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Effects of biologicals on shallot yield and quality

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ABSTRACT

There are very few publications reporting the results of studies on the effects of biologicals on yields and quality of bulbaceous plants. In view of this, the purpose of this paper was to scientifically substantiate effects of biologicals containing bacterial strains of *Pseudomonas aureofaciens* B-111 (IBM B-7096) and *Pseudomonas aureofaciens* B-306 (IBM B-7097) as well as spores and mycelium of the fungus *Trichoderma viride* on the yield and quality of shallot bulbs. To achieve the purpose, the following objectives were set: to investigate biometric parameters of shallot plants depending on biological treatments, to determine the yield and to evaluate the impact of the biologicals on the biochemical composition of bulbs. The biologicals increased in the mean bulb weight by 6–15% and the plant height by 9–15%. The total yield was raised by up to 16.2%. The share of marketable yield was increased by 1.2–7.0%. There was a slight increase in the ascorbic acid content in bulbs (by 3–22%) and a slight decrease in the dry matter content (0.24–1.35%). A slight decrease in the total sugar content was observed (by 0.16–1.76%, depending on biologicals and shallot cultivars).

Keywords: shallot, yield, quality, biologicals, effectiveness.

INTRODUCTION

Shallot (*Allium ascalonicum* L.) belongs to the genus *Allium*. In Europe, shallot is most widely used in the Netherlands, France and Belgium. The top producers in the tropical region are Indonesia and Thailand. Shallot is also common in the USA, Kazakhstan, Moldova, Great Britain, Singapore, Malaysia, Estonia, Ethiopia, and Vietnam. In the Asian region, China, India and Pakistan are the largest producers of shallots (Moldovan et al., 2022; Sałata et al., 2022).

Shallots have a richer and sweeter taste than onions. They are a rich source of flavonoid antioxidants, such as quercetin and kaempferol. They contain proportionally higher concentrations of vitamins and minerals than onions, especially vitamin A, pyridoxine, folate, thiamine, and vitamin C (Shahrajabian et al., 2020). Shallot yield is affected by various factors, both environmental and technological ones, every year. Cultivation of vegetables with increased quality depends on multiple farming factors: varieties, soils, predecessors, vegetation length, precipitation amounts, sum of active temperatures, ratio of mineral fertilizers, etc. The basis of vegetable quality is laid in the field during the growing period. It is difficult to conduct so many comprehensive studies that would reflect dependences of product yield and quality on farming as well as meteorological conditions.

Currently, innovative technologies in the agricultural sector are designed to replace traditional chemical fertilizers, which pollute the environment, with biologicals. Biologicals are used to stimulate plant growth, improve nutrient uptake by plants and inhibit the growth of pathogenic fungi or bacteria. They can consist of bacteria, fungi and their waste products, plant extracts or animal-derived compounds. Bacteria, fungi and yeasts are used for biocontrol of plant pathogens, plant growth enhancement, mitigation of symptoms of environmental stresses caused by weather or soil factors, such as drought or low nutrient availability (Pylak et al., 2019).

Microorganisms of the genera *Pseudomonas* sp. and *Trichoderma* sp. play important roles in suppressing the development of diseases on garlic plants (Pusik et al., 2021). Recently, multiple functions of *Trichoderma* and *Pseudomonas* have been proven and, on this basis, biologicals Trichodermin, Gliocladin and Phytopsin have been created.

Fungi of the genus *Trichoderma* are noticeable for antibiotic (produce antibiotics gliotoxin, viridin, alamethicin) and antagonistic properties. *Trichoderma* microorganisms participate in ammonification and nitrification (Asad, 2022) and boost the fungicidal activity of plant cell sap. Fungi of the genera *Pseudomonas* sp. and *Trichoderma* sp. activate redox processes and enhance adaptive responses of agricultural plants.

The fungal culture of *Trichoderma harzianum* VIZ–18 produces several metabolites and is an ingredient of Gliocladin, which affects the sulfur content in plants. Another formulation, Gaupsin, can suppress an average of 92% of fungal, 70% of bacterial and 15% of viral diseases during onion storage. The action of *Pseudomonas aureofaciens* is attributed to tissue colonization, syntheses of antifungal compounds and complex enzymatic activities (Pusik et al., 2020). Positive effects of the bacteria *Azospirillium lipoferum, Azotobacter chroococcum* and *Bacillus megaterium* on soil fertility and yields of beans (by 15.2%), rapeseeds (by 20.8%), sweet corns (by 11%), and potatoes (by 13%) were noted in comparison with conventional chemical fertilizers (Toader et al., 2019).

The bacteria *Pseudomonas putida, Microbacterium laevaniformans* and *Pantoea agglomerans*, which were used separately or in a mixture, exerted stimulating effects on potato yields. These bacteria converted the hardly available forms of phosphorus into readily available ones (Zaidi et al., 2015). Italian scientists reported about the positive effects of a *Trichoderma virens* (GV41)-based biostimulant on Iceberg lettuce and arugula yields as well as nutrient absorption by Iceberg lettuce and arugula plants. This biostimulant increased the efficiency of nitrogen use from fertilizers, promoted the absorption of natural soil nitrogen by both Iceberg lettuce and arugula, as well as improved nitrogen uptake by roots under conditions of low nitrogen availability (Fiorentino et al., 2018). Application of a *Pseudomonas putida* (strain P3-57)-based bioproduct, P3-57-100%, did not increase cucumber yield but improved in the quality cucumbers: the aroma and taste of juice were enhanced and fruits had low nitrate levels. The protein content was also increased (Kafi et al., 2021).

Biologicals can be applied to soil and plants by spraying leaves (foliar application), soaking seeds (seed treatment) and by irrigation (fertigation/soil application). Biologicals increase seed productivity, biomass accumulation, photosynthesis efficiency and drought tolerance of plants (Naik et al., 2020). Therefore, the main difference between biologicals and other plant protectors resides in their ability to affect harmful organisms by stimulating genetically determined protective capacities of plants. When stimulating plants' immunity, biostimulants induce a complex of non-specific resistance to many fungal, bacterial and viral diseases as well as tolerance to other adverse environmental factors (high temperatures and other stresses). The use of this property of biologicals in shallot cultivation creates fundamentally new approaches to managing shallot quality.

Review of scientific publications on effects of biologicals on vegetable yields and qualities showed scarcity of studies on bulbaceous plants, while onions rank third among vegetable plants grown around the world, after legumes and potatoes (Perković et al., 2021).

MATERIALS AND METHODS

The purpose of this study was to scientifically rationalize the impact of the biologicals Guapsin and Trichodermin on the yield and quality of shallot bulbs, which will enable increasing yields, reducing microorganisms-inflicted damage and extending consumption duration. To achieve the purpose, it was necessary to solve the following tasks:

- to measure the biometric parameters of shallot plants depending on treatments with the biologicals;
- to determine the shallot yield depending on application of the biologicals;
- to evaluate the effects of the biologicals on the biochemical composition of shallots.

The study object was the plant growth and development as well as productive and qualitative indicators of shallot bulbs depending on plant treatments with the biologicals during the growing period. The study subject was the yield and quality of shallot bulbs. The hypothesis of the study was as follows: the biologicals stimulate plant growth, improve the absorption of nutrients by plants and inhibit the development of pathogenic fungi or bacteria. Given that the effectiveness of treatments of vegetable products with biologicals has been proven, similar results could be expected when treating shallot plants.

Pedo-climatic and meteorological conditions

The field experiments were carried out in 2017–2019. The experimental fields are located in the left-bank forest-steppe (Kharkivskyi District, Kharkivska Oblast). The soil in the experimental fields is typical low-humus heavy loamy chernozem, with the humus content of 4.3% and soil solution pH of 6.2. The levels of mobile phosphorus (106–119 mg/kg of soil) and exchangeable potassium (93 mg/kg of soil) in the soil are elevated.

The climate in this region is moderately continental. The meteorological conditions in 2017–2019 according to the Meteorological Station of the Institute of Vegetable and Melon Growing of the National Academy of Agrarian Sciences (IVMG NAAS) of Ukraine are summarized in Table 1. Thus, the mean daily air temperature in April 2017 was 9.7 °C, with the long-term mean temperature of 9.6 °C. The precipitation amount was 69.0 mm, which was significantly more than the long-term mean value (40.8 mm). In May, there was significantly less precipitation (20.5 mm vs. the long-term mean value of 55.5 mm). The mean daily temperature was 14.7 °C, which was similar to the long-term mean value. The air temperatures in June and July were also similar to the long-term mean values, while the precipitation amounts were smaller (23.0 mm and 19.0 mm) than the long-term mean values by 42.0 and 54.3 mm, respectively. Such weather beneficially influenced the shallot yield.

In 2018, the air temperatures in April and May were 2.5 °C and 3.3 °C higher than the long-term mean values; the precipitation amounts were significantly lesser than the long-term mean values:

Table 1. Meteorological conditions during the growing periods of 2017–2019

Year	April			May			June			July		
	I	II	III	I	II	III	I	II	III	I	II	III
Mean daily air temperature, °C												
2017	11.0	7.4	10.8	15.2	11.3	17.8	18.9	19.8	23.6	20.8	22.3	24.2
2018	8.3	12.6	15.4	21.8	18.0	19.7	19.2	21.7	22.7	21.7	22.3	24.7
2019	8.8	9.2	13.0	15.3	18.6	19.9	23.2	25.3	23.5	21.6	20.8	22.1
Long-term mean value (1945–1990)	7.9	9.2	11.6	14.9	16.8	17.9	19.7	20.0	20.8	21.0	21.6	21.5
Precipitation amount, mm												
2017	-	58.5	10.5	2.5	12.0	6.0	1.0	5.5	16.5	-	6.5	12.5
2018	6.5	5.0	7.5	-	17.5	-	13.5	7.5	59.5	1.0	45.5	8.5
2019	-	19.5	6.0	23.5	3.0	32.0	12.5	-	1.5	38.0	2.5	10.5
Long-term mean value (1945–1990)	13.3	13.5	14.0	16.9	12.6	26.0	17.9	25.9	21.2	25.4	24.1	23.8

19.0 and 17.5 mm, respectively, vs. 40.8 and 55.5 mm. In June and July, the air temperature was 21.2 °C and 22.9 °C, respectively, with the long-term mean values of 20.2 °C and 21.3 °C. The precipitation amount in June was 80.5 mm compared to the long-term mean value of 65.0 mm; in July, it was 55.0 mm or by 18.3 mm less than the long-term mean value, affecting the shallot yield.

The mean daily air temperature in April 2019 was 10.3 °C vs. the long-term mean value of 9.6 °C; the precipitation amount was 25.5 mm, which is significantly less than the long-term mean value (40.8 mm). In May, precipitation was more abundant (58.5 mm compared to the long-term mean value of 55.5 mm). The mean daily temperature was 17.9 °C, which was similar to the long-term mean value. In June and July, the air temperatures were also similar to the long-term mean values; the precipitation amounts were 14.0 and 51.0 mm, respectively, or by 51.0 and 22.3 mm less than the long-term mean values, which had an impact on the shallot yield.

Methods and experiment design

Shallots were grown in a vegetable crop rotation, with tomato as a forecrop. The soil moisture was maintained at 80% minimum moisture-holding capacity (MMHC) using drip irrigation. The shallots were planted within the second 10 days of April; the planting scheme was 70 × 8 cm. The soil preparation and plant care were traditional for this growing zone, except for the studied factors (Table 2). The variants were placed systematically. The experiments were two-factor: factor A – shallot cultivar, factor B – experimental variant. The area of the accounting plot is 10.8 m^2. The experiments were carried out in three replications.

The plants were treated with the biologicals during the growing period, starting from the leaf regrowth phase and then every 10 days. One variant of the experiment also included spraying of bulbs with a mixture of the biologicals before planting. The growth, development and phytosanitary condition of plants were monitored during the growing period. The bulb yield and quality were determined after harvest. The growth and development of plants were evaluated during the shallot cultivation. The shallots were harvested within the second 10 days of July when bulbs were fully formed: dry necks and tunic leaves, 99% top lodging. The yield was estimated by weighing bulbs harvested from the record plots. The yield structure (marketable, non-marketable bulbs) as well as the number and weight of diseased bulbs were determined. After harvest, the chemical composition of bulbs was determined: dry matter content (DSTU 7804:2015), total sugar content (DSTU 4954:2008) and vitamin C content (DSTU 7803:2015).

Characteristics of shallot cultivars

Lira (Figure 1) is an early-ripening cultivar bred at the IVMG NAAS of Ukraine. The vegetation period is 72–74 days. It is spicy, universal in use. The bulb is elliptical, weighs 40–50 g. The bulb yield is 15.0–16.4 t/ha; the green top yield

Figure 1. Cultivar Lira

Table 2. Experiment design

No	Variant	Dose, L/ha
1	Control (no treatment)	-
2	Gaupsin (G)	5.0
3	Trichodermin (T)	5.0
4	Gaupsin + Trichodermin (G+$T_{vegetation}$)	2.5+2.5
5	Gaupsin + Trichodermin (G+$T_{bulbs + vegetation}$) *Pre-planting treatment of bulbs + in-vegetation treatment*	10.0+10.0 2.5+2.5

Figure 2. Cultivar Hranat

is 28 t/ha. The cultivar is characterized by even re-growth of green leaves (Catalogue of varieties, 2025). Hranat (Figure 2) is an early-ripening cultivar bred at the IVMG NAAS of Ukraine. The vegetation period is 82–90 days. The bulb is elliptical. The bulb weigh is 20–40 g. The fleshy leaves have a reddish epidermis. The bulb yield is 18.3 t/ha; the green top yield is 37.3 t/ha (potentially 60). The cultivar is resistant to leaf yellowing (Bilenka et al., 2019).

Characteristics of biologicals

Guapsin is a biological insecticide-fungicide. It is used to increase plant yields as well as protect garden and field crops against fungal diseases and pest insects. While remaining active for a long time, the product is safe for plants and beneficial insects. Guapsin also mitigates stress states in plants, accelerates crop growth and boosts immunity.

The Guapsin composition is as follows: aqueous suspension of bacterial strains *Pseudomonas aureofaciens* B-111 (IBM B-7096) and *Pseudomonas aureofaciens* B-306 (IBM B-7097), their metabolic products, starting doses of macronutrients (NPK) (Guapsin. Insecticides. Internet-shop AgroRancho.com.ua.; Stancic et al., 2015). Trichodermin (Viridin) is a biological fungicide for protecting plants against a wide range of fungal and bacterial diseases. It contains a specially selected strain of the fungus *Trichoderma* with enhanced syntheses of multiple natural fungicidal and biologically active substances. The fungus suppresses the development of phytopathogens by direct parasitism, competition for the substrate, secretion of enzymes, antibiotics (gliotoxin, viridin, etc.) and other biologically active substances that inhibit the development of many pathogenic species. In soil, the fungus develops on various cellulose-rich plant residues as well as on mycelia and fruiting bodies of phytopathogens, decontaminating the soil from pathogens. The fungus is able to form mycorrhiza with plant roots, thereby increasing the area of absorption of nutrients and water from soil by plants. The Trichodermin composition is as follows: spores and mycelium of the fungus *Trichoderma viride* (lignorum) and metabolites (biologically active substances) (Viridin (Trichodermin) EnzIm Agro).

Table 3. Biometric parameters of shallot plants depending on treatments with the biologicals (mean for 2017–2019)

Variant	Number of bulbs per bush	Mean bulb weight, g	Plant height, cm	Number of leaves per stem
Lira				
Control	4.8	21.0	45.4	6.4
G	5.2	22.4	50.6	6.1
T	5.3	22.5	52.2	6.3
G + T $_{(vegetation)}$	5.3	23.1	53.7	6.2
G + T $_{(bulbs + vegetation)}$	5.4	23.8	51.5	6.1
Hranat				
Control	5.2	24.8	44.1	6.6
G	5.4	26.4	48.5	7.1
T	5.1	27.3	48.5	7.4
G + T $_{(vegetation)}$	5.0	29.3	50.7	7.6
G + T $_{(bulbs + vegetation)}$	5.3	27.5	50.6	7.5
LSD_{05}	1.9	1.2	0.9	2.8

RESULTS

The 2017–2019 studies justified the feasibility of using biologicals (Guapsin, Trichodermin and their mixtures) on shallots. Application of the biologicals to shallot cv. Lira slightly increased (by 7.7–11.1%) the number of bulbs per bush compared to the control (Table 3). In the control, there were 4.8 bulbs, while Guapsin, Trichodermin and their mixture increased this parameter to 5.2–5.4 bulbs. At the same time, the mean bulb weight was 21.0 g in the control. The biologicals significantly (LSD_{05} = 1.2 g) increased the mean shallot bulb weight by 6.3–11.8%. In cv. Hranat, Guapsin had the greatest, however insignificant, effect on the number of bulbs per bush (3.7%), while Trichodermin and Guapsin + Trichodermin were ineffective. The effect of the biologicals on the mean bulb weight was significant (LSD_{05} = 1.2 g): in the control, the mean bulb weighed 24.8 g, while in the experiments with the biologicals, the mean bulb weighed 26.4–29.3 g, i.e. bulbs were 6.1–15.4% heavier after the biological treatments than in the control. It should be noted that Guapsin + Trichodermin had a more pronounced effect on the mean bulb weight than each of the biologicals alone. Analysis of variance demonstrated that the biologicals contributed 65% to the increase in the mean bulb weight in the studied shallot cultivars.

The biologicals significantly increased (LSD_{05} = 0.9 cm) the plant height: by 5.2–8.3 cm and 4.4–6.6 cm in cvs. Lira and Hranat, respectively, compared to the control. It should be noted that the tallest plants of cvs. Lira and Hranat were grown when the biological mixture (Guapsin + Trichodermin) was used: 53.7 and 50.7 cm, respectively. Vegetation temperature-including statistical processing of experimental data showed that the shallot plant height was inversely moderately correlated with the sum of effective temperatures (r = -0.6). In addition, analysis of variance demonstrated that the contribution of the biologicals to the shallot plant height was 24%, while the responses of cultivars to the biologicals (combined effect of factors A and B) contributed 67% to this parameter. The treatments with the biologicals did not significantly affect the number of leaves: in cv. Lira, there were 6.1–6.3 leaves per stem (6.4 leaves in the control); in cv. 'Hranat', there were 7.1–7.6 leaves, or by 7.0–13.2% more than in the control. The greatest number of leaves in cv. Hranat was observed when the biological mixture was used during the vegetation.

The total yield of shallots (Table 4) in the experiments with the biologicals was significantly higher (LSD_{05} = 0.6 t/ha) compared to the control. Cultivar Lira was more responsive to the biologicals: the total yield in the experiments with the biologicals was 13.7–14.2 t/ha vs. 11.9 t/ha without biologicals. That is, the gain in the total yield was 13.8–16.2% compared to the control. In cv. Hranat, the biologicals increased the total yield by 5.1–8.4%. The higher yield is attributed to the increased number of bulbs per bush and bulb weight. Correlation analysis confirmed a relationship between these parameters (r = 0.98). Analysis

Table 4. Shallot yield after using the biologicals (mean for 2017–2019), t/ha

Variant	Yield, t/ha		Marketable to total yield, %
	Total	Marketable	
Lira			
Control	11.9	10.5	88.2
G	13.7	12.6	92.0
T	14.2	12.7	89.4
G + T $_{(vegetation)}$	13.9	12.8	91.4
G + T $_{(bulbs + vegetation)}$	14.2	13.4	94.4
Hranat			
Control	13.1	11.9	90.8
G	14.2	12.8	90.1
T	14.1	13.2	93.6
G + T $_{(vegetation)}$	14.7	13.2	89.8
G + T $_{(bulbs + vegetation)}$	13.8	13.5	97.8
LSD_{05}	0.6	0.8	

of variance showed that the contribution of the bioproducts to this parameter was 36% and that the combined contribution (cultivar + bioproduct) was 35%. The biologicals significantly (LSD_{05} = 0.8 t/ha) increased the marketable yield of shallots. In cvs. Lira and Hranat, the marketable yield in the experiments with the bioproducts exceeded the control by 16.7–21.6% and 7.0–11.9%, respectively. The mixture (Guapsin and Trichodermin) used for pre-planting treatment of bulbs and during the vegetation had a greater impact on the marketable yield. Analysis of variance showed that the contribution of biologicals to the marketable yield was 30% and that the combined contribution (cultivar + bioproduct) was 36%.

The bioproducts also increased the share of marketable yield in the total yield by 1.2–6.2% in cv. Lira and by 1.5–7.0% in cv. Hranat. It should be noted that the mixture (Guapsin + Trichodermin) used for pre-planting treatment of bulbs and during the vegetation, had the greatest impact on the marketable part of the yield. The effects of the biologicals on the biochemical composition of shallots were investigated (Table 5). It was noted that the biologicals resulted in a slight decrease in the dry matter content in the bulbs of cvs. Lira (0.24–1.35%) and Hranat (0.27–1.27%). Concurrently, their application reduced the total sugar content by 0.32–1.76% in cv. 'Lira' and by 0.16–0.72% in cv. Hranat. However, there was a slight increase in the ascorbic acid content: by 3–21% in cv. Lira and by 14–22% in cv. Hranat.

DISCUSSION

Biologicals stimulate the growth and development of vegetable plants as well as abate stresses caused by adverse weather, as a result increasing yields and improving quality of vegetables. For example, by inoculating white cabbage seeds with bioproducts containing 5% *Trichoderma viride* and *Pseudomonas fluorescens*, it was possible to obtain seedlings with a higher biomass: such seedlings were 39% taller, the stem diameter was 50% larger, and the seedling leaf area was increased by 89%. An increase in cabbage yield of up to 37% was also achieved due to an increased head diameter (Vij et al., 2024).

Pre-planting treatment of potato tubers and treatment of plants during the growing period with bioproducts Biospectr BT (contains rhizosphere bacteria of the genus *Pseudomonas*) and Trichopsin BT (active ingredient - spores of *Trichoderma viride* T-4 and rhizosphere bacterium *Pseudomonas aureofaciens* 306) increased in the plant height and number of stems per potato bush by 6% compared to untreated control plants. The use of these agents also increased the potato yield by 10% (Andriychuk et al., 2023).

The pre-planting treatment of tomato seedlings and treatment of plants during the growing period with a mixture of biologicals containing *Trichoderma harzianum* and *Pseudomonas fluorescens* increased the plant height by 32.5% and fruit weight by 39.7% compared to untreated plants (Kabdwal et al., 2019).

Table 5. Effects of the biologicals on the biochemical composition of shallots (mean for 2017–2019)

Variant	Dry matter, %	Ascorbic acid, mg/100 g	Total sugars, %	Monoses, %	Sucrose, %
Lira					
Control	18.91	3.98	13.27	1.02	11.65
G	18.67	4.11	11.51	1.06	9.94
T	18.37	5.03	12.95	1.12	11.25
G + $T_{(vegetation)}$	17.56	4.39	13.27	1.04	11.63
G + $T_{(bulbs + vegetation)}$	18.01	4.28	12.50	0.94	10.99
Hranat					
Control	19.67	4.36	12.27	1.56	10.31
G	19.40	5.05	11.55	1.70	9.25
T	19.18	5.60	11.95	1.75	9.81
G + $T_{(vegetation)}$	18.40	5.25	12.11	1.75	10.11
G + $T_{(bulbs + vegetation)}$	19.21	5.33	12.01	1.62	9.87
LSD_{05}	3.57	4.94	2.19	9.40	2.65

The use of beneficial microorganisms such as *Pseudomonas* (Novello et al., 2021) and *Trichoderma* spp. (Younes et al., 2023) has a positive effect on the growth, yield, and biochemical composition of onion crops. These microorganisms promote better nutrient uptake, stimulate growth processes by producing hormones, increase stress resistance, and suppress various diseases (Soni and Keharia, 2021; Cao et al., 2023). For instance, according to Dutta et al. (2024), most Trichoderma strains can produce the important plant hormone indole-3-acetic acid. Under field conditions, this leads to improved growth parameters (plant height, leaf diameter), higher chlorophyll content in leaves, as well as increased dry matter content, bulb diameter, and yield compared to the control.

Possible reasons for the reduction in some chemical components (dry matter and total sugar content) in bulbs under the influence of biopreparations include:

1. Increased enzyme activity (peroxidase, catalase), which indicates enhanced metabolism (Ortega-García et al., 2015).
2. Increased total bulb mass due to water and cellular volume, which lowers the percentage of dry matter and sugars, even if the absolute amount of dry matter remains similar to the control (Akbar et al., 2024).
3. Biopreparations may shift plant development toward more active vegetative growth, which reduces the flow of assimilates into the bulbs (Younes et al., 2023; Dutta et al., 2023).

These findings agree with the obtained results on shallots. However, it should be noted that the majority of publications are dedicated to studying the effect of biological products against diseases of vegetable plants during the growing season and during storage. In the conducted studies, the influence of abiotic factors (weather factors) on the chemical composition of shallots was also evaluated, including: the dry matter content in bulbs (Y) of the studied cultivars depended on the sum of active temperatures for the first 10 days of May (x_1) and the sum of active temperatures during April growing (x_2). The dependence is described by the following regression equations:

For cv. Lira:

$$Y = 0.037652 \cdot x_1 + 0.034012 \cdot x_2 + 7.594596 \quad (R = 0.96;\ R^2 = 0.92;\ R^2 = 0.86) \tag{1}$$

For cv. 'Hranat':

$$Y = 0.03451 \cdot x_1 + 0.01217 \cdot x_2 + 11.95055 \quad (R = 0.92;\ R^2 = 0.85;\ R^2 = 0.76) \tag{2}$$

The dependence of sucrose accumulation in bulbs (Y) in the studied shallot cultivars on meteorological conditions at the end of the crop vegetation, i.e. on the precipitation amount for the third 10 days of June (x_1) and the sum of active temperatures for the third 10 days of June (x_2) is described by the following regression equations:

For cv. Lira:

$$Y = -0.011314 \cdot x_1 + 0.028254 \cdot x_2 + 11.95055 \quad (R = 0.96;\ R^2 = 0.92;\ R^2 = 0.86) \tag{3}$$

For cv. Hranat:

$$Y = -0.026010 \cdot x_1 + 0.046651 \cdot x_2 + 1.423894 \quad (R = 0.86;\ R^2 = 0.74;\ R^2 = 0.57) \tag{4}$$

However, despite the wide range of positive effects that *Trichoderma* spp. and *Pseudomonas aureofaciens* have on agricultural plants due to their diverse mechanisms of biological control, there are also certain limitations to their use. This is particularly true for preparations containing different strains of *Trichoderma*. For example, the use of high doses of such preparations (10 times the recommended rate) can inhibit growth processes during the germination of onion seeds (Rivera-Méndez et al., 2021). Furthermore, preparations with different *Trichoderma* strains have been observed to have a certain inhibitory effect on other beneficial soil microorganisms or on the components of other biopreparations.

It should also be noted that comparing the effects of biopreparations with mineral fertilizers is incorrect due to the different mechanisms and magnitudes of their influence on plants. Mineral fertilizers provide plants with ready-to-use nutrients, while biopreparations activate natural mechanisms of nutrient uptake and enhance growth processes.

Additionally, it is impossible to single out a specific "gold standard" among biopreparations because of their varying effects on plants. If the group of biopreparations that stimulate growth and control phytopathogenic microflora are considered, then the preparations with *Pseudomonas aureofaciens* and *Trichoderma* spp. are almost the only widespread representatives. Therefore, it is incorrect to compare them with the preparations that only control phytopathogens (Bacillus subtilis), or only improve growth processes (*Azotobacter, Paenibacillus polymyxa, Bacillus mucilOginosus, Glomus* sp.).

CONCLUSIONS

The treatments of shallot with the biologicals Trichodermin and Guapsin as well as with their mixture during the growing period had stimulating effects on the plant growth and development. There was a significant 6–15% increase in the mean bulb weight. Shallot plants became taller by 9–15% under the influence of the biologicals. It should be noted that the mixture of Guapsin and Trichodermin resulted in a more pronounced increase in these two parameters than using these biologicals separately.

As a result of improved plant development, the total yield of cvs. 'Lira' and 'Hranat' was increased by 13.8–16.2% and by 5.1–8.4%, respectively. The share of marketable yield was raised by 1.2–6.2% in cv. 'Lira' and by 1.5–7.0% in cv. 'Hranat'. The greatest impact on the marketable part of the yield was recorded for the mixture of Guapsin and Trichodermin, which was used to treat bulbs before planting and plants during the growing period.

The treatments of plants with the biologicals during the growing period slightly increased the ascorbic acid content in bulbs: by 3–21% in cv. 'Lira' and by 14–22% in cv. 'Hranat'. The dry matter content in bulbs was insignificantly reduced: by 0.24–1.35% in cv. 'Lira' and by 0.27–1.27% in cv. 'Hranat'. There was also a slight decrease in the total sugar content: by 0.32–1.76% in cv. 'Lira' and by 0.16–0.72% in cv. 'Hranat'.

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