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ORIGINAL ARTICLE

Productivity of organic tomatillo grown in the open ground under conditions of the right-bank forest-steppe of Ukraine

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The paper examines the effect of plant treatment of the tomatillo with bio-agents on the productivity and its marketability under a biologized growing system. The effect of bio-agents on the biometric indicators of the tomatillo plants is scientifically substantiated and proved. It has been established that the plant height can vary from 59.2 cm to 61.1 cm in Likhtaryk variety and it can range within 56.9-62.7 cm in Ananasovyi variety. Bacteria *Azotobacter chroococcum* or yeast *p. Saccharomyces* provide a positive effect of Azotobacterin and Rostmoment on the formation of most fruits, weight and diameter of the fruit. It has been established that the plant leaf area increases up to 72.2 thousand m^2/ha and 83.1 thousand m^2/ha due to application of Rostmoment or Biopolycid, and spraying of plants with Biopolycid increases leaf dry matter by 15%. Likhtaryk variety is characterized by the high yield and fruit marketability when Humisol and Biopolycid are applied five times, where its value is 29.1 and 27.8 t/ha, and the marketability is 86.2%.

Keywords: Morphological features; biometric indicators; tomatillo; fruit yield; marketability

Introduction

The FAO Food Commission considers Ukraine to be among the countries that will become global food donors in the future as the world food crisis is worsening. However, in Ukraine current use of land resources does not meet the requirements of the rational nature management, which leads to environmental changes in general (Kysil V.I., 2000). Under such conditions, it gives urgency to the development and implementation of the agricultural technologies that will ensure a planned level of vegetable yields on the background of the maximized use of the agricultural resource potential and introduction of a biologized system and reduction of anthropogenic burden on the agrocenosis (Scientific basis of organic farming in Ukraine, 2001). The development of organic vegetable farming in Ukraine by 2020 should take into account the development of infrastructure and management mechanisms through the system of standardization, investment with the simultaneous reduction of imported products. The systems are mainly based on the establishment of the principles of conservation and reproduction of soil fertility in agrocenoses and environmentally friendly production. In conditions of a modern megacity, it is relevant to consume environmentally friendly vegetable products as they are grown without chemical agents for crop protection and they have a positive effect on the human livelihood (Pysarenko V.M et al., 2000). In the European countries, organic vegetables have been grown since the end of the twentieth century, but they cost much more than conventional vegetable plants. In Ukraine, the tendency for consumption of such products is constantly growing, which promotes their further production in the specialized farms and households in the suburbs that are engaged in organic farming Pysarenko (P.V. et al., 2018). A stable increase in the complex of parameters, which characterize soil fertility, biologized crop rotations, a resource-saving method of soil cultivation, biological method of seed preparation to sowing and plant protection, the use of trickle irrigation can fully disclose a genetic potential of varieties or hybrids of vegetable plants to ensure proper quality of organic products (Kuts O. V., 2001). The value of the tomatillo is that it contains 15.0-30.0 mg/100 g of vitamin C, 6.0-12.1% of dry matter, 0.9-2.5% of protein, 2.5-9.0% of sugar, 0.25-0.3% of pectin, 0.8% of ash elements. As for the chemical composition, its fruits include tannins, citric and organic acids, mineral salts and alkaloids. By the dry matter content, the tomatillo fruits are similar to figuress, and the content of sugar and citric acid in the tomatillo fruit exceeds their content in sweet pepper and eggplant by 7-8%. Raw mature fruits without cups are used to cook salads, borsch, soup and compote, and in the processed form they are used for canning, marinating and picking, making sauces, paste, mashed vegetables and canned food. Due to high content of pectin contained in the fruits, jam, marmalade, candies, candied fruits and marshmallow can be cooked. Dried fruits are used as spices for meat dishes (Bolotskykh A. S., 2001). The tomatillo fruits are used as an analgesic and diuretic. During consumption, they are characterized by antipyretic, laxative, antihypertensive and helminthic properties being an indispensable dietary and nutritious food. Fresh fruits or their juice are used to treat colds, high blood pressure, bleeding, inflamed respiratory tract, stomach, liver and kidney disease. For the treatment of rheumatism and healing of wounds, the ointment from the chopped tomatillo fruits of is prepared (Sych Z. D., 2013). One of the important issues of modern

agriculture is the use of a biologized system for growing seedlings and proper care of the plant during its cultivation in the open ground. Currently, farms are widely using bio-agents based on the living bacteria: they enrich the soil with nutrients, form biologically active compounds, inhibit the growth of pathogenic microorganisms, and increase overall yield and marketability. According to the data provided by Materynskyi P. V., 2001, a positive dynamics in the increase of leaf and stem mass, reduction of duration of the phases of plant development, which enables to obtain early green beans and significantly improve crop quality, is revealed during seed inoculation of faba bean with rhyzobophyte. In his studies Pavlov L. V., 2017 has found that treatment with Ribav-Estra increases laboratory emergence of tomatoes by 15.0-20.0%. Cherniavsky O. M. et al. has established that the interphase periods of «germinating-flowering» and «flowering-fruiting» are reduced by 1-2 days depending on the bio-agent. Soaking of the root system with Azotophyte promoted the fastest beginning of the fruiting phase of tomato plants. Barbakar O. V. et al. has proved that the increase in the concentration of Azotophyte or Phytocyde solution increases the tomato yield, in particular, due to soaking seeds in a solution of Azotophyte at the concentration of 1 ml/10 liters the yield of tomatoes was 46.2 t/ha, and soaking of the root systems in the solution of Phytocyde increased the yield up to 48.1 t/ha. Onyshchenko O. I. et al. has established that complex application of Mars-U, a mixture of Trichodermin and Humisol on the vegetating tomato plants resulted in the decrease of the disease spread by 50.0-53.3%, biological efficiency was 73.4-76.7%, and the product yield was 20.3-21.6%. The use of these preparations positively affected the quality of fruits, in particular, the content of dry soluble substances and ascorbic acid was by 0.33% and 0.93% higher, respectively. According to Lohinov O. N. et al. the highest yield was obtained under complex treatment with bio-agent «Elena», which increase the yield by 15%. At the same time, bio-agent Azolen also increased the yield of tomato. Consequently, the relevance of application of various bio-agents while growing organic vegetables, including the tomatillo, in accordance with the current trends of the development of vegetable production both in the scientific and practical aspects, is becoming evident.

Materials and methods of research

Experiments on determination of the bio-agent effect on the total yield of the tomatillo varieties Likhtaryk and Ananasovyi were carried out at the research site of the Department of Landscape Gardening, Horticulture and Viticulture at Vinnytsia National Agrarian University in 2016-2017. Seedlings were grown under conditions of the film greenhouse ZIMET according to guidelines of the Institute of Vegetable and Melon Growing of NAAS for the solanaceous plants. Seedlings were planted in the open ground according to the scheme of 70 × 35 cm in the second decade of May. In the course of vegetation, the tomatillo plants were treated with bio-agents, namely: Humisol, Rostmoment, Azotobacterin, Biomag, Biopolycid, Phosphoretherin. Plants were sprayed 5 times in the following sequence: for the 1st time-in 10-12 days after pricking off, the 2nd-in 10-12 days after the first treatment, the 3rd-in 10-12 days after transplanting the seedlings to a permanent place of vegetation, the 4th and 5th-in 10-12 days after the previous application of a bio-agent. The control was the variant where bio-agents were not applied. Variants in the experiment were placed by the method of randomized blocks with a triple replication. The beginning of phases of plant growth and development was determined by the observation method; biometric measurements were made by the laboratory method, namely: plant height and stem diameter before fruit setting, fruit diameter, fruit number, fruit mass, leaf area and leaf dry matter before flowering; and the total plant yield was determined by the mathematical analysis. Leaf area was determined by the methods of Bondarenko H.L., Yakovenko K.I., et al. dry matter content-by the method of Parshykova T. V., et al. crop recording was conducted in accordance with the guidelines of Bolotskykh O.S. et al.

Results and discussion

At the primary stages of organogenesis, the tomatillo seeds were not treated with bio-agents, so germination and formation of the first true leaf depended on the varietal features of the plant only. Crop emergence in Likhtaryk and Ananasovyi varieties was observed on the 7-9th day, and the first true leaf was formed on the 14-17th day. A positive effect on the growth and development of the tomatillo, especially in the phases of budding, flowering and fruiting, was established after pricking off and double plant treatment with the preparations. A higher effect of the preparations was obtained after planting of seedlings in the open ground and application of the subsequent plant treatment with bio-agents and their adaptation to environmental conditions. During that period, the phases of growth and development depended on the varietal plant characteristics and the applied bio-agent. Likhtaryk variety was characterized by a short period of bud formation on a plant when treated with Biomag. Thus, buds began to form on the 71st day in Likhtaryk variety. A similar effect of the bio-agent was established during the phases of flowering and fruit setting. As a result of bacteria activity, the phases of plant growth and development are accelerated by 1-5 days compared to the control variant. It is obvious that Biomag, which included living cells of *Azotobacter chroococcum* bacteria and products of their metabolism, can accumulate nitrogen to a greater extent, which is better absorbed by the root system of plants and used for the synthesis of organic matter and during intensive processes of growth (Table 1).

Table 1: Beginning of the phases of the tomatillo growth and development depending on the bio-agent, the day from the sprout emergence (average for 2016-2017).

Variety	Bio-agent	The phase of plant growth and development, the day since seeding			
		budding	flowering	fruit setting	fruiting
Likhtaryk	Without bio-agent (C)	73	88	97	129
	Humisol	73	87	95	131

	Rostmoment	75	87	97	128
	Azotobacterin	76	88	97	130
	Biomag	71	84	94	129
	Biopolycid	75	89	100	134
	Phosphoretherin	75	86	95	129
	Without bio-agent (C)	75	88	94	131
	Humisol	72	84	97	131
Ananasovyi	Rostmoment	75	87	97	129
	Azotobacterin	73	86	97	130
	Biomag	73	86	97	128
	Biopolycid	76	90	100	133
	Phosphoretherin	72	86	96	129

C - Control

Organic farming had a positive impact on the agrophytocenosis of the vegetable crop rotation and the tomatillo plants and especially on biometric indicators of both plant and the food body. In the case of positive air temperatures, soil moisture and balanced nutrition, reduced effect of harmful organisms and bacteria *Azotobacter chroococcum, Paenibacillus polymyxa, Enterobacter nimipressuralis*, the height of the tomatillo plants and stem diameter were almost the same but depended on the type of bio-agent applied. In the interphase period of «flowering-fruiting», plant height ranged within 59.2-61.1 cm in Likhtaryk variety and 56.9-62.7 cm in Ananasovyi variety. As a result of plant spraying with Humisol or Biomag, the height of tomatillo plants exceeded the height of plants in the variant, where bio-agents had not been used. In the indicated variants, 2% excess was observed in Likhtaryk variety and 7.0-10.0% in Ananasovyi variety, respectively, compared to the control. The stem diameter varied within 1.5-1.6 cm depending on the factors under research. Due to the activity of bacteria *Azotobacter chroococcum, Paenibacillus polymyxa, Enterobacter nimipressuralis* or yeast *p. Saccharomyces* and products of their metabolism, a positive effect of bio-agents on the increase of leaf area and leaf dry matter was revealed. As a result of cultivation of Likhtaryk variety and application of Rostmoment or Biopolycid, the leaf area ranged within 72.2 thousand m^2/ha and 83.1 thousand m^2/ha and exceeded the control rate by 10.0-26.0%. When growing Liktaryk variety, Biopolycid contributed to an increase in leaf dry matter by 15.0%. When growing Ananasovyi variety and applying Humisol, Rostmoment, Biomag, Biopolycid, Phosphatenterin, the index of the total leaf area and leaf dry matter significantly exceeded the control index. Bacteria *Azotobacter chroococcum* or yeast bacteria *p. Saccharomyces* provided a positive effect of Azotobacterin and Rostmoment on the fruit number per plant, fruit mass and fruit diameter, regardless of the variety under research. In these variants, the total number of fruits was 182-193 in Likhtaryk variety and 186-188 in Ananasovyi variety, and it exceeded the number of fruits in the control by 2.0-3.0%. Plant treatment of Likhtaryk variety with a liquid concentrate on the basis of biohumus Humisol provided the highest mass of the tomatillo fruit, which was at a level of 6.2 g, while application of Humisol when growing Likhtaryk variety or application of Rostmoment when growing Ananasovyi variety increases the diameter of the tomatillo fruit by 8.0%. Due to humic acids and fulvic acids, natural phytohormones, Humisol affects the processes of the plant growth more intensively, which ensured formation of the largest mass of fruits and their diameter (Table 2).

Table 2. Biometric indicators of the tomatillo plants depending on the bio-agents applied, (average for 2016-2017).

Variety	Trial variant	Plant stem height, cm	Stem diameter, cm	Plant leaf area, thousand m^2/ha	Leaf dry matter,%	Fruit number, pieces	Fruit mass, g	Fruit dimeter, cm
	Without bio-agent (C)	60.1	1.5	65.9	59.5	178.0	4.9	2.4
	Humisol	61.1	1.6	47.0	43.4	182.0	6.2	2.6
Likhtaryk	Rostmoment	59.2	1.5	72.2	56.1	183.0	5.6	2.5
	Azotobacterin	60.8	1.5	55.4	42.8	182.0	5.5	2.5
	Biomag	61.1	1.5	52.5	43.3	189.0	5.2	2.5
	Biopolycid	60.1	1.5	83.1	68.4	183.0	5.9	2.5
	Phosphorenterin	60.6	1.5	45.5	36.2	183.0	5.5	2.5
	Without bio-agent (C)	56.9	1.5	46.5	34.5	183.0	5.4	2.4
	Humisol	61.1	1.5	64.3	54.5	183.0	5.8	2.5
Ananasovyi	Rostmoment	60.9	1.5	64.3	54.5	188.0	5.8	2.6
	Azotobacterin	58.3	1.5	64.5	50.6	186.0	5.8	2.5
	Biomag	62.7	1.5	65.9	55.6	183.0	5.5	2.5
	Biopolycid	59.2	1.5	61.8	55.6	180.0	5.5	2.5
	Phosphorenterin	61.2	1.5	65.2	60.0	180.0	5.9	2.5

C - Control

Table 3. Yield of the tomatillo grown in the open ground. t/ha.

Variety (A)	Trial variants (B)	Yield. t/ha			± before control		Marketability.%
		2016	2017	Average	t/ha	%	
Likhtaryk	Without bio-agent (C)	18.3	26.3	22.3	-	-	71.2
	Humisol	25.7	32.4	29.1	+6.8	+30.5	86.2
	Rostmoment	22.6	29.9	26.3	+4.0	+17.9	74.5
	Azotobacterin	23.0	28.5	25.8	+3.5	+15.7	78.4
	Biomag	24.3	28.1	26.2	+3.9	+17.5	72.0
	Biopolycid	22.6	32.9	27.8	+5.5	+24.7	75.3
	Phosphorenterin	22.9	29.4	26.2	+3.9	+17.5	78.2
Ananasovyi	Without bio-agent (C)	22.6	28.0	25.3	-	-	79.5
	Humisol	22.9	32.1	27.5	+2.2	+8.7	72.2
	Rostmoment	23.6	32.6	28.1	+2.8	+11.1	78.4
	Azotobacterin	23.1	32.7	27.9	+2.6	+10.3	72.5
	Biomag	23.5	28.5	26.0	+0.7	+2.8	70.5
	Biopolycid	23.3	29.3	26.3	+1.0	+4.0	73.7
	Phosphorenterin	24.3	31.2	27.8	+2.5	+9.9	77.5
	LSD_{05} (A)	1.1	0.7				
	(B)	2.1	1.3				
	(AB)	2.9	1.8				

C - Control

The yield of the tomatillo grown in the open ground was variable and depended on the applied bio-agents (table 3). In general. it ranged within 22.3 t/ha 29.1 t/ha. Likhtaryk variety was characterized by a rather high yield under application of Humisol and Biopolycid. On average over the years of cultivation. these variants had yields of 29.1 and 27.8 t/ha. which was 6.8 and 5.5 t/ha more than in the control. Other researched bio-agents also contributed to the yield increase of Likhtaryk variety. but the increase value was inferior to the indicated variants. When cultivating Ananasovyi variety. application of Rostmoment. Azotobacterin. Phosphorenterin and Humisol also promoted a significant yield increase. The yields in these variants were within 28.1-27.5 t/ha. In the study. the lowest yield was obtained when applying Biomag for growing Ananasovyi variety. In the given variant the yield increased only by 2.8%. Humisol. Azotobacterin. Phosphoretherin contain essential elements and trace elements. fulvic acids. vitamins. amino acids. phytohormones. useful microflora except for humic substances. while Rostmoment as a bioregulator and stimulator of vital activity of plants on the basis of yeast bacteria *p. Saccharomyces* and products of their metabolism can increase the tomatillo yield from 8.7% to 30.5%. During plant fruiting. Likhtaryk variety was characterized by high fruit marketability (86.2%) under Humisol application. Slightly lower fruit marketability was obtained in the variant where the plants were treated with Azotobacterin and Phosphoretherin. which exceeded the control index by 7.2% and 7.0%. respectively. During the cultivation of Ananasovyi variety. there was observed a decrease in fruit marketability under application of bio-agents. while fruit marketability was the highest (79.5%) when grown without bio-agents. Obviously. bacteria of the applied bio-agents do not enhance resistance of Ananasovyi variety to harmful microorganisms.

Conclusions

1. At the main stages of the tomatillo plant development. Biomag accelerates the processes of budding. flowering and fruit setting. 2. Biometric indicators of the tomatillo plants depend on the bio-agent type. Plant height ranges within 59.2-61.1 cm in Likhtaryk variety and 56.9-62.7 cm in Ananasovyi variety. however. application of Humisol or Biomag increases plant height by 2.0-10.0%. 3. Bacteria *Azotobacter chroococcum* or yeast *p. Saccharomyces* provide a positive effect of Azotobacterin and Rostmoment on the formation of a greater fruit number per plant. fruit mass and fruit diameter. Application of Rostmoment or Biopolycid increases plant leaf area up to 72.2 thousand m^2/ha and 83.1 thousand m^2/ha. and plant spraying with Biopolycid increases leaf dry matter by 15.0%. 4. Likhtaryk variety is characterized by high yield (29.1 and 27.8 t/ha) and fruit marketability (86.2%) when Humisol and Biopolycid are applied five times.

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