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RESEARCH ARTICLE

Influence of Iron, Zinc and Boron on the physiological state and productivity of *Allium sativum* L.

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The importance of studying in agriculture the impact of individual micronutrients on the course of production processes and their impact on the quality of garlic is an important issue. The influence of iron, zinc and boron in different norms against the background of the recommended norm NPK. The research results showed significant increasing of chlorophyll content by the application of Iron 10 and 20 kg/ha – 12.0 and 16.4%; by the application zinc increasing of chlorophyll was significant on all variants – 15.1; 48.0 and 30.4% in respectively with the norms. By the application of boron content of chlorophyll was the least significant – 10.9% at the maximum norm – 6 kg/ha. The dynamic activity of antioxidant enzymes was similar before the dynamics of growth processes. The activity of the enzyme was highest for the optimal norms of micronutrients. Among the studied complex of the enzymes most significantly increases actityes catalase (CAT) and glutathione S-transferase (GST). Zinc has the greatest effect on the formation of bulb mass. The increase in bulb weight by the application of zinc fertilizer was significant in all variants – + 14.3–20.0% to control. Fertilization with microelements in the minimum and optimal norms contributed to a significant increase in yield, the application of maximum norms led to a decrease in productivity in general, except boron, where plant productivity increased with increasing norms, from which it can be concluded that garlic needs were insufficient 6 kg/ha is not the maximum. With fertilization of iron in the norms of 10 and 20 kg/ha the yield increase was 4.26 and 4.85 t/ha and was significant, by the application of 30 kg/ha of iron the yield of garlic was higher than the control by 3.70 t/ha. Zinc fertilization had the best effect on yield increase (+ 4.25–5.12 t/ha). A significant increase in yield for boron fertilization was observed at the maximum rate (+3.26 t/ha). By the application of zinc and boron contributed to the extension of the marketability of garlic bulbs to 210 and 220 days for warm storage and up to 240 and 260 days for cold. During warm storage, after 210 and 260 days – during cold storage there was a mass germination of the cloves. Bulbs of the control variant and y the application of iron germinated after 120 and 180 and 190–210 days according to the variant and storage regime. Further research is to study the combinations of the studied micronutrients on physiological processes and biochemical parameters and to optimize their norms for local fertilization.

Keywords: Antioxidant enzyme activity; Chlorophyll; Garlic; Micronutrients; Storability; Weight; Yield

Introduction

Garlic (*Allium sativum* L.) has accompanied mankind along his long history as a known vegetable and medical plant. First reports are 4 000 years old (Maas & Klaas 1995, Lallemand et al. 1997, Fritsch & Friesen 2002, Simon & Jenderek 2003, Volk et al. 2004). It is commonly used as a spice or in the medicinal purposes. In Ukraine, it has been generally cultivated for both local consumption and export. The area and production of garlic in Ukraine are about 25 thousands hectare, with an average yield of 9,6 t/ha. (FAO).

Micronutrients play an active role in the plant metabolic process from cell wall development to respiration, photosynthesis, chlorophyll formation, enzymes activity, nitrogen fixation etc. Micronutrients work as a co- enzyme for a large number of enzymes (Ding et al. 2004, Lawrence et al., 2011, Poldma et al., 2011, Ameri et al., 2012, Aminifard et al., 2012). It also plays an essential role in improving yield and quality and highly required for better plant growth and yield of many crops (Alam et al., 2010). Soil application of micronutrients during crop growth (onion) was successfully used for correcting their deficits and improving the mineral status of plants as well as increasing the crop yield and quality (Jawaharlal et al., 1986; Thakare et al., 2007; Ali, 2013).

Boron deficiency in fresh market fruits is often not documented by growers. Boron deficiency, however, is widespread and can serious yield diminution and irregular ripening of fruit (Adams, 1978). Boron becomes less accessible to plants as soil pH increases (Bunt, 1956). Therefore, the practice of applying lime to improve the uptake of other nutrients can cause B deficiency (Fleming, 1980).

Zinc is one of the seven micronutrients vital for crop growth. Zinc plays a considerable role in various enzymatic and physiological activities and performs many catalytic functions in plant system besides alteration of carbohydrates, chlorophyll and protein synthesis. Deficiencies of zinc become so extensive that it ranks next to N and P (Takkar and Randhawa, 1980). Zinc is also an important micronutrients concerned in metabolic processes, enzymatic system, seed production and rate of maturity in plants. It is essential for synthesis of tryptophan, which is originator of indoleacetic acid. It also plays an important role in starch metabolism in plants (Alloway, 2008). Zinc is crucial for plant growth because it controls the synthesis of indoleacetic acid, which noticeably regulates plant growth and also active many enzymatic reactions which is necessary for chlorophyll synthesis and carbohydrate formation (Vitosh, 1994).

The decisive role in increasing plant productivity belongs to biochemical protection systems. Among them, much attention is paid to elucidating the role of antioxidant enzymes in metabolism and the formation of plant resistance to abiotic factors (Polesskaya et al, 2006, Turpaev, 2002). Antioxidant enzymes are involved in the neutralization of reactive oxygen species, the accumulation of which in the plant cell initiates the processes of oxidative destruction of membrane structures (Polesskaya et al, 2006, Tarchevskiy, 2002).
This study was conducted to establish the optimal norms of micronetrients for garlic in the condition of Right Bank Forest-Steppe of Ukraine and to determine the impact of different norms of iron, zinc and boron on the growth and physiological processes in garlic plants and their impact on garlic yield and quality during storage.

Materials and Methods

The research of the influence of amino acids was carried out in 2017–2019 in the conditions of the condition of Right-Bank Forest Steppe of Ukraine on the experimental field of the Department of Vegetable Growing of Uman National University of Horticulture in accordance with generally accepted methods (Bondarenko and Yakovenko, 2001, Ulianych et al., 2019; 2020).
The soil of the experimental field is black, puddle, heavy loam with a well-developed humus horizon (about 2.9% of humus) in the deep of 40–45 cm. Soil pH was determined in water (soil water ratio 1:1). Electrical conductivity (ECe) of the soil suspension was measured using conductivity meter. The P, K and Zn were determined by using AB-DTPA method (Ryan et al, 2001) (Table 1).

Table 1. Chemical properties of soil used in experiment.

Indicator	Units	Content
organic carbon	%	2,2
pH	–	6,0–6,2
Extractable P (AB-DTPA	mg/kg	102
Extractable K (AB-DTPA)	mg/kg	123
NO3-N	mg/kg	64
Fe (AB-DTPA)	mg/kg	0,43
Zn (AB-DTPA)	mg/kg	0,79
B (AB-DTPA)	mg/kg	0,28

Planting was carried out by the scheme of 45 × 6 cm at the end of the 5–10 of October. The total area: for the experiment 400 m², for plot 100 m²; for sampling 10 m². The experiment was laid out in a Factorial Randomized Block Design were employed and four replication.
Single factor experiment consisted of fertilization Iron sulphate ($FeSO_4$), Zinc sulphate (Zn_2SO_4), Boric acid (H_3BO_3), as well as control (without fertilizer). Fertilizers were applied before plowing. Micronetrients were used against the background of the recommended for the Right-Bank Forest-Steppe of Ukraine norm of macronutrients ($N_{11}0P_{70}K_{70}$).

This experiment included the following fertilization

Control (without fertilizer)
Iron sulphate ($FeSO_4$), Fe (10 kg/ha), Fe (20 kg/ha), Fe (30 kg/ha), Zinc sulphate (Zn_2SO_4), Zn (1 kg/ha), Zn (2 kg/ha), Zn (3 kg/ha) Boric acid (H_3BO_3), B (2 kg/ha), B (4 kg/ha), 10. B (6 kg/ha).
During the investigation, parameters including length and width of leaf, leaf blade area and total leaf area per plant on the 60th day after planting (DAP) were determined, plant height and the number of leaves (per plant, pcs) were calculated by, and the leaf blade area was determined by a calculated (linear) method, using the parameters of length and width of the leaf by the formula:

$$S_n=0.67 \times ab$$

Where: S_n – One leaf area, cm²; a – The largest leaf width, cm; b – Leaf length, cm; 0.67 is the coefficient that reflects the configuration of the leaf.

We studied the effect of different norm of micronutrients on enzymes activity, productivity of plants, pigments contents in leaf, vitamins B complex and vitamin C of garlic cloves, and storability.

Plant materials
Garlic (*Allium sativum* L.) cv. Lyubasha.
Assimilating pigments content were determined by spectrophotometric method (Ermakov et al., 1987).

Activity measurements of antioxidant enzymes
Enzyme activities were determined, 10 days after spraying plants by organic acids solutions. A one g of plant tissue from control and treated plants was homogenized on ice in 4 ml extraction buffer (50 mM^{-1} phosphate buffer pH 7.0, containing 1mM EDTA, 1mM phenylmethylsulfonyl fluoride and 1% polyvinylpolypirrolidone). The homogenate was centrifuged for 25 min at 15,000 × g^{-1} and 4°C. The supernatant was used for enzyme activity assays. The means ± SD were calculated from the data of at least 3 independent measurements. SOD activity was determined spectrophotometrically by measuring the ability of the enzyme to inhibit the photochemical reduction of nitro blue tetrazolium (NBT) in the presence of riboflavin in light (Dhindsa et al. 1981). One unit (U^{-1}) of SOD was the amount that causes 50% inhibition of NBT reduction in light. The enzyme activity was expressed in terms of specific activity (U mg $protein^{-1}$). CAT activity was determined by the decomposition of H_2O_2 which, in turn, was measured by the decrease in absorbance at 240 nm (Upadhyaya et al. 1985). One U^{-1} equals the amount of H_2O_2 (in μmol^{-1}) decomposed in 1 min^{-1}. POD activity was determined by monitoring the increase in absorbance at 470 nm during the oxidation of guaiacol (Upadhyaya et al. 1985). The amount of enzyme producing 1 μmol $min\text{-}^{1}$ of oxidized guaiacol was defined as 1 U^{-1}. GR activity was determined by measuring the absorbance increment at 412 nm when 5.5 dithiobis(2–nitrobenzoic acid) (DTNB) was reduced by GSH, generated from glutathione disulfide (GSSG) (Smith et al. 1988). The specific activity was calculated as the amount of reduced DTNB, in μmol min^{-1} protein mg,

Ɛ420=13.6 mM^{-1} cm^{-1}. GST activity was determined spectrophotometrically by using an artificial substrate, 1–chloro–2.4–dinitrobenzene (CDNB), according to Habig et al. (1974). One U is the amount of enzyme producing 1 μmol conjugated product in 1 min, Ɛ340 = 9.6 $mM^{-1}cm^{-1}$. The protein contents of the extracts were determined by the method of Bradford (1976).

Bulb dry matter (%)

The average dry matter weight (g^{-1}) of bulbs after curing were measured by drying 10 randomly sampled bulbs in an oven with a forced hot air circulation at 70°C until a constant weight was obtained. The percentage of bulb dry matter was calculated by taking the ratio of the dry weight to the fresh weight of the sampled bulbs and multiplying it by 100.

Determination of content of vitamins B complex

A weight 50 g was cut into small pieces and extracted with 0.1 NHCL (sodium chloride) on the water bath at suitable temperature and time period. All extracts were filtered through 0.40 micron filter and taken into 100 ml-1 volumetric flask which was added up for mobile phase.

The standard preparation

stock of standard (Sigma Aldrich Analytical grade Reagent) prepared by dissolving 0.01 g-1 of each standard in 100 ml of mobile phase followed by successive dilutions.

High-performance liquid chromatography (HPLC)

Analysis of HPLC (Shimadzu, Model Prominence 20A) equipped with UV detector and Supelco Discovery Cis18 column (25 -cm-1 in length and 0.45-cm^{-1} internal diameter) was used. Mobile phase was 50 m MK_2HPO_4 and MeOH (70:30) at 1 ml min^{-1} flow rate and 10μL^{-1} of each sample/standard was injected and monitored at UV 254 nm.

Analysis of vitamin C

Lyophilized samples (each 0.2 g^{-1}) were ground and added to 30 mL^{-1} of 3% metaphosphoric acid solution and homogenized at 11,000 rpm for 2 min using a T25 basic ULTRA–TURRAX homogenizer (IKAWerke GmbH & Co. KG, Staufen, Germany). The volume was made up to 50 mL^{-1} with 3% metaphosphoric acid solution. The extract (2 mL^{-1}) was centrifuged at 12,000 rpm^{-1} for 3 min^{-1}, and the supernatant filtered through a 0.45 lm^{-1} polyvinylidene difluoride (PVDF) membrane filter (Whatman I nternational Ltd., Maidstone, UK). All samples were immediately analyzed using an HPLC system, equipped with a PU (2089 pump), an AS (2057 auto injector), and a MD (2010 UV) vis variable wavelength detector (JASCO Corp., Tokyo, Japan). Separation was carried out in a Crest Pak C18S column (15094.6 mm^{-1}, i. d., 5 lm^{-1}, JASCO Corp.), and the isocratic elution was carried out with 0.1% trifluoroacetic acid in distilled water as a mobile phase for 15 min (flow rate 0.8 mL^{-1} min^{-1}). The peak was read at 254 nm-1 using an UV detector and quantification was determined via external calibration against ascorbic acid.

Garlic storage regimes

During the storage period, the indicators of air temperature and relative humidity in the warm storage regime were relatively stable, and in the cold – strictly controlled and remained at the same level throughout the period (Figure 1).

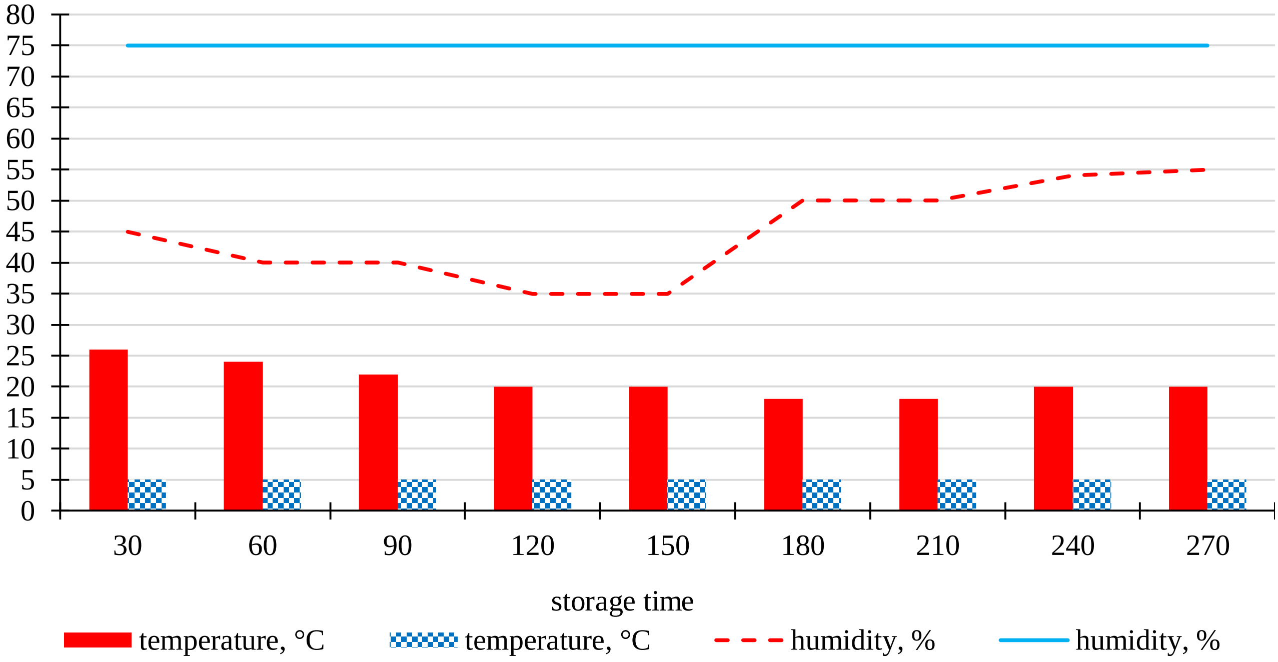

Figure 1. Parameters of temperature (oC) and humidity (%) under room conditions and cold storage.

Statistical analysis

The validity of the research and significance of the differences between the mean values of the variables examined were evaluated according to the results of dispersion and correlation analysis of mathematical statistics (Ehrmantraut et al., 2000).

For the food and chemical composition, three samples analyzed were performed in three replicates. The results were expressed as averages. The antioxidant activity, and chemical composition were analyzed at $p \leq 0.05$ (for yield and bulb weight), 0.01 (for enzyme activities, pigments content in leaf, vitamins B complex and vitamin C in cloves, dry matter).

Results

The research results show that by the application of iron 20 kg/ha is optimal for growth processes (Table 2). Thus, with a application of 30 kg/ha of iron, the height of plants was higher than the control by 7.8%. The same tendency was observed by the application of zinc, but the increase in the height of garlic plants before control was 17.2; 22.1 and 15.1% in accordance with the norm of 1, 2 and 3 kg/ha. By the application of boron contributed to a slightly smaller increase, but with the increase in the norm, the height of plants also increased (+ 13.0; 14.6 and 16.6% before control). This pattern of growth processes and the formation of the leaf complex is observed in all variants. Application of with iron at the rate of 10 kg/ha increased the leaf area to 21.8%, zinc at the rate of 2 kg/ha - up to 28.4%, boron – up to 24.2%. At the same time, the increase in the leaf index by the application of iron reached 27%, zinc – 38.4%, boron – 38.1%. A significant increase in chlorophyll content was by the application of iron 10 and 20 kg/ha – 12.0 and 16.4%; by the application of zinc, the increase in chlorophyll content was significant in all variants – 15.1; 48.0 and 30.4% respectively to the norm. By the application of boron, the increase of chlorophyll content was the least significant – 10.9%.

Table 2. Parameters of plant growth, leaf and pigment complex of garlic cultivar Lyubasha under the action of different norms of micronutrients (average 2017–2019).

Variant		Plant height (cm)	Number of leaves (pcs)	Leaf area (cm²)	Area of the leaves per plant, cm²	Leaf area index	Leaf's total chlorophyll content,% d.w.
Control (without fertilizer)		63,21	9,12	93,87	506,62	1,87	1,63
Iron	10 kg/ha	68,57	9,31	108,82	599,21	2,22	1,82*
	20 kg/ha	70,31*	9,51	114,33	643,51*	2,38*	1,89*
	30 kg/ha	68,13	9,31	106,52	586,53	2,17	1,76
Zinc	1 kg/ha	74,11*	9,61	117,43*	668,17*	2,47*	1,87*
	2 kg/ha	77,16*	9,82*	120,53*	700,57*	2,59*	2,41*
	3 kg/ha	72,74*	9,41	115,63*	643,76*	2,38*	2,12*
Boron	2 kg/ha	71,43*	9,82*	109,02	633,66	2,34*	1,76
	4 kg/ha	72,43*	9,82*	111,83	649,95*	2,40*	1,76
	6 kg/ha	73,68*	10,13*	116,63*	699,29*	2,59*	1,80*
LSD (0,05*; 0,01**)		6,56*	0,52*	21,05*	134,22*	0,46	0,17**

Means bearing same * and ** in each column are statistically similar at p≤0,05 and p≤0.01.

The dynamics of the activity of antioxidant enzymes was similar to the dynamics of growth processes. The activity of enzymes was the highest at optimal norms of micronutrients. The increase in SOD activity was significant in all variants by the application of iron (+ 4.9–11.3%) and zinc (+ 8.4–11.3%) and boron in the maximum norm (+ 9.4%). CAT activity (Figures 2 and 3) increased most significantly among the studied complex; CAT activity increased by 32.2–42.0% during by the application of iron; zinc – 37.8–49.1%; boron – 1.0–11.9%. POD activity (Figure 4) was slightly lower than the previous ones, but the most significant activation of the enzyme by the application of zinc 2 and 3 kg/ha – 33.7 and 27.2% before control. Glutathione reductaze (GR) sharply increased activity by the application of zinc 2 kg/ha – 51.1%, while in all variants of the experiment, this figure ranged from 1.6% (boron 2 kg/ha) to 23.5% zinc 3 kg/ha) (Figures 5 and 6). The activity of glutathione S-transferase (GST) was more consistent in the experiment, but the most significant increase was recorded at optimal norms of micronutrients. Among the studied enzyme complex, the activity of catalase (CAT) and glutathione S-transferase (GST) increased most significantly.

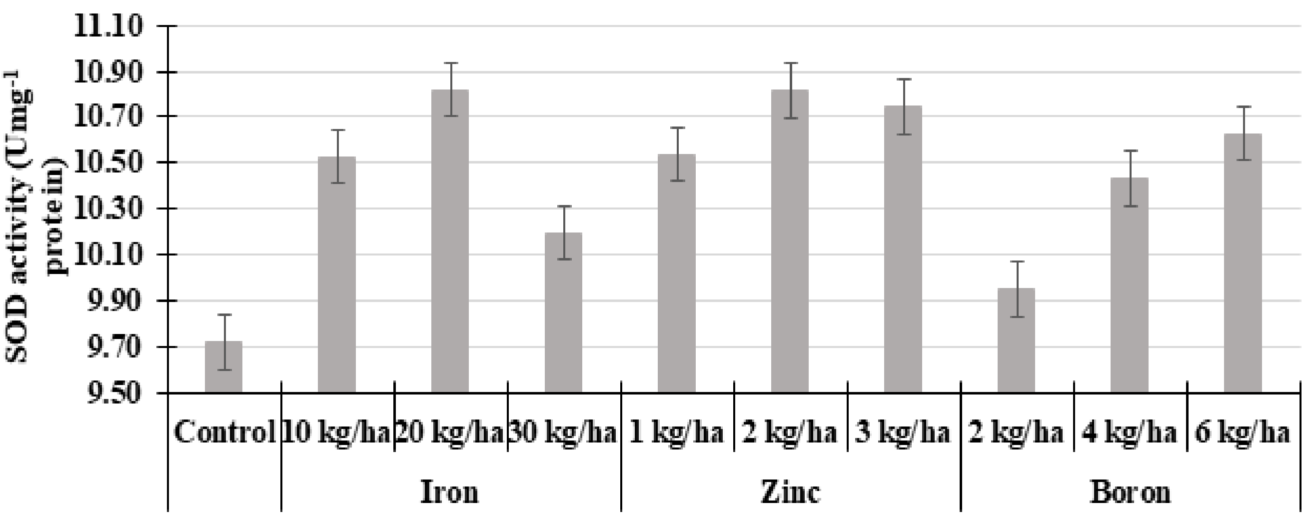

Figure 2. Superoxide dismutase activity in leaves of the garlic plant (average 2017–2019) (LSD (0.01) = 0,84).

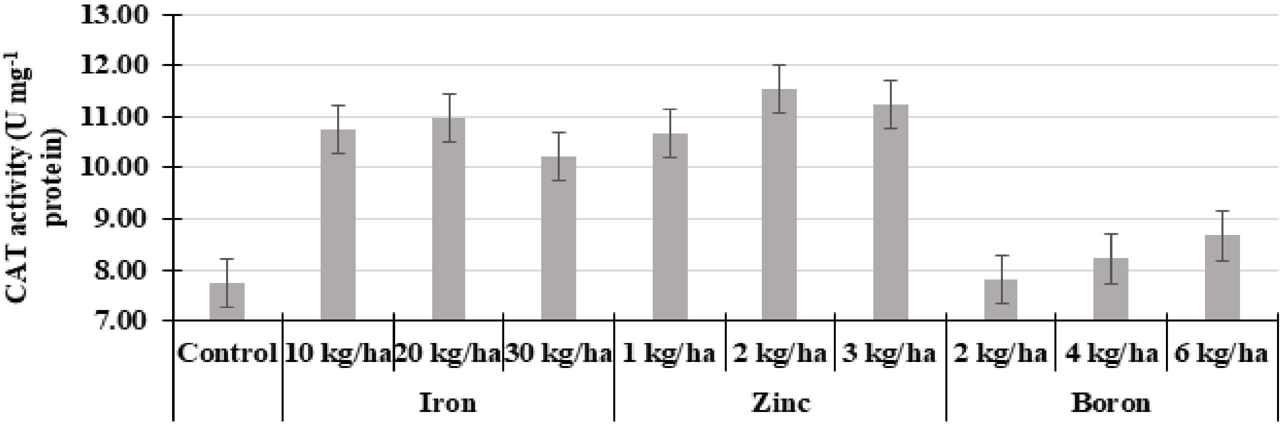

Figure 3. Catalase activity in leaves of the garlic plant (average 2017–2019) (LSD (0.01) = 1,97).

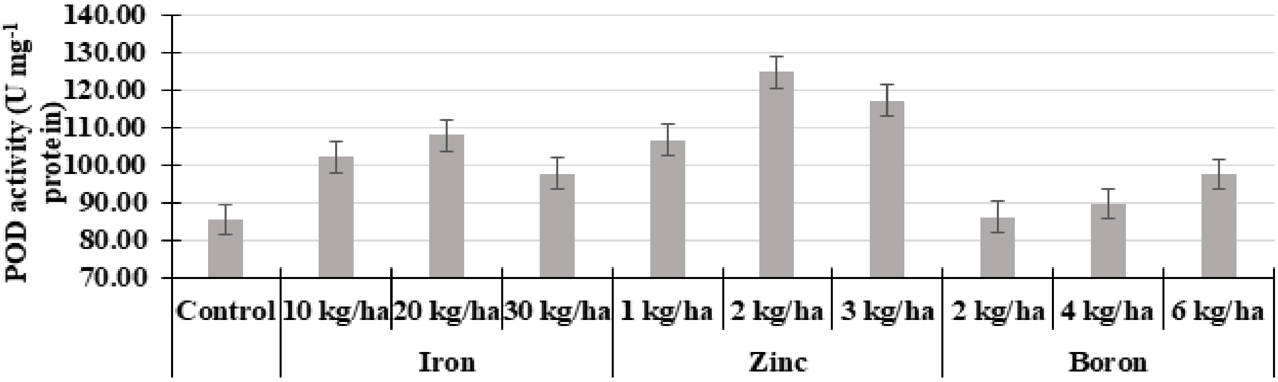

Figure 4. Guaiacol peroxidase activity in leaves of the garlic plant (average 2017–2019) (LSD (0.01) = 11,63).

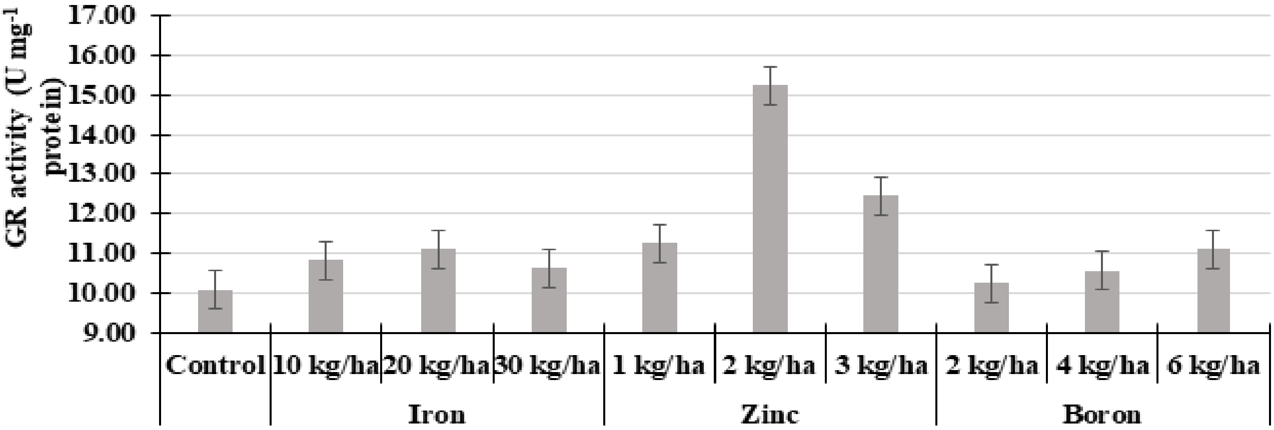

Figure 5. Glutation reductaze activity in leaves of the garlic plant (average 2017–2019) (LSD (0.01) = 1,02).

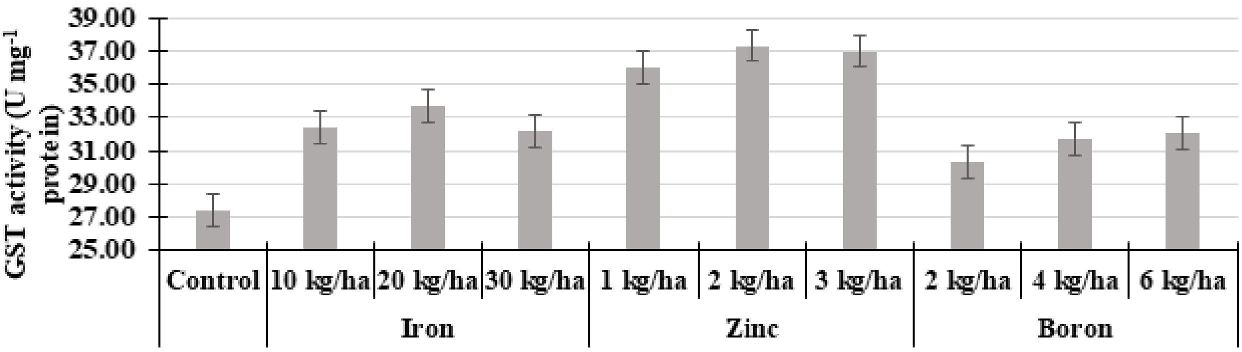

Figure 6. Glutathione S-transferase activity in leaves of the garlic plant (average 2017–2019) (LSD (0.01) = 4,08).

The size and weight of the bulb is a determining factor in the marketability and structure of the garlic crop. As a result of the received data it is revealed that zinc (Figure 7) influences bulb mass formation the most. The increase in bulb weight by the application of zinc was significant in all variants – + 14.3–20.0% to control. Application of iron, the increase in bulb weight ranged from 6.9 to 14.6%. By the application of boron, the increase in bulb weight was the smallest, and a significant increase was only in the version with boron 6 kg/ha. From the obtained data there is a certain pattern: by the application of iron and zinc in the optimal norms the increase is the largest, and by the application of boron increases proportionally to increase the norm of micronutrents.

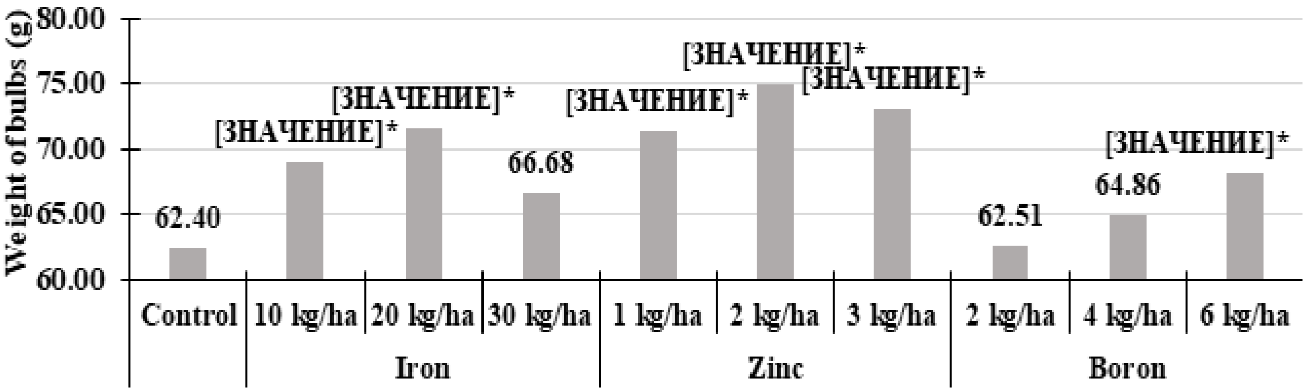

Figure 7. Weight of garlic bulbs (g-1) (average 2017–2019), (LSD (0.05) = 5,22) (Means bearing same * in each column are statistically similar at p≤0,05).

Yield is the main indicator that characterizes the efficiency of crop cultivation. By the application of iron fertilization at the rates of 10 and 20 kg/ha, the increase in yield was 27.9 and 31.8% and was significant, the application of 30 kg/ha of iron, the yield of garlic was higher than the control by 24.2%, but lower than the option with 10 kg/ha (Figure 8). By the application of zinc had the best effect on yield increase (+ 27.9–33.6%). A significant increase in yield by the application of boron was conceived at the maximum norm (+21.4%).

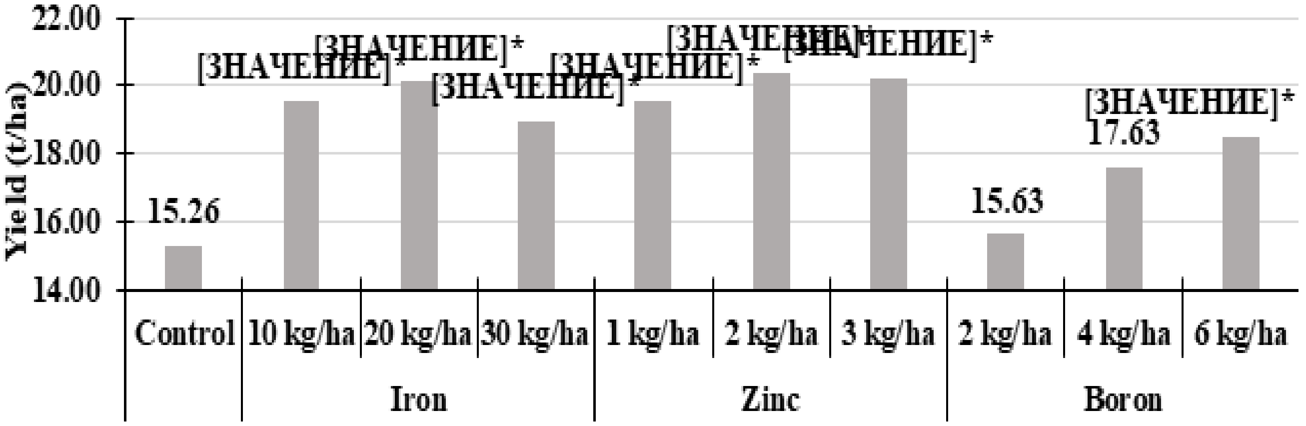

Figure 8. Yield (t ha^{-1}) of garlic (average 2017–2019) (LSD (0.05) = 3,03) (Means bearing same * in each column are statistically similar at p≤0,05).

There is a certain dynamics by the application of: with the increase of the microelement norm, the dry matter content also increases, but the above data, in particular, the course of biochemical processes had other regularities. There was a significant increase in dry matter in all variants by the application of zinc and boron, while application of iron this figure increased insignificantly (Table 3). A significant increase in protein content was observed only with by the application of zinc 11.9–15.8%.

A certain pattern has been revealed: by the application of iron and boron fertilization, the protein content decreases with increasing norm, and the protein content increases with increasing zinc norm.

Statistical data processing showed that there be medium strength connection between dry matter content and ascorbic acid (R2 = 0,6192) and a close relationship between dry matter content and B vitamins (R2 = 0,8335) (Figure 9).

The marketability of garlic cloves depends on the duration of the dormancy period (before germination). During storage, the marketability of garlic bulbsby the application of iron was stored on average over the years of research up to 140–150 days for warm storage and up to 180–200 days for cold storage.

The use of zinc and boron contributed to the extension of the marketability of garlic bulbs to 210 and 220 days for warm storage and up to 240 and 260 days for cold. During warm, after 210 and 260 days – during cold storage there was a mass germination of cloves. Bulbs of the control variant and by the application of iron germinated after 120 and 180 and 190–210 days according to the variant and storage regime. Further storage (up to 270 days) shows only theoretical data on the weight loss of bulbs.

Table 3. Biochemical parameters of garlic cultivar Lyubasha under the action of different norms of micronutrients (average 2017–2019).

Variant		Bulb's dry matter content,%	Protein content, mg/100 g	Ascorbic acid, mg/100 g	B vitamins complex, mg/100 g
Control		30,29	5,87	7,43	20,18
Iron	10 kg/ha	30,38	6,43	7,52	21,45
	20 kg/ha	30,86	6,25	7,61	21,72
	30 kg/ha	31,35	6,17	7,66	22,56
Zinc	1 kg/ha	32,95*	6,57*	7,87*	23,21*
	2 kg/ha	33,34*	6,64*	7,78	23,01*
	3 kg/ha	32,73*	6,79*	7,56	22,88
Boron	2 kg/ha	33,10*	6,17	8,10*	23,32*
	4 kg/ha	33,30*	6,21	8,33*	23,35*
	6 kg/ha	33,59*	6,28	8,36*	24,46*
LSD (0,01)		2,12	0,57	0,42	2,74

Means bearing same * in each column are statistically similar at p≤0,01.

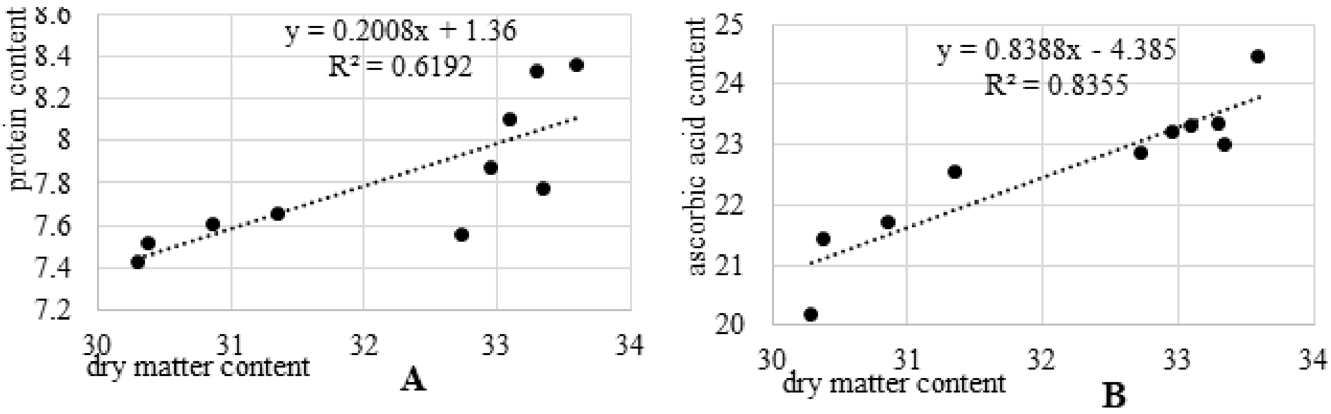

Figure 9. Statistical model of the dependence protein (A) and ascorbic acid content (B) of dry matter content.

The total weight loss of the bulb during warm storage in the control was 39.8% for cold storage – 14.7%. By the application of iron, the percentage of weight loss decreased to 31.7–36.3% during warm storage and 10.6–13.0% during cold storage (with an increase in the microelement norm, the weight loss of the bulb decreases). By the application of zinc in the optimal norm noted the lowest weight loss of the bulb (28.2% for warm storage and 9.0% for cold storage). By the application of boron, the weight loss of the bulb decreased in accordance with the increase in the norm of micronutrients (Figures 9 and 10).There be a close relationship between dry matter content and weight loss of the bulb at the beginning and end of the storage period, where the coefficient of approximation ranged from R2 = 0.8703-0.9286 at the beginning of storage and R2 = 0.8815–0.8788 at the end storage period (Figures 11 and 12).

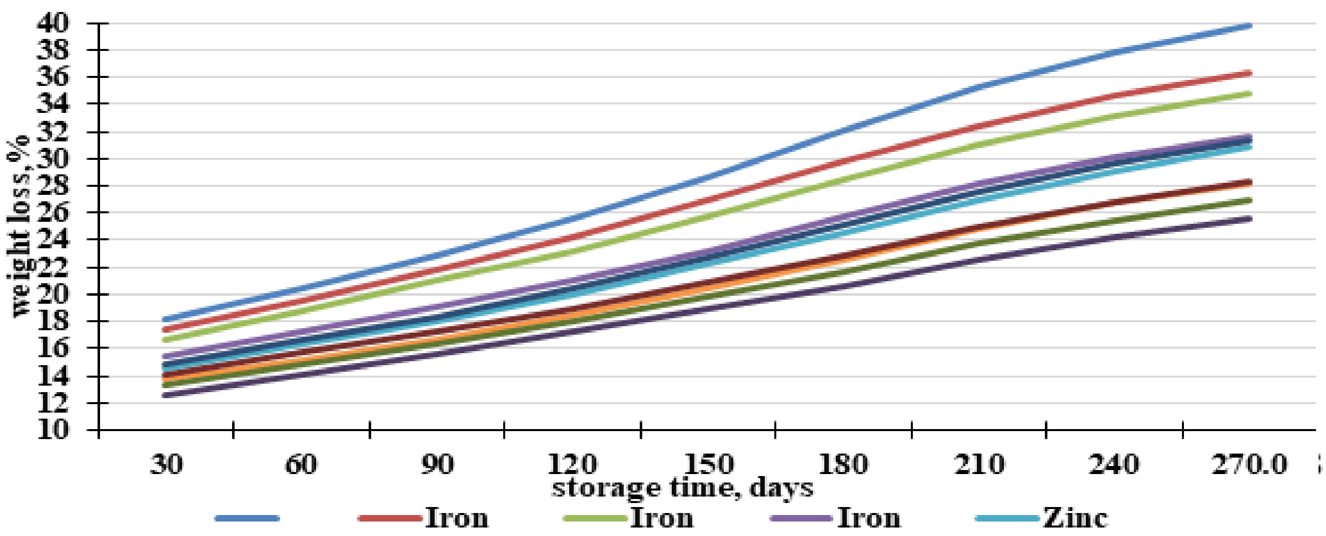

Figure 10. Effect of different norms of micronutrients on weight loss (%) of garlic cultivar Lyubasha during 9 months (270 days) of storage under room temperature (average 2017–2019).

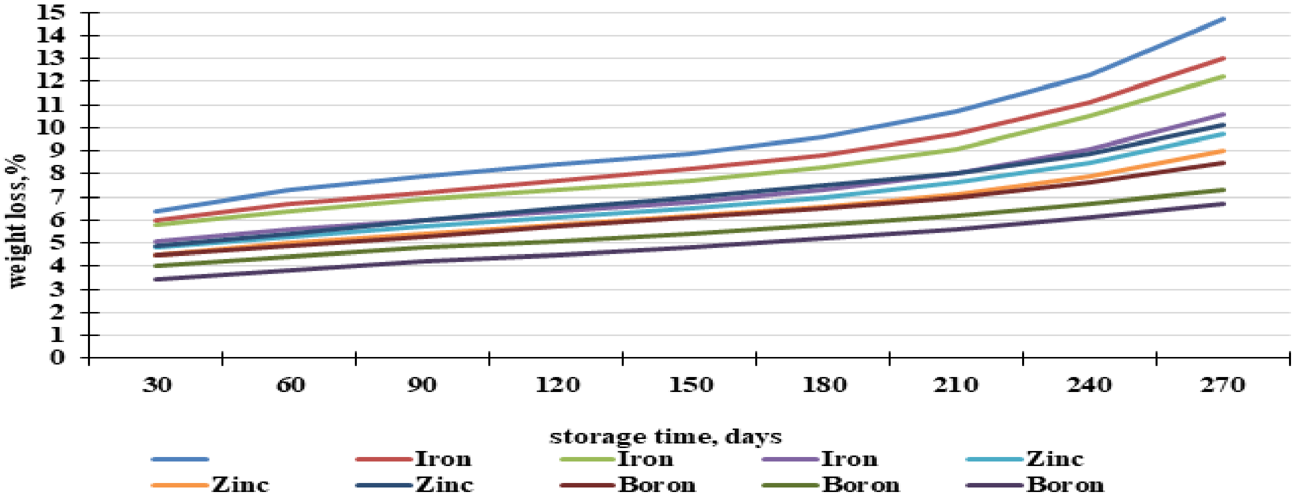

Figure 11. Effect of different norms of micronutrients on weight loss (%) of garlic cultivar Lyubasha during 9 months (270 days) of storage under cold storage regime (average 2017–2019).

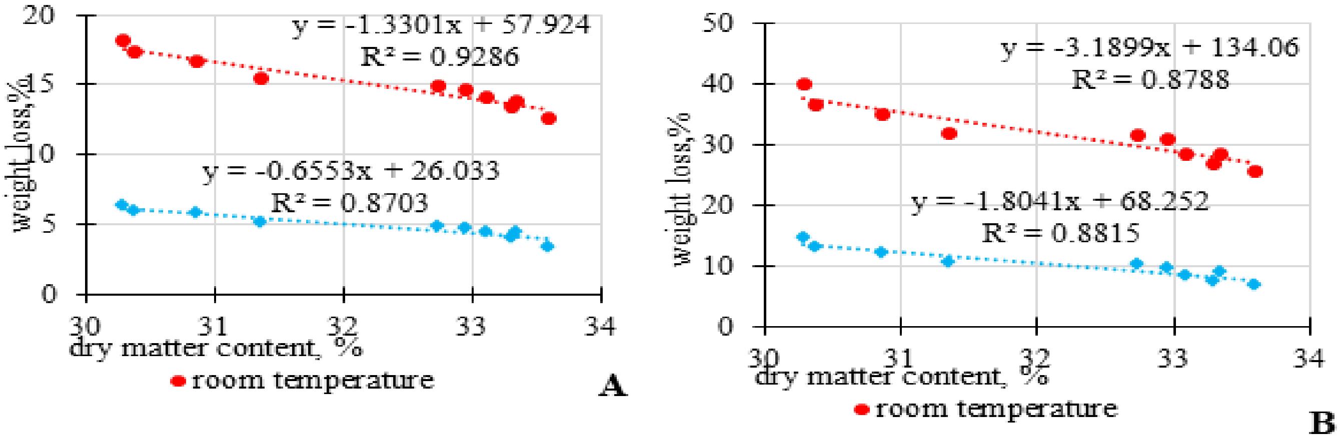

Figure 12. Statistical model of the dependence of loss of bulb weight during storage for 30 days (A) and 270 days (B) of dry matter content with (average 2017-2019).

Discussion

The results are in conformity with the findings of Srivastava et al. (2005), Rahohida et al. (2010), Yousuf et al. (2015) and Choudhary et al. (2014) in garlic crop. The application of micronutrients soil or foliar spray significantly influenced bulb yield of onion crop (Pramanik and Tripathy, 2017 and Singh et al., 2015). Micronutrients takes active part in photosynthesis, which ultimately helps towards increase in number and weight of bulbs. Similarly, significant influence of micronutrients mixture on growth and yield parameters of garlic as reported by Srivastava et al. (2005), Rahohidas et al. (2010), Yousuf et al., (2015) and Choudhary et al. (2014) in garlic crop. Pramanik and Tripathy (2017) reported that application of micronutrients mixture have marked influence on growth and yield attributing characters of onion like plant height, number of roots per plant, diameter of bulb and bulb weight as well as bulb height. The improvement in the nutrients use efficiency could be attributed to an enhancement in absorption and assimilation of the micronutrients which provided balanced nutrition to the crops for higher growth and thereby nutrients uptake which ultimately resulted into higher yield of the crops. The increase in content of micronutrients and their uptake by garlic crop due to use of multi-micronutrients fertilizers have also been reported by El Sayed et al., (2015) and El-Tohamy et al. (2009) in garlic and Hamid and Mohsen (2013) in tomato crop.

Conclusion

As a result of research it is established that zinc and boron have the greatest influence on plant growth and formation of the leaf apparatus, and the pigment complex reaches its maximum by the application of zinc. By the application of boron, the increase in chlorophyll content was the least significant - 10.9% at the maximum norm - 6 kg/ha. As a result of research it was found that the activity of key enzymes of the antioxidant system (SOD, CAT, POD, GR, GST) differs significantly in the variants of the experiment and depends on the micronutrient and its norm. The dynamics of the activity of antioxidant enzymes was similar to the dynamics of growth processes. The activity of enzymes was the highest at optimal norm of micronutrients. Among the studied enzyme complex, the activity of catalase (CAT) and glutathione S-transferase (GST) increased most significantly. The most significant increase in the weight of the bulb was influenced by zinc, where the increase was 8.93–12.50 g. The use of zinc and boron contributed to a greater accumulation of dry matter and extended the marketability of garlic bulbs up to 210 and 220 days for warm storage and up to 240 and 260 days for cold.

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