UDC 635.25:631.81.095.337

EFFECT OF BORON FOLIAR APPLICATION ON ONION YIELD

R. Rosa, PhD, D. Sc.
ORCID ID: 0000-0001-6344-538X
J. Franczuk, PhD, D. Sc.
ORCID ID: 0000-0002-8440-850X
A. Zaniewicz-Bajkowska, PhD, D. Sc., Prof. Tit. [1]
ORCID ID: 0000-0002-0317-8571
D. Słonecka, M. Sc.
ORCID ID:0000-0002-8696-2774
L. Hajko, M. Sc.
ORCID ID: 0000-0001-5293-8402
K. Remiszewski, M. Sc.
ORCID ID: 0000-0003-4294-3659
Siedlce University of Natural Sciences and Humanities, Poland
O. Dydiv, Cand. Sc.
ORCID ID: 0000-0003-4155-5945
Lviv National Agrarian University, Ukraine

https://doi.org/10.31734/agronomy2021.01.089

Роса Р., Франчук Ж., Заневич-Байковська А., Слонецька Д., Хайко Л., Ремішевський К., Дидів О. Виробничі ефекти використання бору при вирощуванні цибулі звичайної

Цибуля (*Allium cepa* L.), що належить до сімейства *Alliaceae,* є однією з найважливіших і найпопулярніших овочевих та пряних культур, вирощуваних у всьому світі. Правильне забезпечення рослин бором може сприятливо впливати на ріст і врожай цибулі, що надзвичайно важливо на ґрунтах, бідних на цей елемент. Брак бору спричинює багато анатомічних, фізіологічних та біологічних порушень у рослин. Це може призвести, серед іншого, до зупинки поділу клітин і, отже, пригнічення подовження коренів. Це дуже погано для цибулі, кореневої системи якої в будь-якому разі дуже багато, і водночас ця рослина потребує хорошого водопостачання.

Польовий експеримент був проведений у Центрально-Східній Польщі, за 85 км на схід від Варшави, на ґрунті лувісолу. Метою дослідження було визначити вплив різних доз бору, що надходять у вигляді позакореневої аплікації нітрату кальцію з бором (8,5 N-NO3, 17 CaO, 0,05 B), на вихід та вміст сухої речовини і цукор у цибулі. Бор застосовували один, два або три рази на стадіях розвитку цибулі BBCH 16, BBCH 17 та BBCH 41-45. Застосовувані дози бору становили 2,2, 4,5 та 6,7 г • га$^{-1}$.

Застосування бору сприяло збільшенню врожаю цибулі. Ефект урожайності був особливо помітний у 2019 році, він характеризувався гіршими умовами вологості з 2020 року. Застосування бору сприяло збільшенню врожаю цибулі. Найкращий урожайний ефект отримали після трьох застосувань бору в загальній дозі 6,7 г • га$^{-1}$. Комерційний урожай цибулі на цьому об'єкті становив 72,5 т • га$^{-1}$ (у середньому за роки досліджень) і був значно вищим, ніж у контролі, а також після одноразового внесення бору. Разом із збільшенням дози бору пропорційно зросла частка товарного врожаю цибулі в загальному врожаї, але вміст сухої речовини в цибулі зменшувався. Однак позакореневе підживлення бором не змінило загального вмісту цукру.

Ключові слова: *Allium cepa* L., бор, позакореневе підживлення, урожайність, суха маса, загальний цукор.

Rosa R., Franczuk J., Zaniewicz-Bajkowska A., Słonecka D., Hajko L., Remiszewski K., Dydiv O. Effect of boron foliar application on onion yield

A member of the *Alliaceae* family, onion (*Allium cepa* L.) is one of the most important and popular vegetable and spice crops grown worldwide. Boron is one of the most important micronutrients necessary for cell division, nitrogen and carbohydrate metabolism and water balance in plants. A sufficient supply of boron, especially to soils poor in this element, can be beneficial for plants growth and the yield. Boron deficiency causes many anatomical, physiological and biological disorders in plants. Its shortage can, among others, stop cell division and, consequently, inhibit root elongation. This affects the growth of onion, the root system of which is very shallow and poorly developed so this plant needs an adequate water supply. Large deficiencies of boron cause that the tip of the roots may even wither away and die. The field experiment was carried out in east-central Poland, 85 km east of Warsaw, on Luvisol soil. The purpose of the research was to study the effect of foliar application of different doses of boron on the yield of onion and its dry matter and sugar content. Boron was applied one, two or three times in 2.2, 4.5 and 6.7 g ha^{-1} doses at the onion development stages of BBCH 16, BBCH 17 and

BBCH 41–45. The use of boron affected the onion yield. The effect was particularly visible in 2019, which was characterized by worse humidity conditions than 2020. The highest yield was recorded when boron was applied three times, at a total dose of 6.7 g ha^{-1}. The marketable onion yield in that plot was 72.5 t ha^{-1}, and was significantly higher than in control or after a single boron application. As the dose increased, the share of the marketable onion yield to the total yield increased proportionally, but dry matter content decreased. On the other hand, foliar boron treatment did not change total sugar content. Foliar treatment of onion with calcium nitrate containing boron contributed to an increase in the yield. Foliar feeding of onion with boron did not alter the total sugar content of plants.

Key words: *Allium cepa* L., boron, dry matter, foliar fertilization, yielding, total sugars.

Problem setting. Onion (*Allium cepa* L.) is one of the most important commercial crops not only in Poland but also in the world. According to the Food and Agriculture Organization (FAO), it is the third most cultivated vegetable in the world by production quantity after tomato and watermelon, with a total of 99.9 million tons produced in 2019. In the European Union 5.9 million tons of onions were produced, about 535 thousand tonnes of which in Poland [11]. In the EU, Poland ranks third in the production of this vegetable [10]. In Ukraine, the production of onions in 2019 was about 998 thousand tones [11].

One of the most important micronutrients necessary for cell division, nitrogen and carbohydrate metabolism and water balance in plants is boron [4]. Deficiency of this element causes a lot of anatomical, physiological and biological disorders in plants. It can lead to a halt in cell division in the root apical meristem, which, consequently, leads to the inhibition of root lengthening. With very large deficiencies, the tip of the roots may even wither away and die. Boron deficiency also affects photosynthesis and transport of its products. It can also decrease stomatal conductance and CO_2 absorption, with an increase in starch assimilation and a decrease in sucrose assimilation [6].

Analysis of recent research and publications. Boron natural content depends mainly on the type of the soil and the parent rock from which it has developed. Unlike sandy soils, where boron can be found in small amounts, clay soils are generally rich in this element. Its concentration in soils varies from 2 to 200 mg·kg^{-1}, but its forms available to plants represent less than 5 to 10 % [5]. In Poland, sandy soils dominate, and the content of this element is insufficient, which makes it necessary to supplement its deficiency with mineral fertilizers applied both to the soil and in the form of foliar spraying [23]. The uptake of boron by plants depends, among others, on soil pH and water content, as well as on the presence of other ions in the soil solution [5]. Low boron content in the soil is also due to continuous use of mineral fertilizers and manure. Increasing mineral fertilizer doses are associated with a build-up of negative boron balance [16].

According to Smriti et al. [22] and Dake et al. [7], foliar or to-the-soil boron treatment in onion cultivation can have a beneficial effect on the growth and yield of these plants. Its positive effects in the cultivation of other vegetables has been confirmed by many authors, like Islam et al. [17], Meena et al. [16], Sultana et al. [23] and Franczuk et al. [12].

Problem statement. Thus, it is necessary to supply boron to plant leaves or to the soil. The experiment dealt with the effects of boron foliar application on the onion yield and the content of dry matter and total sugars.

The main materials and methods. The field experiment was carried out between 2019 and 2020 in east-central Poland (52º14'N, 22º10'E) on Luvisol soil. The average organic carbon concentration of the soil was 1.3 %, with pH in H_2O of 6.7 and hums layer 30–40 cm deep. Total macronutrient content in 1 dm^3 of the soil was as follows: 13 mg of NO_3-N; 30 mg of NH_4-N; 65 mg of P; 150 mg of K; 1219 mg of Ca; 60 mg of Mg; 1,5 mg of B (average of 2019–2020). The 'Spirit' cv. of onion (Bejo Zaden) was used in the experiment founded in three replications, in a randomised block design.

The soil was prepared at the end of March in accordance with agricultural recommendations for this crop species. Mineral fertilizers (for each experimental combination) were applied up to the optimal level for onion: 180 kg N, 70 kg P_2O_5, and 145 kg K_2O per ha. The seeds of onion were dressed (Zaprawa Nasienna T and Biosept 33 SL) and sown at a seeding rate of 6 kg·ha^{-1} on 5 April (2019) and 28 March (2020) with 30 cm spacing. After sowing, the experimental plots were sprayed with the Stomp 330 EC herbicide. Another herbicide, Goal 480, was applied just after the plants emerged and two-three weeks later. In the later stages of the onion growing season weeding was done mechanically. If necessary, other treatments were performed on the basis of an up-to-date integrated onion protection program.

Experimental factors and treatments are presented in Table 1. Calcium nitrate 8.5 N (8.5 % N-NO_3, 17 % CaO) and calcium nitrate 8.5 N with boron

(8.5 % $N\text{-}NO_3$, 17 % CaO, 0.05 % B) were used at doses of 3 l ha^{-1} + 250 l ha^{-1} H_2O. Spraying was carried out during the following onion developmental stages: BBCH 16, BBCH 17 and BBCH 41–45. In 2019, plants reached those stages on 11 and 25 June and 31 July, respectively, and in 2020 on 18 June, and 7 and 30 July.

Onion was harvested by hand on 29 August in 2019 and on 25 August in 2020. The area of each plot to be harvested was 4.8 m^2. The total and marketable yields of bulbs (t ha^{-1}) were determined after the harvest. From each plot, a sample of bulbs was collected (about 1 kg) to determine dry matter content by drying them to constant weight at 105°C. Total sugars content was measured by the Luff-Schoorl method [9].

The results were statistically processed with ANOVA (one-way) for the randomized block design. The significance of differences between means was determined with Tukey's test at the significance level of $p \leq 0.05$. All the calculations were performed with the Statistica software (version 13, Statsoft, USA).

Meteorological data provided by the IMGW-PIB Hydrological and Meteorological Station in Siedlce in 2019–2020 confirmed climate change and the dynamism of weather conditions in this part of Europe (Table 2). The average monthly air temperatures recorded in April, June and August 2019 were higher by 1.4–5.3°C than the average multi-annual values for the same months. In 2020, monthly temperatures in the spring were close to average ones, while in June and August they exceeded multi-annual values by 2.5°C and 1.6°C, respectively. The average air temperature for the entire onion growing period was 1.4°C higher in 2019 and 0.3°C higher in 2020 than for the 1981–2010 multi-annual period.

Moisture conditions in 2020 were significantly better for onion growth and development than in 2019. Total rainfall during the onion growing season in 2019 was 263.8 mm, which was 28.8 mm lower than the average for the 1981–2010 period. In 2020, total rainfall in the April-August period exceeded the multi-annual average by 99.9 mm. In both years of the research, immediately after sowing onion seeds, the amount of precipitation was very small (April), which prolonged the process of their germination. In May, both in 2019 and in 2020, an above-average amount of precipitation was recorded, which allowed refreshing moisture reserves in the soil after very dry April. June 2019 was also very dry (28.6 mm of precipitation) and very wet in 2020 (169.6 mm). In both years of the research, less rain than the multi-annual average was recorded in July, while the amount of precipitation in August was average.

Table 1

Treatments detail combination

Notation	Treatment	Doses of nitrogen, calcium and boron (g·ha^{-1}) supplied via foliar application:		
		$N\text{-}NO_3$	CaO	B
C1	*Control 1* no treatment (only soil fertilization: 180 kg N, 70 kg P_2O_5, 145 kg K_2O)	-	-	-
C2	*Control 2* without boron but with pre-seeding mineral fertilizer application to the soil and three foliar doses of calcium nitrate 8.5N (3 l·ha^{-1})	1125	2250	-
B1	*One dose of boron* pre-seeding mineral fertilizer application to the soil, one foliar dose of calcium nitrate 8.5N with boron (3 l·ha^{-1}) and two foliar doses of calcium nitrate 8.5N (3 l·ha^{-1})	1125	2250	2.2
B2	*Two doses of boron* pre-seeding mineral fertilizer application to the soil, two foliar doses of calcium nitrate 8.5N with boron (3 l·ha-1) and one foliar dose of calcium nitrate 8.5N (3 l·ha^{-1})	1125	2250	4.5
B3	*Three doses of boron* pre-seeding mineral fertilizer application to the soil and three foliar doses of calcium nitrate 8.5N with boron (3 l·ha^{-1})	1125	2250	6.7

Table 2

Weather condition in the experiment area, 2019–2020 (Siedlce Meteorological Station, Poland)

Years	Month					Mean / Sum	
	IV	V	VI	VII	VIII	IV-VIII	I-XII
Air temperature (°C)							
2019	9.4	13.0	21.5	18.0	19.3	16.2	9.9
2020	7.9	11.1	18.7	18.4	19.3	15.1	9.7
1981-2010	*8.0*	*13.6*	*16.2*	*18.4*	*17.7*	*14.8*	*7.8*
Precipitation (mm)							
2019	8.9	113.9	28.6	40.3	72.1	263.8	475.9
2020	6.9	111.4	169.6	39.2	65.4	392.5	666.2
1981-2010	*32.1*	*56.9*	*70.9*	*65.6*	*67.1*	*292.6*	*526.5*

Results and discussion. The average total and marketable yields of onion were 59.2 and 57.2 t ha^{-1} in 2019 and 72.3 and 69.3 t ha^{-1} in 2020 (Table 3). The yield recorded in 2020 was significantly higher than in 2019. Undoubtedly, this was due to more favourable weather conditions for onion growth in the second year of research.

The average onion trade yield in 2019 was significantly higher than the average yields in Poland (21.6 t ha^{-1}) and the EU (34.7 t ha^{-1}) [10; 15]. High yields resulted from good growing conditions and the high-yielding onion variety tested in the experiment. According to its breeder, 'Spirit' is a very high-yielding variety, better than many others available on the market. The field experiment was carried out in an area with favourable conditions for horticultural production. It is located in the valley of the River Liwiec, with very good soil, favourable microclimate and a long tradition of growing vegetables.

Statistical analysis of the results showed a significant effect of foliar boron application on the yield. The C2 and B1-B3 treatment combinations i.e. those with calcium nitrate applied three times to the leaves, resulted in higher onion yields compared to those with fertilizers applied to the soil (C1). However, differences in yields were not always statistically significant. In 2019, spraying onions with boron two or three times at a total dose of 4.5 and 6.7 g ha^{-1}, respectively, resulted in a significant increase in the total yield compared to control 1 (with no foliar feeding). In addition, three doses of boron-enriched calcium nitrate also resulted in a significant increase in the marketable yield in relation to plot B1 (treated with one dose of calcium nitrate with boron and two doses of calcium nitrate). However, in 2020 three doses of boron contributed to a significant increase in the marketable onion yield only in relation to C1 control. As an average for two experimental years, application of two or three doses of boron-enriched calcium nitrate increased the onion yield compared to the C1 control plot in a statistically significant way. The marketable yield of onion treated three times with boron was also significantly higher than in control C2 (treated with three doses of calcium nitrate, without boron) and in B1 (treated with one dose of boron-enriched calcium nitrate and two doses of calcium nitrate).

According to Goldbach and Wimmer [13] and Miwa et al. [20], boron increases the growth and yield of plants because it stimulates division and elongation of the cell and development of its walls. Boron plays an important role in the metabolism of carbohydrates and proteins. It is also crucial for development of the nitrogen-fixing cyanobacteria [1; 2]. Pramanik and Tripathy [13] reported an increase in the yield of *Allium cepa* L., compared to control with no treatment, after spraying plants twice with Borax solution (2×0.25 %). The authors also found that foliar spraying had a better yield effect than soil application of this fertilizer. Manna and Maity [19] reported a significant increase, referring to the control, in the onion yield after two foliar doses of 0.5 % boron solution. Increasing the dose of boron resulted in a proportional increase in the yield of onion. Smriti et al. [22] achieved similar results. Biswas et al. [8] also reported a significant increase in the yield of marketable onion, as compared to the control, after two doses of Borax at a concentration of 0.25 %.

It was found that the foliar application of boron increased the share of the marketable onion yield in the total yield (Fig. 1). This share increased with an increase in the number of boron doses. In the control plot, with no treatment, the share of marketable yield to the total yield was on average 93 %. With three doses of calcium nitrate, it increased to 94.5 %. One dose of boron increased this share to 95.5 %, and two and three doses resulted in 97.1 % and 98.4 % shares of the marketable yield in the total yield.

Table 3

Onion yield

Treatment	Total yield (t·ha^{-1})			Marketable yield (t·ha^{-1})		
	2019	2020	Mean	2019	2020	Mean
C1	50.1 a	66.0 a	58.0 a	46.6 a	61.6 a	54.1 a
C2	56.9 ab	73.6 a	65.2 abc	54.3 abc	69.9 ab	62.1 ab
B1	55.8 ab	67.6 a	61.7 ab	53.9 ab	64.6 ab	59.2 ab
B2	64.6 b	75.8 a	70.2 bc	63.4 bc	73.2 ab	68.3 bc
B3	68.7 b	78.5 a	73.6 c	67.5 c	77.4 b	72.5 c
Mean	59.2 A	72.3 B	65.8	57.2 A	69.3 B	63.2
ANOVA	Years (Y)	Treatment (T)	Y × T	Years (Y)	Treatment (T)	Y × T
F-value	42.07	42.52	41.87	31.31	40.36	31.22
p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{0.05}$	4.2	9.4	13.4	4.1	9.3	13.2

* Means followed by different lowercase letters in columns and different uppercase letters in rows differ significantly at $p \leq 0.05$

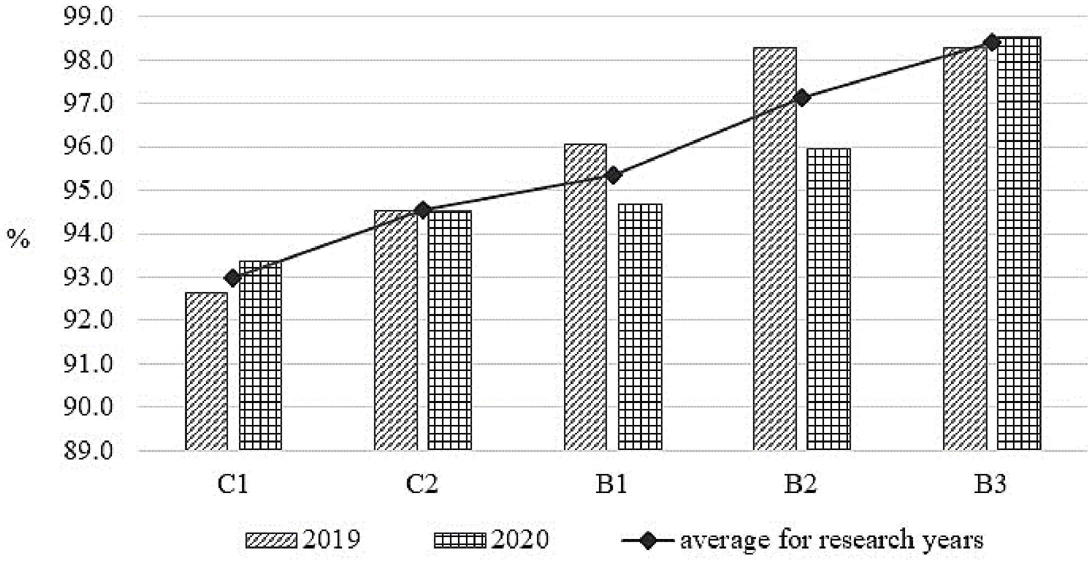

Fig. 1. The share of marketable yield in the total yield.

The onion dry matter content was on average 11.45 % (Table 4). In 2019, foliar treatment did not result in its significant changes. In 2020, onion sprayed once with boron-enriched calcium nitrate and twice with calcium nitrate without boron (B1) contained significantly more dry matter than plants fed three times with calcium nitrate enriched with boron (B3). In both years, increasing the number of boron doses resulted in a decrease in onion dry matter content as compared to plots treated three times with calcium nitrate without boron. Onion from the plot B3 contained significantly less dry matter than plants from plots C2 and B1. The opposing results were obtained by Manna and Maity [19], when they found that as the number of boron doses increased, onion dry matter content increased. After foliar application of boron at a concentration of 0.5 %, plants contained significantly more dry matter than those grown in control without boron. Gurjar et al. [14] also reported an increase in dry matter content in onion fertilized with boron. After soil application at doses of 1.0 and 2.0 kg ha^{-1}, it contained significantly more dry matter than control plants and those treated with 0.5 kg ha^{-1}B.

Table 4

The content of dry matter and total sugars in onion

Treatment	Dry matter (%)			Total sugars ($g \cdot 100g^{-1}$ F.M.)		
	2019	2020	Mean	2019	2020	Mean
C1	11.17 a	11.65 ab	11.41 ab	4.89 a	4.52 a	4.70 a
C2	11.80 a	11.91 ab	11.86 b	5.12 a	5.14 a	5.13 a
B1	11.42 a	12.08 b	11.75 b	4.95 a	5.24 a	5.10 a
B2	11.33 a	11.71 ab	11.52 ab	4.51 a	4.86 a	4.69 a
B3	11.16 a	11.28 a	11.22 a	4.87 a	4.48 a	4.68 a
Mean	11.38 A	11.72 B	11.55	4.87 A	4.85 A	4.86
ANOVA	Years (Y)	Treatment (T)	Y × T	Years (Y)	Treatment (T)	Y × T
F-value	12.64	25.77	12.64	0.06	1.26	0.06
p	0.002	<0.001	<0.001	>0.05	>0.05	>0.05
$LSD_{0.05}$	0.20	0.46	0.65	ns**	ns	ns

* Means followed by different lowercase letters in columns and different uppercase letters in rows differ significantly at $p \leq 0.05$

** Not significant

FM – fresh matter

Treatment combinations applied to onion grown in 2019 and 2020 resulted in total sugars content ranging from 4.48 to 5.24 $g \cdot 100\ g^{-1}$ FM. Statistical analysis of the results did not show a significant effect of treatment or weather conditions during the experimental years on this parameter.

Conclusions. Foliar treatment of onion with calcium nitrate containing boron contributed to an increase in the yield. The highest yield was recorded after spraying plants three times with a total dose of 6.7 g ha^{-1} of boron. As the dose increased from 2.2 to 6.7 g ha^{-1}, the share of the marketable onion yield in the total yield increased, but dry matter content decreased. Foliar feeding of onion with boron did not alter the total sugar content of plants.

References

1. Bolanos L., Brewin N. J., Bonilla I. Effects of boron on Rhizobium-legume cell-surface interactions and nodule development. *Plant Physiology*. 1996. No. 110. P. 1249–1256.

2. Bonilla I. et al. The aberrant cell walls of boron-deficient bean root nodules have no covalantly bound hydroxyproline-proline-rich proteins. / *Plant Physiology*. 1997. No. 115. P. 1329–1340.

3. Boron uptake, yield and quality of carrot (*Daucus carota* L.) in response to boron application. / Sultana S. et al. *International Journal of Plant and Soil Science*. 2015. No. 8(5). P. 1–5.

4. Brady N. C. The nature and properties and soils. 10th edition, A. K. Ghosh. Printing-Hall of India Pvt. Ltd., New Delhi. 1990. P. 383.

5. Brodowska M. Znaczenie boru w uprawie roślin. (Boron importance in plant cultivation.) URL: https://nawozy.eu/wiedza/porady-ekspertow/nawozenie/znaczenie-boru-w-uprawie-roslin.html (Accessed 21 April 2021).

6. Brown P. H. et al. Boron in plant biology. *Plant Biology*. 2002. No. 4. P. 205–223.

7. Dake S. D., Hiwale B. G., Patil V. K., Naik P. G. Effect of micronutrients on growth, yield and quality of onion (*Allium cepa* L.) cv. Baswant 780. National symposium on Alliums: current Scenario and Emerging Trends, 12–14 March, 2011, Pune. P. 205.

8. Effect of micronutrient application on vegetative growth and bulb yield attributes of Rabi onion (*Allium cepa* L.) / Biswas P. et al. *International Journal of Current Microbiology and Applied Sciences*. 2020. No. 9(3). P. 556–565.

9. EU 2009. Commission Regulation NO 152/2009. Official Journal of the European Union L54. P. 1–130.

10. EUROSTAT 2020. Agricultural production – crops. URL: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agricultural_production_-_crops#Vegetables (Accessed 26 April 2021).

11. FAOSTAT 2021. Onions production in 2019, Crops/Regions/World list/Production Quantity (pick lists). UN Food and Agriculture Organization, Corporate Statistical Database. URL: http://www.fao.org/faostat/en/#data/QC/visualize (Accessed 26 April 2021).

12. Franczuk J., Rosa R., Zaniewicz-Bajkowska A., Słonecka D. Effects of boron application and treatment with effective microorganisms on the growth, yield and some quality attributes of broccoli. *Journal of Elementology*. 2019. No. 24(4). P. 1335–1348.

13. Goldbach H. E., Wimmer M. A. Boron in plants and animals: is there a role beyond cell-wall structure? *Journal of Plant Nutrition and Soil Science.* 2007. No. 170(1). P. 39–48.

14. Gurjar P., Lekhi D. R., Uikey A. Effect of sulphur and boron on growth and quality of onion (*Allium cepa* L.). *International Journal of Chemical Studies*. 2020. No. 8(3). P. 1955–1957.

15. GUS. Rocznik Statystyczny Rolnictwa. (Statistical Yearbook of Agriculture). Głowny Urząd Statystyczny w Warszawie, 2020.

16. Improvement of growth, yield and quality of tomato (*Solanum lycopersicum* L.) cv. Azad T-6 with foliar application of zinc and boron. / Meena D.C. et al. *International Journal of Bio-resource and Stress Management*. 2015. No. 6(5). P. 598–601.

17. Islam M., Hoque M. A., Reza M. M., Chakma S. P. Effect of boron on yield and quality of broccoli genotypes. *International Journal of Experimental Agriculture*. 2015. No. 5(1). P. 1–7.

18. Kocoń A. Potrzeby nawożenia mikro-elementami. (The need for fertilization with micronutrients.) *Studia i Raporty IUNG-PIB*. 2013. No. 34(8). P. 133–144.

19. Manna D., Maity T. K. Growth, yield and bulb quality of onion (*Allium cepa* L.) in response to foliar application of boron and zinc. *Journal of Plant Nutrition*. 2016. No. 39(3). P. 438–441.

20. Plants tolerant of high boron levels / Miwa K. et al. *Science*. 2007. No. 318(5855). P. 1417–1417.

21. Pramanik K., Tripathy P. Effect of micronutrients on growth and total yield of onion (*Allium cepa* L.). *The Bioscan*. 2017. No. 12(01). P. 322–326.

22. Smriti S., Kumar R., Singh S.K. Effect of sulphur and boron nutrition on growth, yield and quality of onion (*Allium cepa* L.). *Journal of Applied Biology*. 2002. No. 12. P. 40–46.

23. Szulc W., Rutkowska B. Diagnostics of boron deficiency for plants in reference to boron concentration in the soil solution. *Plant, Soil and Environment*. 2013. No. 59. P. 372–377.

Стаття надійшла 28.04.2021