before determining the dry matter, the leaves were washed in cold water and dried at ambient temperature. The analyses were carried out in three replications for each sample. The Petri dishes were dried at 105°C for about 2 h and then weighed to the nearest 0.001 g. Next, the ground material of the plant was out on Petri dishes, weighed and placed in a laboratory dryer, first at 60°C for 12 h, and then for 2 h at 105°C. Petri dishes with dry plant mass were then placed in a desiccator, cooled and then weighed. When the difference between two successive weights did not exceed 0.001 g, the result was recorded. The obtained sample was the basis for calculating the dry matter content. The content of dry matter in the test sample was calculated according to the formula:

$$\%DM = 100\frac{c - a}{b - a}$$

where: a − weight of Petri dish, b − weight of Petri dish with the plant material, c − weight of Petri dish with the plant material after drying at 105°C [Rutkowska and Budzyńska-Topolowska 1981].

In the dry matter of faba bean leaves, the contents of the following elements were determined: total nitrogen was determined according to the Kjeldahl method (method accredited for food products), which consists in treating the sample with sulfuric acid in the presence of a catalyst. Then the acid solution is alkalized with sodium hydroxide, the ammonia distilled from the alkaline solution is collected in a known amount of sulfuric acid solution, the excess of which is titrated with a solution of sodium hydroxide. The total protein content is converted from nitrogen by multiplying the nitrogen content by 6.25 [Krełowska-Kułas 2003]; phosphorus was determined by spectrophotometric method [Krełowska-Kułas 2003]; the content of boron was determined by using ASA – atomic absorption spectrometry [Moon et al. 1996]. All chemical analyses were carried out at the Al-Muthann University Laboratory.

The statistical analysis of the obtained results was performed using the SAS statistical package v.9.2. Statistical analyses were based on the model of analysis of variance (ANOVA) and Tukey's multiple tests (or confidence interval) at the assumed significance level of 0.05. The analysis concerned mainly the effects of cultivars and spraying with nano-boron on the tested variables, and the years had the role of the controlled replication agent. The statistical averages were compared according to the LSD test under the probability level of 5% [SAS 2008].

In October–December period, faba bean was poorly supplied with water. In 3 months, 280.2 to 298.7 mm of rainfall decreased, with average air temperature in this period from 5.6 to 20.7°C. January–March, faba bean was better stocked with water. In 3 months, 348 to 368.1 mm of rainfall decreased, with average air temperature in this period from 12.0°C in January to 20.9°C in March. This weather course provided good conditions for the development of faba bean (Fig. 2).

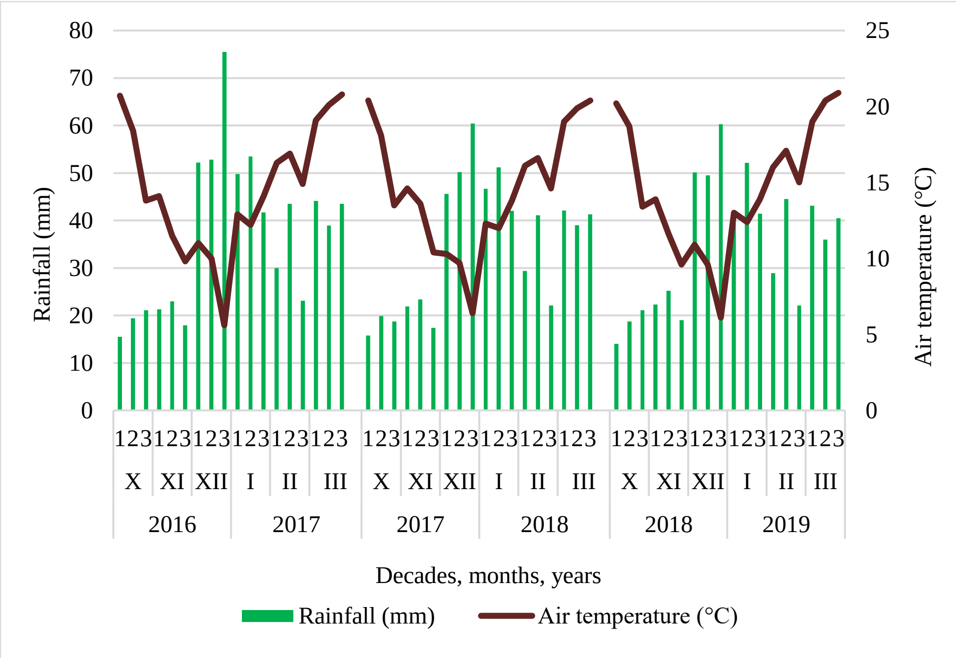

Fig. 2. Rainfall and air temperature during the growing season of faba bean, according to the meteorological station in Al-Muthanna

RESULTS AND DISCUSSION

Soil conditions

Results of soil granulometric analysis and some physicochemical properties are presented in Table 1. The experiment was carried out on silty clay loam soil type [WRB 2014]. According to percentage content of sand, silt and loam fraction, this is a granulometric subgroup – silty clay loam. Soil granulometric composition was determined by means of the aerometric method according to Prószynski [Ryżak et al. 2009]. The fraction of sand was 19.37%, the dust fraction was 45.67% and the loam was 34.96% (Tab. 1). This soil is classified to agronomic category as mineral. The agronomic category of soils was medium to heavy [WRB 2014].

Table 1. Granulometric composition of soil

Season	Composition content of the granulometric fractions (%)									Soil classification
	sand					silt			loam	
	mm									
	2.0–1.0	1.0–0.5	0.5–0.25	0.25–0.10	0.10–0.05	0.05–0.02	0.02–0.005	0.005–0.002	<0.002	
2016/2017	0.98	1.45	3.96	6.98	7.11	15.02	16.68	14.75	33.07	Silty clay loam
2017/2018	0.94	1.49	3.79	7.06	6.17	15.13	16.63	14.01	34.78	Silty clay loam
2018/2019	0.87	1.56	3.54	7.00	5.21	15.29	16.54	12.96	37.03	Silty clay loam
Average	0.93	1.50	3.76	7.01	6.16	15.15	16.62	13.91	34.96	–

Source: Own experiment results, which made in agricultural field of Al-Muthanna Governorate

The soil resources in the available components was as follows: phosphorus was low (8.2 mg $P_2O_5 \cdot 100$ g^{-1} soil], magnesium and potassium – very high (7.60 mg Mg·100 g^{-1} and 161 mg $K_2O \cdot 100$ g^{-1} soil), copper – medium (8.02 mg Cu·kg^{-1} soil), manganese, iron and zinc also medium and was respectively 328 mg Mn · kg^{-1} of soil, 3858 mg Fe · kg^{-1} of soil, and zinc the average was 48.4 mg Zn · kg^{-1} of soil. In the case of boron, the average level was low, about 3.09 mg B · kg^{-1} of soil. The average acidity of the soil in a solution of KCl was 7.4 pH; these values allowed the classification of the experimental soil as alkaline (Tab. 2).

Table 2. Physical and chemical properties of soil in agricultural field of Al-Muthanna

Years	Content of assimilable macronutrients ($mg \cdot kg^{-1}$ soil)			pH (KCL)	Micronutrients content ($mg \cdot kg^{-1}$ soil)				
	P_2O_5	K_2O	Mg		Cu	Mn	Zn	Fe	B
2016/2017	86.0	1450	78.0	7.7	7.51	318	40.1	3791	3.25
2017/2018	84.0	1800	77.0	7.2	7.56	329	48.3	3863	3.07
2018/2019	77.0	1580	73.0	7.4	8.99	338	56.7	3920	2.95
Average	82.0	1610	7.6	7.4	8.02	328	48.4	3858	3.09

Source: Own experiment results obtained in the Laboratory the University of Al-Muthanna

Nitrogen concentration in plant leaves

The results in Table 3 showed significant increase in the concentration of nitrogen in leaves of the plant with the increase of the concentrations of nano-boron in the spray solution. Concentration of B_2 gave the highest mean of 44.50 g N · kg^{-1} while the control treatment B_0 gave a mean at 37.88 g N · kg^{-1}. This is probably due to the important role of boron: spraying plants with boron increases the nitrogen uptake and thus increases its concentration in plants [Bahkuni et al. 2010]. There while were no significant differences in the content of nitrogen in faba bean leaves between objects with different concentrations of nano-boron in the spray solution.

In the 'Aquadols' cultivar, significantly higher concentrations of nitrogen in faba bean leaves was recorded; with the highest mean of 45.71 g N · kg^{-1}, compared to the 'Aquadlegi' cultivar, which revealed the lowest average of nitrogen content (37.13 g N · kg^{-1}) (Tab. 3), which may be due to genetic differences between cultivars. These results differed with those reported by Khattab et al. [2016].

Table 3. Effect of spraying with nano-boron and cultivars and their interaction on the nitrogen concentration in plant leaves ($g \cdot kg^{-1}$)

Cultivar (C)	Nano-boron (B)**			Mean
	B_0	B_1	B_2	
'Aquadols'	42.13	45.87	48.93	45.71
'Aquadlegi'	33.63	37.70	40.07	37.13
Mean	37.98	41.79	44.50	41.42
$LSD_{0.05}$				
B		2.85		
C		1.42		
C × B		ns*		

*not significant at $p_{0.05}$; ** B_0 – control object without boron fertilization; B_1 – 5 $mg \cdot dm^{-3}$, B_2 – 10 $mg \cdot dm^{-3}$

Phosphorus concentration in plant leaves

Nano-boron spraying significantly increased the concentration of phosphorus in the leaves of the plant. The concentration of boron B_2 gave the highest mean of 5.08 g P · kg^{-1}, while the control object gave the lowest concentration of phosphorus in the plant leaves. Possibly, due to the increased concentration of nitrogen (Tab. 3), that stimulates and encourages the uptake of phosphorus plant roots by increasing their growth and then increasing the top of plant and their yield [Ali et al. 2014].

The results did not show any significant differences between cultivars and the interaction between spraying with nano-boron and cultivars regarding phosphorus concentration in plant leaves (Tab. 4).

Table 4. Effect of spraying with nano-boron and cultivars and their interaction on the phosphorus concentration in plant leaves ($g \cdot kg^{-1}$)

Cultivars (C)	Nano-boron (B)**			Mean
	B_0	B_1	B_2	
‘Aquadols’	3.50	4.10	4.83	4.14
‘Aquadlegi’	4.00	4.66	5.33	4.66
Mean	3.75	4.38	5.08	4.40
$LSD_{0.05}$				
B	0.14			
C	ns*			
C × B	ns			

*not significant at $p_{0.05}$; ** marks as in Table 3

Boron concentration in plant leaves

The results showed in Table 5 that there was a significant increase in the concentration of boron in the leaves of plant due to the nano-boron added to the spray solution. The highest applied concentration of boron (B_2) gave the highest mean of this feature – 70.90 mg B · kg^{-1} compared to control object (B_0) (59.50 mg B · kg^{-1}). The reason for the increased boron in plant leaves may be due to the increase in the amount of nano-boron in the spray solution and then increase in the amount absorbed by the plant, which led to increased concentration in the leaves, and this result was confirmed by the findings of Al-Hassani and Abbas [2018].

Table 5. Effect of spraying by nano-boron and cultivars and their interaction on the boron concentration in plant leaves ($mg \cdot kg^{-1}$)

Cultivars (C)	Nano-boron (B)**			Mean
	B_0	B_1	B_2	
‘Aquadols’	62.20	69.80	73.20	68.40
‘Aquadlegi’	56.80	59.60	68.60	61.70
Mean	59.50	64.70	70.90	65.05
$LSD_{0.05}$				
B	8.42			
C	ns*			
C × B	ns			

*not significant at p0.05; ** marks as in Table 3

The results did not show any significant differences between cultivars and the interaction between spraying with nano-boron and cultivars on the boron concentration in plant leaves (Tab. 5).

Chlorophyll content in plant leaves

Significant superiority of cultivar (‘Aquadols’) in the content of chlorophyll in the leaves, compared to the cultivar (‘Aquadlegi’) was shown (Tab. 6). This may be because cultivar ‘Aquadols’ was more responsive to the environmental conditions prevailing in the region, increasing the chlorophyll rate in the leaves. This results agreed with that recorded by Al-Tamimi et al. [2018].

Foliar fertilization with the nano-boron preparation resulted in a significant increase in the chlorophyll content in the in faba bean leaves only at a double dose of this fertilizer, compared to the control without of foliar fertilization (Tab. 6).

Table 6. Effect of spraying by nano-boron and cultivars and their interaction on chlorophyll content in plant leaves (SPAD)

Cultivars (C)	Nano-boron (B)**			Mean
	B_0	B_1	B_2	
‘Aquadols’	37.60	44.20	44.20	42.00
‘Aquadlegi’	35.90	35.50	38.10	36.50
Mean	36.70	39.90	41.20	
$LSD_{0.05}$				
B	4.40			
C	2.90			
C × B	ns*			

*not significant at $p_{0.05}$; ** marks as in Table 3

Patrick and Stoddard [2010] proved that the development of leaves, flowers, and then seeds, are key processes in the creation of faba bean yield. The faba bean winter form have generally required for vernalization, allowing flowering in the lower node than in non-grown plants. This is due to the fact that some germplasm is neutral during the day, and another germplasm is long-term with a day length of 9.5 to 12 h. Progress in flowering is consistent with the conventional thermal time model, from 830–1000°C above 0°C – required to start flowering and an optimal temperature of around 22–23°C. Flowers can detach from the plant due to lack of pollination because proximal flowers on the same group they are fertilized due to vegetative and reproductive rivalry for assimilation or because of stress such as drought. In turn, Khazaei et al. [2018] found that horse bean is considered to be relatively sensitive, among legumes, to drought stress. The amount of epicuticular wax (ECW) is considered an important strategy for drought adaptation in this species, which has a relationship between ECW and stomata apparatus. The authors demonstrated significant differences in ECW concentration, ranging from 0.680

to 2.104 mg · dm^{-3}. However, they did not find a relationship between ECW and any measure of morphology and function of the stomata due to the high variability of ECW in faba bean germplasm, which is independent of stomatal traits and water content in the leaves.

Dry weight of the plant

It was shown that dry weight of the plant increased significantly with each increase in the concentration of nano-boron in the spray solution (Tab. 7). Increased dry weight of plant may be due to increasing the concentrations of nitrogen (Tab. 3), phosphorus (Tab. 4) and boron (Tab. 5) in plant leaves, which positively reflected on the dry weight of plant. These results were consistent with those reported by Alag et al. [2015]. Davar-Panah et al. [2016] proved that the highest fertilization with nano-boron at two doses led to a significant improvement in fruit quality, including TSS, a decrease in TA and an increase in the ripeness index and pH of the juice. Physical characteristics of seeds and fruits did not change, however, and the antioxidant activity was unchanged.

'Aquadols' cultivar was significantly superior in terms of dry weight content in plants and it gave an average of 36.06 g · plant^{-1} in comparison to the 'Aquadlegi' cultivar, which gave the lowest value (31.56 g · plant^{-1}) (Tab. 7).

Table 7. Effect of spraying with nano-boron and cultivars and their interaction on dry weight of the plant (g)

Cultivars (C)	Nano-boron (B)**			Mean
	B_0	B_1	B_2	
'Aquadols'	32.17	36.33	39.67	36.06
'Aquadlegi'	27.67	32.01	35.01	31.56
Mean	29.92	34.17	37.34	–
LSD $_{0.05}$				
B	3.68			
C	2.45			
C × B	ns*			

*not significant at $p_{0.05}$; ** marks as in Table 3

The reason for this may be due to the fact that the distribution of dry matter in plants is influenced by environmental and genetic factors, in addition to the ability of the 'Aquadols' genetic cultivar to exploit the environmental factors in increasing the accumulation of dry matter in plant tissues, which contributed to the increase in dry weight of plants. This results were different from those found by Hussein and Obaid [2013] and Jasim and Obaid [2014], who showed no significant increase in the dry weight of the plant among the cultivars of faba bean under the influence of boron fertilization. Jarecki et al. [2016] believe, that due to the fine grinding grinding of "nano" fertilizers and the activation of food nanoparticles, they provide extremely easily and quickly absorbable nutrients, comprehensively feed plants, stimulate them to grow and improve their vitality, immunize crop plants for stress associated with drought, frost and disease.

CONCLUSIONS

1. Foliar fertilization with boron at a concentration of 10 mg·dm^{-3} increased the content of nitrogen, phosphorus, boron and chlorophyll in faba bean leaves and the dry matter content of plants, as compared to the control object. The chlorophyll content in faba bean leaves was significantly increased only after using a double concentration of nano-boron in the sprayed solution compared to the control object.

2. 'Aquadols' cultivar was superior in the leaf content of nitrogen, chlorophyll content and dry weight of the plant.

3. There was no significant effect of the interaction of cultivars and foliar fertilization with nano-boron fertilizer in relation to any of the studied traits.

4. It may be recommended to supplement the faba bean plant twice with nano-boron fertilizer at a concentration of 10 mg·dm^{-3} in broad agricultural practice.

REFERENCES

Abbas S.H., 2012. Analysis of the performance of genetic structure traits in the rest under the influence of different levels of fertilization NPK. Kufa J. Agric. Sci. 4(2), 13–21.

Abedi J.A., 2011. Directory of Chemical and Organic Fertilizers in Iraq. Plant Agron. 38(1), 1–21.

Alag M.K., Mubarak M., Abdul-Razak A., Ahmed S.A.H., Hamzah I.A., 2015. Effect of spraying Benzyl adenine (BA), Zinc and Boron on yield and components of faba bean. J. Center Biotechnol. Res. 9(1), 67–76 [in Arabic].

Ali N.S., Rahi H.S., Shaker A.A., 2014. Soil fertility. Scientific Book House. College of Agriculture, University of Baghdad, pp. 88.

Al-Hassani R., Abbas H., 2018. Synthesis, Characterization and Biological Activities of New Azo Dyes – Azomethine Compound and Their Metal Complexes. J. Glob. Pharma Technol. 289–301.

Al-Rawi K.M., Allah K.A.M., 2000. Design and analysis of agricultural experiments. Dar Al Kutub, Printing & Publishing Est. University of Al Mosul, Ministry of Higher Education and Scientific Research, The Republic of Iraq, 7–13.

Al-Tamimi B.H., Jabbar I.I., Al-Tamimi H.M., 2019. Synthesis and characterization of nanocrystalline diamond from graphite flakes via a cavitation-promoted process. Heliyon 5, e01682.

Bahkuni G., Khurana N., Chatterjee C., 2010. Impact of boron deficiency on changes in biochemical attributes, yield and seed reserves in Chickpea. Commun. Soil Sci. Plant Anal. Book Abstract 42(2), 199–206.

Chkhartishvili L., 2011. Nanoboron (Overview). Nano Stud. 3, 227–314.

Davarpanah S., Tehranifar A., Davarynejad G., Abadía J., Khorasani R., 2016. The influence of foliar and boron nano fertilizers on pomegranate fruit (*Punica granatum* cv. Ardestani) fruit yield and quality. Sci. Hortic. 210, 57–64.

Gasim S., Hamad S.A.A., Abdelmula A., Ahmed I.A.M., 2015. Performance and quality characteristics of inbred broad bean lines grown in marginal Sudan environmental conditions. Food Sci. Nutr. 3(6), 539–547, https://doi.org/10.1002/fsn3.245

Governor Muthanna, 2019. https://en.wikipedia.org/wiki/Muthanna_Governorate

Hassani A.R., 2018. Effect of spraying with bromine and a hormonal nutrient mixture on the growth and yield of *Vicia faba* L. varieties. Doctoral Thesis. Department of Field Crops Science. Faculty of Agriculture, Muthanna University, Iraq, pp. 98 [in Arabic].

Hussein J.A., Obaid A.S., 2013. The Effect of Spraying Some Paper Fertilizers and Their Interaction with Boron in the Concentration of Some Nutrients in Leaves of *Vicia faba* L. Al-Furat J. Agric. Sci. 4(5), 56–63 [in Arabic].

Jarecki W., Buczek J., Bobrecka-Jamro D., 2016. Influence of foliar fertilization on chlorophyll content in leaves and chemical composition of horse bean seeds (*Vicia faba* L. (Partim)). J. Elementol. 21(4), 1305–1313, https://doi.org/10,5601/jelem.2015.20.2.94

Jasim A.H., Obaid A.S., 2014. Effect of foliar fertilizers spray, boron and their interaction on broad bean (*Vicia faba* L.) yield. Sci. Pap., Ser. B, Hortic. 58, 271–276.

Khalil N.A., Metwally A.M., Magdy M.S., Morshedi O.A., 2015. Cereal crops and pulses. Faculty of Agriculture, Cairo University, pp. 186.

Khazaei H., Santanen A., Frederick KSL., Stoddard F.L., 2018. Genotype variability in the amount of broadleaf leaf wax in the germline collection of large horse bean (*Vicia faba* L.). Genet. Resour. Plants 17(03), 1–3, https://doi.org/10.1017/S1479262118000461

Khattab E.A., Badr E.A., Afifi M.H., 2016. Response of some varieties of faba bean (*Vicia faba* L.) to boron and potassium. Int. J. Chem. Tech. Res. 9, 98–103.

Krełowska-Kulas M., 1993. Badanie jakości produktów spożywczych [Quality assurance of food products]. PWE, Warszawa.

Machul M., 2001. Ocena stanu odżywienia roślin azotem przy użyciu rośliny testowej [Assessment of nutritional status of plants with nitrogen using a test plant]. Post. Nauk Rol. 3, 71–83.

Meier U. (ed.), 2001. Growth stages of mono- and dicotyledonous plants. BBCH Monograph. 2nd ed., Federal Biological Research Centre for Agriculture and Forestry, https://www.politicheagricole.it/flex/AppData/WebLive/Agrometeo/MIEPFY800/BBCHengl 2001.pdf

Moon C.S., Zhang Z.W., Shimbo S., Hokimoto S., Shimazaki K., Saito T., Shimizu A., Imai Y., Watanabe T., Ikeda M., 1996. A comparison of the food composition table-based estimates of dietary element intake with the values obtained by inductively coupled plasma atomic emission spectrometry: an experience in a Japanese population. J. Trace. Elem. Med. Biol. 10(4), 237–244.

Patrick J.W., Stoddard L.F., 2010. The physiology of flowering and filling horse bean seeds. Field Crops Res. 115(3), 234–242, https://doi.org/10.1016/j.fcr.2009.06.005

Ramadi R.H., Abdullah N.A.M., Shawl T.A., Al Saidi A.H., Al Sikhan M.S., Shalabi T.A., 2016. Botany and Environmental Nanotechnology. Faculty of Agriculture, Kafr El-Sheikh University, 1st ed. pp. 189 (in Arabic).

Rutkowska U., Budzyńska-Topolowska J., 1981. Wybrane metody badania składu i wartości odżywczej żywności [Selected methods of testing the composition and nutritional value of food]. PZWL, Warszawa, pp. 358.

Ryżak M., Bartmiński P., Bieganowski A., 2009. Methods for determination of particle size distribution of mineral soils. Acta Agrophys. 175, 1–97.

Salem A.K., El-Harty E.H., Ammar M.H., Alghamdi S.S., 2014. Evaluation of faba bean (*Vicia faba* L.) performance under various micronutrient foliar applications and plant spacing. Life Sci. J. 11(10), 1298–1304.

SAS, I.I. 2008. SAS/STAT®9.2. Users Guide.

Shireen F., Nawaz M.A., Chen C., Zhang Q., Zheng Z., Sohail H., Sun J., Cao H., Huang Y., Bie Z., 2018. Boron: Functions and Approaches to Enhance Its Availability in Plants for Sustainable Agriculture. Int. J. Mol. Sci. 19(7), 1856–1870.

Singh A., Prasad S.M., 2017. Nanotechnology and its role in agro-ecosystem: a strategic perspective. Int. J. Environ. Sci. Technol. 14(10), 2277–2300.

WRB, 2014. World reference base for soil resources 2014. International soil classification system for naming soils and creating legends for soil maps. Food and Agriculture Organization of the United Nations, Rome, 2015, http://www.fao.org/3/i3794en/I3794en.pdf

Financing source: Statutory research, funds obtained from the Ministry of Science and Higher Education

Streszczenie. Celem niniejszego badania było określenie wpływu opryskiwania nawozem dolistnym nanoboron na zawartość niektórych składników odżywczych i chlorofilu w liściach oraz suchej masy roślin dwóch odmian bobiku. Doświadczenie polowe przeprowadzono na jednym z pól uprawnych gubernatorstwa Al-Muthanna w Iraku (30°12'N, 45°21'E), w sezonach 2016/2017–2018/2019. Doświadczenie przeprowadzono w układzie zależnym, split-plot, w trzech powtórzeniach, gdzie czynnikiem pierwszego rzędu były odmiany (‘Aquadlegi’, ‘Aquadols’), a czynnik drugiego rzędu stanowiły nawożenie nawozem nanoboron – w stężeniu 5 i 10 $mg \cdot dm^{-3}$ oraz obiekt kontrolny bez nawożenia nawozem nanoboron. Dolistne nawożenie tym nawozem w stężeniu 10 $mg \cdot dm^{-3}$ zwiększyło zawartość azotu, fosforu, boru i chlorofilu w liściach bobiku oraz zawartość suchej masy roślin, w porównaniu z obiektem kontrolnym, bez nawożenia nawozem nanoboron. Zawartość chlorofilu w liściach bobiku zwiększyła się istotnie dopiero po zastosowaniu podwójnego stężenia nawozu nanoboron, w opryskiwanym roztworze, w porównaniu z obiektem kontrolnym. Odmiana ‘Aquadols’ charakteryzowała się wyższą zawartością suchej masy, azotu i chlorofilu w liściach niż odmiana ‘Aquadlegi’. Można zalecić zastosowanie w szerokiej praktyce rolniczej 2-krotny oprysk bobiku nawozem nanoboron w stężeniu 10 $mg \cdot dm^{-3}$.

Słowa kluczowe: bobik, nanonawozy, składniki odżywcze, chlorofil, sucha masa, odmiany

Received: 13.07.2019
Accepted: 9.12.2019