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The Influence of Biopreparations on the Growth and Development of Tomatoes under Biological Cultivation

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ABSTRACT

The study of the effect of biological preparations on the growth, development and yield of tomatoes was carried out at the experimental field of the Educational-Scientific-Practical Center of the Mykolaiv National Agrarian University under the conditions of the Southern Steppe of Ukraine according to generally accepted methods: field, laboratory and statistical. In order to study the elements of the organic tomato cultivation technology, a two-factor field experiment was conducted under the conditions of the Southern Steppe of Ukraine: Factor A: cultivar: 1. Rio Fuego; 2 Missouri. Factor B: complex fivefold treatment with biological preparations: Azotophyt-r, FitoHelp, Organic Balance, Mycohelp, Actoverm, Lepidocide during the growing season: first – 12–14 days after the emergence of seedlings, then every 12–14 days. As a result of the conducted research, the effect of biological preparations on biometric indicators of plant growth and development, namely plant weight, above-ground height and root length as well as dry weight accumulation in the vegetative mass of Rio Fuego and Missouri tomato cultivars. The above-ground mass of tomato plants of the Rio Fuego variety in the flowering phase in the variant with treatment was 196.8 g·piece^{-1}, which exceeded the weight of the plant from the control variant by 38.2 g·piece^{-1}, or 24.1%. The positive dynamics of the increase in raw vegetative mass during the treatment was noted during the fruiting period – 1036.4 g·piece^{-1}, in the control – 857.3 g·piece^{-1}. The increase in the raw mass of one plant, on average, was 20.9%. It was found that the use of biologics during the growing season of tomatoes contributed to an increase in the aboveground mass and a decrease in the percentage of roots to the total mass of the studied cultivars. The effect of biological preparations on the commercial yield of tomato fruit, which differed according to the years of research, was studied. The biologics used throughout the years with different agroclimatic conditions gave approximately the same results. The yield of the Rio Fuego cultivar increased in 11.1 Mg·ha^{-1}, or 24.9% due to the biologics. The Missouri cultivar turned out to be less productive throughout the years of research, but it was more responsive to the treatment with biologics, with the increase in the marketable fruit yield in comparison with the control being 10.9 Mg·ha^{-1} (29.9%).

Keywords: biologics, Rio Fuego, Missouri tomato cultivars, fresh weight, dry weight, root system productivity, marketable tomato yield.

INTRODUCTON

The significant focus on increasing crop productivity over the past decades has been followed by the use of significant numbers of chemicals in agricultural production, which has led to an excessive burden on the environment, including soils. The effect of the increased use of chemicals is becoming less and less sustainable, and soils are rapidly losing their fertility. Therefore, in the near future, agricultural development trends will be aimed at restoring soil fertility and improving the environmental situation through the use of environmentally friendly technologies, including the use of agronomical beneficial microorganisms. Microbiological preparations for enhancing nitrogen fixation from the air and mobilization of phosphorus compounds from the soil play a significant role in this, reducing the consumption of mineral fertilizers and increases

the realization of the genetic potential of plants (Patyka, 2004; Domaratskiy et al., 2022).

The development and use of new environmentally friendly crop protection products that are non-toxic to humans, animals and the environment is crucial today. Bioinoculants and other bio-stimulants, along with bio-pesticides, are gaining popularity to improve crop growth, health and yield, as well as to suppress the development of phytopathogens. The use of biological preparations is one of the ways to increase plant productivity while preserving soil fertility without worsening the ecological state of the environment (Domaratskyi et al., 2020). They help reduce the use of synthetic materials and improve the environment and human health (Dara, 2022). Compared to the use of high rates of mineral fertilizers and plant protection agents, biologically active substances, universal growth regulators, adaptogens and anti-stressors can reduce their negative impact (Domaratskiy, 2021; Pichura et al., 2023). A promising trend in vegetable growing is the use of such substances in the cultivation of tomatoes, which allows revealing the potential of new cultivars and hybrids and obtaining maximum yields.

An analysis of the scientific literature on the use of biological products for growing vegetables and, in particular, tomatoes shows inconsistent results of their use, but most researchers agree that they create a significant environmental effect. Kolisnyk, et al. (2016) indicate the effectiveness of using these substances for obtaining friendly and uniform seedlings, increasing yield, and receiving products at an early date. For example, (Rogach et al., 2018) point to the positive effect of the Vitazyme growth stimulator on the growth, development, and productivity of the main vegetable crops, i.e. tomatoes, peppers, and eggplants. The preparation treatment led to an increase in the linear size of solanaceous plants, which resulted in increased number of leaves per plant and leaf mass. Under the influence of the preparation, the leaf surface area and leaf index increased. The use of the preparation led to an increase in the concentration of chlorophyll and an increase in the chlorophyll index in all crops. Studies by (Kolisnyk et al., 2016) revealed that seed treatment with Azotophyt-R increased the germination energy of tomato seeds by 13%, seed germination by 3%, as well as increased the weight of roots, stems and leaves of seedlings in Azotophyt-R-treated seeds. Similar results were obtained by (Vdovenko, 2019) when growing tomatoes in the open field using the seedling method in the Vinnytsia Oblast. The complex use of biological products led to rapid rooting of plants due to better supply of the root system with nutrients and organic compounds, accelerated the onset of the main phases of growth and development, as well as suppressed the activity of pathogenic microorganisms. The microorganisms contained in the biologics contributed to the setting and formation of more fruits of early and medium early cultivars. The researcher points out that the use of biological products for growing tomatoes provided an increase in total yield to 38.5 $Mg \cdot ha^{-1}$, or 22%, an increase in product marketability to 80%, better taste, and appearance of the fruit metting the requirements of the standard. In studies of the influence of biological substances of the BTU-center line on germination, growth and development of tomato plants, (Kalytka, Karpenko, 2011; Gerasko, Vdovenko, 2018) it was established that the treatment of seeds with biopreparations during the vegetation period of tomatoes accelerated the passage of phenological phases and the onset of fruiting, by an average of 6–8 days. Also, biologics significantly influenced the structure of yield: the diameter of the fruit increased by 19 %, which increased the yield compared to the control variant.

In addition to speeding up the phenological stages, improving the structure of the crop, increasing the yield of tomatoes, numerous publications by (Klochko et al., 2018; Tytova, Sergienko, 2018) indicate the effect of the biopreparations against pathogens and high antagonistic activity against various groups of phytopathogenic microorganisms, as well as the synthesis of antibiotic and phytohormonal compounds. For example, (Klochko, et al., 2018) determined the effect of *Pseudomonas sp.* 2303 culture on nematodes, as a result of which 10–15% of phytoparasitic and saprobiotic nematodes died after 24 hours. The treatment with preparations of nitrogen-fixing and phosphate-mobilizing bacteria combined with fungicides with reduced consumption rates helped to control the incidence of tomatoes, cucumber, and cabbage with whitehead mycoses and increase their yield, which makes it possible to reduce the pesticide load on agrocenoses by an average of 17–33%. A lower number of nematodes in the soil and an increase in tomato yields as a result of the introduction of *Bacillus*

methylotrophicus R2-2 and *Lysobacter antibioticus* into the soil together with ameliorants were reported by (Zhou, et al., 2016). Similar conclusions were drawn in studies (Varkey, et al., 2018) under greenhouse conditions. As a result of inoculation of tomato roots with the endophytic fungus *Piriformospora indica* and two rhizobacteria (*Bacillus pumilus* and *Pseudomonas fluorescens*), plant immunity was enhanced, which led to reduction of nematodes.

Many researchers highlight the positive impact of biologics on the phytosanitary condition of tomato crops. (Yarovy, Kuzmenko, 2013) indicate that the treatment of tomato plants during the vegetation period showed a decrease in the number of pathogens of fungal origin: Fusarium (*F. oxysporum f. sp. lycopersici*) by 4.8%, *Aspergillus* spp. by 2.3%, *Rhizopus* spp. by 5.8%, respectively. Experiments of (Kipngeno, et al., 2016) with *Bacillus subtilis* and *Trichoderma asperellum* bacteria reduced the damage to tomato seedlings by *Pithium* bacteria by 40–45% and significantly increased the dry weight of plants, promoted the growth of roots and shoots, leaf area in tomatoes. Studies by American scientists (Fan, et al., 2017; Olanrewaju, et al., 2017) indicate that the products based on *Bacillus* species, which are well known as PGPB and BCA, are effective against various phytopathogens. In the *Bacillus amyloliquefaciens* group (*Bacillus Amyloliquefaciens, Bacillus siamensis* and *Bacillus velezensis*), *Bacillus velezensis* species were recognized as plant-associated bacteria and are able to establish beneficial relationships with plants directly or indirectly. For example, the biologics based on bacteria of the *Ralstonia* and *Mitsuaria* genera showed good results against bacterial wilt of tomatoes (Marian, et al., 2018).

Kovalyov (2022) investigated the formation of a thin-leaved diplotaxis crop under the conditions of using Amalgerol and sodium humate in a film greenhouse. Because of the experimental studies, the high efficiency of the use of Amalgerol and sodium humate in the cultivation of thin-leaved double-rowed Gracia cultivar was established. At the same time, the increase in the yield of thin-leaved double-rowed cultivar with the use of Amalgerol and sodium humate was 5.57 and 3.48%.

A significant number of researchers point to the positive effect of biological products on the quality of tomato fruits. Under the influence of *Pseudomonas sp.* 19Fv1T and *P. fluorescens* C7 bacteria, the sugar content in fruits (Bona et al., 2018) increased. The use of mixed biologics and plant growth regulators improves product quality by increasing the dry matter content of tomato fruits as well as the proportion of total sugar and ascorbic acid.

Thus, numerous scientific data indicate the effectiveness of the use of biologics in the technology of growing vegetable crops and tomatoes in particular. However, the sources contain inconsistent data on the effect of stimulants and bio-fungicides on the wet and dry weight of plants, root growth under complex application on tomato plants in the southern steppe of Ukraine for the scientific substantiation of elements of organic technology of tomato cultivation.

The purpose of the research was to study the effect of complex use of bioregulators, biological fungicides and bio-insecticides on plant growth and development indicators and yield of tomato cultivars

MATERIALS AND METHODS

The research was conducted in the period from 2021 to 2023 in the experimental field of Mykolaiv National Agrarian University (Mykolaiv Oblast, Ukraine) on southern heavy loamy chernozem with a humus content of 3.2% in the topsoil. The experiment was conducted three times, with systematic variations arrangement. The area of the experimental plot is 250 square meters, the control plot is 125 square meters. The experiment studied the effect of biologics on the growth, development, yield and quality of Rio Fuego and Missouri tomato cultivars. The technology of cultivating tomatoes in the experimental plots was generally accepted for the zone, save for new techniques that were studied in the experiments.

The system of protection and fertilization of tomatoes during organic cultivation in the open ground during the growing season was carried out with preparations BTU-Center (Ukraine): Azotophyt – 0.3 l·ha^{-1}, Phytohelp – 1.5 l·ha^{-1}, Organic Balance – 0.5 l·ha^{-1}, Mycohelp – 2.0 l·ha^{-1}, Actoverm – 3 l·ha^{-1}, Lepidocide – 7 l·ha^{-1} in the phase of growing vegetative mass – the beginning of flowering, the formation of the first fruits – mass flowering, mass fruiting – fruit ripening. The variant with standard tomato cultivation technology served as a control.

To study the elements of tomato growing technology according to organic technology, a

two-factor field experiment was laid under the conditions of the Southern Steppe of Ukraine: Factor A: cultivar: 1. Rio Fuego; 2. Missouri. Factor B: complex fivefold treatment with biological preparations: Azotophyt-p, Phytohelp, Organic Balance, Mycohelp, Actoverm, Lepidocide during the vegetation period: first – 12–14 days after the emergence of seedlings, then every 12–14 days.

The research program included biometric observations, determination of indicators of photosynthetic activity of tomato plants (fresh weight of plants, dry matter content and leaf area per plant), yield evaluation, fruiting dynamics, and standard product yield.

The Azotophyt-p bioactivator contains free-living bacteria *Azotobacter chroococcum*, which can secrete growth hormones (phytohormones) and plant development, fix atmospheric nitrogen, and inhibit the growth of phytopathogenic microflora. It contains macro- and microelements, biologically active products of their vital activity: amino acids, vitamins, phytohormones, and fungicidal substances.

Phytohelp biologics with antimicrobial and growth-stimulating effects. It contains a concentrated mixture of natural bacteria *Bacillus subtilis*. Provides anti-stress effect to adverse conditions, as well as protects against pathogens of a wide range of bacterial (*Pseudomonas, Xanthomonas, Erwinia*) and fungal diseases (*Septoria spp., Blumeria spp., Cladosporium spp. Drechslera spp., Ascochyta spp., Erysiphe spp.*).

Organic-balance is a concentrated mixture of viable and inactivated microorganisms and their active metabolites, live bacteria: nitrogen-fixing, phosphorus- and potassium-mobilizing – transforming hardly soluble compounds into forms available for plants. Microorganisms with fungicidal qualities protect plants from bacterial and fungal diseases; components of the growing environment (macro-, microelements and organic food sources).

Mycohelp is a multifunctional, multicomponent microbial preparation. Composition: saprophytic fungi antagonists of the genus *Trichodtrma*, live cells of bacteria *Bacillus subtilis, Azotobacter, Enterobacter, Enterococcus*, biologically active products of vital activity of producer microorganisms.

Actoverm is a biologics with insecticidal and acaricidal action, a complex of natural avermectins – Avermectin C (0.2%) or (1.8%), which is formed in the vital activity of the producer strain of *Streptomyces avermitilis* and has high insecticidal and acaricidal qualities.

Lepidocide – BTU®-p is a bioinsecticide against lepidopteran insects. Composition: viable cells of the *Bacillus thuuingiensis var. kurstaki* bacteria endospores and biologically active products of bacterial activity: protein crystals – endotoxins.

Tomatoes of the Rio Fuego and Missouri cultivars were used for the study. Rio Fuego tomato is a medium-early determinant type of 110–115 days. Missouri is a mid-season determinant type of 118–135 days.

When planning the experiments, the methodology of (Yeschenko et al., 2018) was used. The fresh weight of plants was determined on OHAUS SPU 413C electronic scales. Biometric measurements were performed on typical 25 plants of each experiment. The dry matter content of fruits was determined by the gravimetric method as the ratio of raw weight and weight after drying at 105 °C in a SNOL58/350A drying oven.

Harvest assessment was carried out every five days. During each harvest, the fruits were counted and the weight of both marketable and non-marketable fruits was determined. The non-marketable part of the harvest included fruits affected by diseases and damaged by pests, deformed, underdeveloped, with mechanical damage. The research results were statistically processed using the analysis of variance method with the use of Agrostat New software.

RESULTS AND DISCUSSION

The *Azotobacte*r genus bacteria contained in the natural growth activator Azotophyte belong to microorganisms that have the ability to activate immune processes in the plant, suppress the development of pathogens, and enhance plant growth and development.

The biologics proved to have an impact on the indicators of plant growth and development, namely plant mass, height of the aboveground and length of the underground parts, which is confirmed by the conducted studies. The values of biometric values determined the adaptation to environmental conditions and the effectiveness of biologics. One of the important biometric indicators is the growth dynamics of tomato plants. Plant height depended on the cultivar characteristics and applied biologics (Table 1).

Table 1. Height of tomato plants (average in 2021–2023)

Indicators	Development phase	Tomato cultivar			
		Rio Fuego		Missouri	
		Control (water treatment)	Biologics treatment	Control (water treatment)	Biologics treatment
Height of tomato plants, m	Budding	0.52 ± 0.10	0.53 ± 0.04	0.52 ± 0.05	0.49 ± 0.04
	Flowering	0.74 ± 0.07	0.84 ± 0.11	0.62 ± 0.11	0.62 ± 0.06
	Fruiting	0.82 ± 0.11	0.87 ± 0.11	0.72 ± 0.11	0.73 ± 0.11

The growth dynamics of the Rio Fuego cultivar was characterized by better performance in the variant with the introduction of the biologics. Thus, already in the budding phase, after two treatments with bioactivators and biofungicides, the growth rate of tomato plants was slightly higher compared to the control variant. With three treatments in the flowering phase, the difference between the variants was significant – 0.10 m. In the fruiting phase of tomatoes, the difference in plant height was leveled, but the treated plants exceeded the control variant by 0.05 m.

The effect of biological products on the height of plants of the Missouri cultivar was less pronounced. The height of plants in the treated and control variants was at the same level at all stages of tomato development.

Research results indicate a positive effect of biological preparations on the growth processes of other crops, namely winter wheat and spring barley when grown under similar soil and climatic conditions of the Southern Steppe of Ukraine (Panfilova et al., 2019; Panfilova et al., 2023). Thus, when seeds were treated with the natural growth activator Azotophyt, plant height and productivity of winter wheat and spring barley increased compared to the control option, where treatment was not carried out.

A number of researchers point out that the plants treated with biologics are able to effectively retain water in their tissues, which affects the fresh vegetative mass. Along with the increase in plant height, there was an accumulation of fresh vegetative mass of tomato plants due to the effect of biologics in Table 2.

The most significant effect of the preparations on the plant's fresh weight was observed during the formation of generative organs – the flowering and fruiting phase of both studied cultivars. During this period, plants need nutrients and moisture the most and react best to improved growth and development conditions. The treatment of tomato plants with a solution of biofungicides and bioactivators during the flowering and fruiting phase contributed to an increase in the fresh vegetative weight.

The aboveground mass of Rio Fuego tomatoes in the flowering phase in the treatment variant was 196.8 g·piece^{-1}, which exceeded the mass of the control variant by 38.2 g·piece^{-1}, or 24.1%. The positive dynamics of the increasing fresh weight under the treatment was noted during the fruiting period – 1036.4 g·piece^{-1}, in the control - 857.3 g·piece^{-1}. The growth of fresh weight of one plant, on average, was 20.9%.

The increase in fresh weight was less significant in the Missouri tomatoes in comparison with the control variant, but a growth dynamics was observed – by 10% in the flowering phase and by 14.9% in the fruiting phase.

The dynamics of the accumulation of the dry weight content was similar to the increase of the aboveground mass of the tomato plants and depended on the treatment with biologics.

The indicators of dry weight were maximum during the fivefold treatment in the fruiting phase in both studied cultivars and ranged from 16.3 to 16.7%. The greatest effect on the accumulation of dry matter in the aboveground mass was observed in tomato plants of the Missouri cultivar compared to the plants of the control variant – by 13.2%. In the Rio Fuego cultivar, the difference in dry matter accumulation was 9.9% compared to the control.

The root system of a plant is a multifunctional organism that provides the plant with vital nutrients and moisture. The degree of development of the root system influences the physiological processes of the plant and its resistance to adverse environmental conditions.

Characteristics of the formation and functioning of the tomato root system depended on the complex application of growth stimulators and biofungicides. The root system of the studied tomato cultivars reacted to biologics differently. The length of the main root of Rio Fuego tomatoes under the treatment with biologics was

Table 2. Biometric indicators of growth and development of tomato plants under the biological cultivation (average in 2021–2023)

Indicators	Development phase	Tomato cultivar			
		Rio Fuego		Missouri	
		Control (water treatment)	Biologics treatment	Control (water treatment)	Biologics treatment
Fresh weight of plants, g·piece^{-1}	Budding	34.9 ± 1.48	36.5 ± 1.52	43.2 ± 2.40	44.3 ± 1.90
	Flowering	158.6 ± 8.38	196.8 ± 9.82	154.5 ± 24.3	169.8 ± 27.5
	Fruiting	857.3 ± 4.34	1036.4 ± 5.82	916.5 ± 4.81	1053.2 ± 5.22
The dry weight of plants, %	Budding	9.54 ± 0.46	9.75 ± 0.47	9.16 ± 0.26	11.3 ± 0.72
	Flowering	14.0 ± 0.41	14.7 ± 0.44	11.7 ± 0.89	14.6 ± 0.94
	Fruiting	15.2 ± 0.43	16.7 ± 0.44	14.4 ± 0.22	16.3 ± 0.71
Root length, cm	Budding	15.4 ± 0.64	13.6 ± 0.20	13.2 ± 0.31	16.3 ± 0.44
	Flowering	20.0 ± 4.27	17.4 ± 3.46	18.4 ± 0.46	21.7 ± 3.81
	Fruiting	21.4 ± 4.62	20.6 ± 3.33	19.5 ± 0.47	23.4 ± 3.61
Fresh weight of the root, g·piece^{-1}	Budding	3.0 ± 0.2	2.8 ± 0.25	3.8 ± 0.20	3.7 ± 0.47
	Flowering	13.5 ± 5.78	9.7 ± 5.87	13.4 ± 1.28	13.7 ± 1.40
	Fruiting	16.3 ± 4.93	13.8 ± 4.32	15.1 ± 0.51	16.5 ± 0.68
Dry weight of the root, %	Budding	18.3 ± 0.47	21.5 ± 1.42	18.4 ± 0.36	19.2 ± 0.40
	Flowering	31.0 ± 0.50	32.7 ± 0.47	29.7 ± 0.45	32.9 ± 0.66
	Fruiting	34.3 ± 0.75	36.8 ± 0.91	31.4 ± 0.62	35.6 ± 0.57

shorter at all developmental phases than the root system of the control variant. This difference was 11.7% in the budding phase, 13% in the flowering phase, and only in the fruiting phase, the length of the main root of the control and the variant with biologics treatment was different by only 3.7%.

The results of analyzing the length of the main root of the Missouri cultivar were slightly different from the studied factors. At all phases of the plant development, the growth dynamics of the main root in the variant with biologics treatment had higher indicators than in the control. In the budding phase, the length of the root was 23.5% greater than that of the control, in the flowering phase – 17.9%, and in the fruiting phase – 20%.

Similar results were obtained in the analysis of the fresh weight of the tomato root system. On average over three years of research, the root mass of the Rio-Fuego cultivar was higher in the control variant in all phases of plant development, but the most significant difference was in the flowering phase and amounted to 28.1%.

The root system of the Missouri cultivar responded better to the treatment with biologics, and the fresh weight of the roots in the fruiting phase was slightly higher than in the control – 9.3%.

Similar results were obtained by a group of researchers during the treatment of tomato seedlings with the Azotofit®-R biologics (Kolisnyk, et al., 2016; Rogach, 2018). They came to the conclusion that under the conditions of cultivation under direct sunlight, the indicators of the mass of roots, stems and leaves treated with the biological preparation exceeded the parameters from the control variant by 2.6; 1.6 and 1.7 times, respectively. In the conducted studies, the mass of the root system did not grow so significantly, and in the Rio Fuego variety, this indicator in the control version exceeded the version after treatment with biological preparations. It is likely that the reaction of the root system to complex treatment with biological preparations also depends on the characteristics of the variety.

A more significant indicator is the percentage of roots to the total mass of plants. If the total biomass of the plant (aboveground and underground) is taken as 100%, then the tomato root accounts for 1.3–8.0%, depending on the growing technology (Table 3).

The highest percentage of tomato roots over the years of research was observed in the control variants and remained at the same level in the studied cultivars. Roots had a higher specific weight in the budding phase – 7.9–8.0% and in the flowering phase – 7.8–7.9%. Similar results were obtained with the ratio of dry aboveground and root weight of tomato plants (Table 4). The percentage of roots to the total dry mass of

tomatoes was higher in the control variants with water treatment in both studied cultivars. The maximum indicators were recorded in the fruiting phase – 28.3–28.9%.

Therefore, the use of biologics during the growing season of tomatoes contributed to the increase of the aboveground mass and to the decrease of the root percentage to the total plant mass in the studied cultivars.

Other researchers have obtained conflicting results on the effects of natural activators and growth inhibitors on tomato plants (Rogach et al., 2022). According to their data, treatment with gibberellic acid significantly increased plant height, and tebuconazole decreased it. Gibberellic acid increased the number of leaves on the plant, while tebuconazole did not. In their studies, the drugs increased the number of leaf blades per plant, the weight of raw material leaves, the area of leaf blades and the area of leaves at the end of the study period. The mass of dry matter of stems and roots increased under the influence of gibberellic acid, and decreased during the treatment with tebuconazole. Gibberellic acid increased the dry matter of the whole plant, while tebuconazole did not change it. Therefore, the effect of various biological substances on the biometric indicators of tomato plants needs further study.

To characterize the development of the root system of tomatoes, the level of productivity per 1 ha, which is expressed as the ratio of dry weight of above-ground mass and dry weight of roots $Mg \cdot ha^{-1}$ is a more meaningful indicator. The level of productivity of the root system shows the degree to which the root system ensures the functioning of the aboveground mass of the plant (Table 5).

The productivity of the Rio Fuego cultivar root system increased significantly over the years of research due to the combined effect of growth

Table 3. The ratio of above-ground and underground fresh weight of tomato plants

Variant	Development phase	Fresh weight of plants, g·piece^{-1}			Percentage of roots to the total mass, %
		Total	Above-ground	Roots	
Rio Fuego					
Control	Budding	37.9	34.9	3.0	7.9
	Flowering	172.1	158.6	13.5	7.8
	Fruiting	873.6	857.3	16.3	1.9
Biologics treatment	Budding	39.3	36.5	2.8	7.1
	Flowering	206.5	196.8	9.7	4.7
	Fruiting	1050.2	1036.4	13.8	1.3
Missouri					
Control	Budding	47.0	43.2	3.8	8.0
	Flowering	167.9	154.5	13.4	7.9
	Fruiting	931.6	916.5	15.1	1.6
Biologics treatment	Budding	48.0	44.3	3.7	7.7
	Flowering	183.5	169.8	13.7	7.4
	Fruiting	1066.9	1053.2	16.5	1.5

Table 4. Ratio of dry above-ground and root weight of tomato plants

Variant	Development phase	Rio Fuego			Missouri		
		Dry weight of above ground mass, g·piece^{-1}	Dry weight of roots, g·piece^{-1}	Percentage of roots to total dry mass, %	Dry weight of above ground mass, g·piece^{-1}	Dry weight of roots, g·piece^{-1}	Percentage of roots to total dry mass, %
Control	Budding	9.5	0.4	4.0	9.2	0.7	7.1
	Flowering	14.0	4.9	25.9	11.7	4.4	27.3
	Fruiting	15.2	6.2	28.9	14.4	5.7	28.3
Biologics treatment	Budding	9.75	0.7	6.7	11.3	0.8	6.6
	Flowering	14.7	3.1	17.4	14.6	4.0	21.5
	Fruiting	16.7	5.6	25.1	16.3	6.3	27.9

Table 5. The level of productivity of the tomato root system in the fruiting stage under the treatment with biopreparations (average in 2021-2023)

Variant	Rio Fuego			Missouri		
	Dry weight, Mg·ha^{-1}		kg of above-ground mass per 1 kg of roots	Dry weight, Mg·ha^{-1}		kg of above-ground mass per 1 kg of roots
	Above-ground	Roots		Above-ground	Roots	
Control	0.54	0.22	2.4	0.51	0.20	2.5
Biologics treatment	0.59	0.19	3.1	0.58	0.22	2.6

Table 6. Marketable yield of tomatoes depending on treatment with biologics in organic farming

No.	Variant	Years of research			Average over the years	± to the control, Mg·ha^{-1}	± to the control, %
		2021	2022	2023			
Rio Fuego							
1.	Control (water treatment)	41.8	46.3	45.4	44.5	–	–
2.	Biologics treatment	53.4	57.4	56.1	55.6	+11.1	+24.9
Missouri							
1.	Control (water treatment))	34.3	38.1	37.3	36.6	–	–
2.	Biologics treatment	44.5	50.1	48.0	47.5	+10.9	+29.9
LSD05 Throughout the research by factor A by factor B		2.21 1.27 1.10	2.13 1.31 1.34	2.90 1.68 1.45	× × ×	× × ×	× × ×

stimulators and biofungicides, reaching 3.1 kg, which was 0.7 kg higher than the control variant.

The productivity of the roots of the Missouri cultivar did not have a significant difference between the control variant and when treated with biological preparations and was at the level of 2.5–2.6 kg.

The yield of tomatoes in the experiment was influenced by several factors, the most important of which are: biologics, cultivar qualities, cultivation technology and meteorological conditions throughout the year (Table 6).

The obtained marketable yield of tomato fruits differed depending on the years of research, but the biologics used throughout the years with different agro-climatic conditions gave approximately the same results.

The analyzed yield values of the studied cultivars, depending on the treatment with biologics, showed that the Rio Fuego cultivar had a higher marketable fruit yield, ranging from 53.4 to 57.4 Mg·ha^{-1}, which exceeded the yield of the control cultivar by 11.6 to 10.7 Mg·ha^{-1}. On average, over the three years of the study, the yield of the Rio Fuego cultivar increased in 11.1 Mg·ha^{-1}, or 24.9% due to the biologics. The Missouri cultivar turned out to be less productive throughout the years of research, but it was more responsive to the treatment with biologics, with the increase in the marketable fruit yield in comparison with the control being 10.9 Mg·ha^{-1} (29.9%). Other researchers (Gajc-Wolska et al. 2018; Karpenko, 2019; Borzykh et al., 2022) obtained similar results of the effect of biological preparations on increasing the yield of vegetable crops in open and closed soil. They indicate the ability of biological preparations to suppress tomato diseases and increase the productivity and quality of fruits. The use of biological preparations ensured an increase in the yield of healthy fruits of tomato varieties by 19–66% and sweet pepper fruits in closed soil.

CONCLUSIONS

Complex fivefold treatment of Rio Fuego and Missouri tomato plants with biological preparations: Azotophyt-r, Fitohelp, Helprost, Organic Balance, Mycohelp, Actoverm, Lepidocid during the growing season affected the biometric indicators of plant growth and development, namely plant weight, above-ground height and

root length as well as dry weight accumulation in the vegetative mass. The growth dynamics of the Rio Fuego cultivar was characterized by the best indicators in the variant with biologics treatment during the threefold application in the flowering phase, the difference compared to the control variant was 0.10 m.

The most significant effect of the preparations on the fresh weight was observed during the formation of the generative organs, i.e. in the flowering and fruiting phases of both studied cultivars. The aboveground mass of tomato plants of the Rio Fuego variety in the flowering phase in the variant with processing was 196.8 g·piece^{-1}, which exceeded the weight of the plant from the control variant by 38.2 g·piece^{-1}, or 24.1%, during the fruiting period raw mass of one plant increased, on average, by 20.9%. The fresh weight of the Missouri tomatoes treated with biologics increased by 10% in the flowering phase and by 14.9% in the fruiting phase in comparison with the control variant. The increase of the aboveground fresh weight of the Missouri tomatoes treated with biologics in comparison with the control variant was not significant, but a growth dynamics by 10% in the flowering phase and by 14.9% in the fruiting phase was observed.

Indicators of dry weight in the plant mass were maximum during the fivefold treatment in the fruiting phase in both studied cultivars and ranged from 16.3 to 16.7%. The root system of the Missouri cultivar was more responsive to the introduction of biologics, and the fresh weight of the roots was 9.3% greater than the control variant in the fruiting phase. The yield of the Rio Fuego cultivar increased in 11.1 Mg·ha^{-1}, or 24.9% due to the biologics. The Missouri cultivar turned out to be less productive throughout the years of research, but it was more responsive to the treatment with biologics, with the increase in the marketable fruit yield in comparison with the control being 10.9 Mg·ha^{-1} (29.9%).

Therefore, the research results showed that the reaction of tomato plants to the use of biological preparations, manifested in the growth dynamics, the accumulation of raw and dry matter of the above-ground and underground mass, the formation of the yield of marketable fruits, depended on varietal characteristics, which requires further research on different varieties and hybrids of tomatoes.

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