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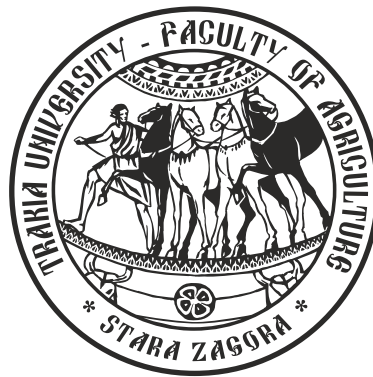
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Effect of bioorganic fertilizers and growth regulators on productivity and immune response of field tomatoes

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Abstract. In conditions of growing tomatoes in the open field the effect of bioorganic fertilizers and growth regulators have been studied based on humic acids Nagro and Stimix on the main growth indicators, yield and immune response of plant in tomatoes for medium early production of the variety Milyana. It has been found that seed treatment and seedlings with the bioorganic products Nagro and Stimix improve the biometric indicators of seedlings and plants during vegetation and accelerate the process of flowering of tomato phenophases. Fertilization with those bioorganic fertilizers at phase flowering increases the earliest and total yield. The application of the technological complex of activities including fertilization with mineral fertilizers $N_{16}P_{20}K_{22}$, treatment of seeds with organic fertilizers Nagro and Stimix, and spraying of plants with conventional plant protection products leads to reduction of attack from *Phytophthora infestans* and *Alternaria solani* in tomatoes.

Keywords: tomatoes, organic productions, growth indicators, yield, immune response

Introduction

Tomatoes are one of the perspective crops grown outdoors in Bulgaria where commercial organic products are already being used and there are good reasons for this. Above all, this is related to the negative influence of the chemicals used on the quality of production. The harmful effects of mineral fertilizers and pesticides can be limited by their partial replacement with organic and their combination with agro-technical measures, providing natural conditions for the inactivation of pathogenic and normal plant development (Marin, 2005). It is assumed, that inclusion in organic fertilizer technology may change in addition to the nutrition balance and phytosanitary status of the crop (Rzhevskay et al., 2014). In this regard, research on biological action of bio-fertilizers and growth regulators in tomato production, is a mandatory stage in the development of new elements of the integrated technology for growing this outdoor culture (Muzikantov and Dorohov, 2002; Tosunov, 2008).

The purpose of the present study is to investigate bio-organic fertilizers and growth regulators based on humic acids Nagro and Stimix as elements of outdoor tomato cultivation technology, establishing their impact on plant growth and development, disease resistance and yield.

Material and methods

The experimental work was carried out in the year 2009-2011 on the territory of Maritsa Vegetable Crops Research Institute (MVCRI) on alluvial-lush soil with tomatoes variety Milyana. Soil

characteristics: humus content-2.1% (Turin), mineral nitrogen ($NH_4 + NO_3-N$), determined by the distillation method-1.8 mg/100 g soil, mobile P_2O_5 -16.1 mg/100 g and mobile K_2O – 18.2 mg/100 g soil (Egner-Rhyme), soil reaction pH/H_2O - 6.9 (potentiometric). The experiment was carried out by block method in four iterations of scheme 120+40/40. The tomato seeds were pre-sowed with the bio-fertilizers Nagro and Stimix in concentration 1:100 for 4 h followed by treatment of plants with the same bio-fertilizers at a concentration of 1:100 in the blooming phase and after the first harvest. The experiment is on a mineral background $N_{16}P_{20}K_{22}$: ammonium nitrate-500 kg/ha, superphosphate-450 kg/ha and potassium sulfate- 450 kg/ha. Phosphorus and potassium fertilizers are introduced with the main soil treatment and nitrogen during the vegetation. Ration and total yield (kg/ha), index of attack by *Alternaria solani* (Ell. & Mart.) L.R. Jones and Grout and *Phytophthora infestans* Mont. de Bary (%) were reported. The degree of attack by the *Alternaria solani* and *Phytophthora infestans* is counted on a five-digit scale (Gannibal et al., 2011): 0 - lack of signs, 1 - single spots, 2 - to 25%, 3 - 26-50%, 4 - over 50% of the leaf surface is covered with spots, the plant is strongly suppressed. The attack index was calculated using the McKinney formula, the effect of using bio-fertilizers of Abbott, the mathematical processing results of Duncan (Dimova and Marinkov, 1999).

Characterization of bio-organic liquid fertilizers: Nagro - 19.17% dry substance; 10.29 g/l organic substance; pH - 8.5; N(common) - 0.77g/l; phosphorus (P_2O_5) - 387 ml/l; potassium (K_2O) - 4624 ml/l; C:N (6:1); trace elements Cu - 0.51 ml/l, MgO - 541 ml/l, Mo - 669 ml/l, S - 1.8%, Zn - 6.0 mg/kg, Fe - 154ml/l, B - 1.02 ml/l, humic acids - 1.63 g/l, polyacids - 8.67 g/l. Stimix - free amino acids - 15-30 g/l, humic acids- 30-50 g/l, organic silicon, live microbial crops, biologically active substances.

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Results and discussion

As a result of the experiments, we found that bioorganic fertilizers based on humic acid Nagro and Stimix have a very functional effect on the growth and development of tomatoes and combine the qualities of bio-fungicides and growth regulators. Seed treatment with bio-products Nagro and Stimix increases germination energy and germination rate, improves biometric performance of seedlings, accelerates the process of passing the phenophases,

shortens the time for planting plants to a permanent place by 2 days. The pre-sowing treatment of seeds with Nagro and Stimix at a concentration of 1:100 in 4 hours affects the dynamics of seed germination in tomatoes (Table 1). On the eighth day after sowing in the control variant there were 33.5% of germinated plants, in the treated variants - 42.5% and 47.5%, respectively, for Nagro and Stimix. In biological fertilizers variants, germinable seed energy is 16-19% higher compared to the control. On the eighteenth day of sowing in the treated variants, 100% germination was reported and

Table 1. Effect of treatment of tomato seeds with Nagro and Stimix on germination energy and germination rate

No	Variant	Germination (%) / day					
		8	Effect %	11	Effect %	14	18
1	Control	33.5 ^c	-	54.5 ^b	-	83.3	94.3
2	Nagro	42.5 ^b	18.83	63.5 ^a	19.29	87.5	100.0
3	Stimix	47.5 ^a	27.37	65.0 ^a	16.15	87.5	100.0

a,b,c – Duncan's Multiply Range Test, P<0.05

Table 2. Terms for the flow of the phenophases in tomato variety Milyana

No	Variant	Phenophase/day			
		Mass germination	The first couple of true leaves	The second couple of true leaves	The third couple of true leaves
1	Control	11	20	28	35
2	Nagro	9	17	25	33
3	Stimix	9	17	25	33

a,b,c – Duncan's Multiply Range Test, P<0.05

in the control - 94%.

Table 2 reflects the results of phenophases in seedlings development. Seed treatment with Nagro and Stimix accelerates plant growth and 2-day field planting time. Variants in which the tomato seeds were presowed with Nagro and Stimix yielded better seedlings than the control (Table 3). This is expressed in mass and length of the root, mass and height of the stem, number and mass of the leaves. The increase in the mass of plants is 18.72-52.06%, the root mass 30.68-44.54%, the number of leaves 11.86-23.73%, the differences are mathematically proven. The increased leaf mass intensifies the photosynthesis process. Some researchers have found that the increase in yields using the organo-mineral fertilizer system for tomatoes is linked to the redistribution of ammonium and nitrate forms of nitrogen in the soil. Seed treatment with biopreparations and humic acids strengthens this process and affects the absorption of nitrogen and other elements. An increase in the amount of ammonium and reduction of nitrate nitrogen is noted.

This leads to slowing of the nitrification process and has a positive effect on soil nutrient digestion and an increase in total and early yields of tomatoes (Shevchuk et al., 2015). In our experiment the incorporation of the Stimix and Nagro foliar fertilizers at a 1:100 leaf-flow rate in the blooming phase and after the first harvest enhances the immune response of plants to diseases and increases the yield of tomatoes. The degree of fungal attack by *Phytophthora infestans* and *Alternaria solani* decreases by more than 50% when applying the following technology set of events: seed treatment with Nagro and Stimix organic fertilizers at a concentration 1:100 for 4 hours, foliar fertilization with Nagro and Stimix at a concentration of 1:100 in blooming phase and after first harvest plus spraying of plants with conventional plant protection products (Tables 4 and 5). The treatment of seeds and leaf feeding plants with Nagro and Stimix in the blooming phase and after the first harvest increases the early production of tomatoes (Table 6). In recent years, the use of growth regulators and bioproducts to increase crop yields and quality in

Table 3. Influence of Nagro and Stimix bio-fertilizers on the biometric indices of seedlings

Variant	Mass of plants (g)	Root		Stem		Leaves		
		Mass (g)	Length (mm)	Height (mm)	Diameter (mm)	Mass (g)	Number	Mass (g)
Control	6.51	0.61	84.8	164.8	5.1	2.34	4.5	1.76
Nagro	13.58 ^{***}	1.10 ^{***}	103.8 ^{**}	243.2 ^{***}	7.4 ^{***}	5.62 ^{***}	5.9 ^{***}	5.83
Stimix	8.01 ^{ns}	0.88 ^{**}	92.8 ^{ns}	200.5 ^{**}	6.3 ^{**}	3.10 [*]	5.1 [*]	7.23
GD _{5%}	2.03	0.15	13.48	25.85	0.69	0.73	0.33	
GD _{1%}	2.74	0.21	18.21	34.91	0.94	0.99	0.45	
GD _{0.1%}	3.64	0.29	24.25	46.49	1.25	1.32	0.60	

Table 4. Development of *Phytophthora infestans* in tomato crops

No	Variant	Attack index, %	Effect, %
1	Control	39.64	-
2	Nagro - seed treatment, leaf fertilization	16.39	58.65
3	Stimix - seed treatment, leaf fertilization	17.73	55.27

Table 5. Development of *Alternaria solani* in tomato crops

№	Variant	Attack index, %		Effect, %
		$\bar{x}$	$\pm sd$	
1	Control	15.21 ^a	1.49	-
Seed treatment with bio-fertilizers				
2	Nagro	11.15 ^b	1.85	26.68
3	Stimix	9.41 ^{bc}	1.59	33.39
Seed treatment with bio-fertilizers, two-fold of plants during vegetation				
4	Nagro	5.71 ^d	1.29	62.45
5	Stimix	6.07 ^d	1.93	60.07

a,b,c,d– Duncan's Multiply Range Test, $P < 0.05$

Table 6. Influence of bio-products on the yield

Variant	Yield, kg/ha			
	Early	Effect, %	Total yield, kg/ha	Difference from the control, kg/ha
Control	17057.6 ^c	-	30460.1 ^c	-
Nagro - seed treatment	23614.6 ^{bc}	27.8	48687.3 ^{ab}	18227.2
Nagro - seed treatment, leaf fertilization	25565.1 ^b	33.3	45873.0 ^b	15412.9
Stimix - seed treatment	25388.2 ^b	32.8	49875.6 ^a	19415.5
Stimix -seed treatment, leaf fertilization	31195.4 ^a	45.3	51142.0 ^a	20681.9

a,b,c – Duncan's Multiply Range Test, $P < 0.05$

agricultural crops has grown. The list of bioproducts of organic origin is expanded at the expense of humic acid growth regulators. Our results demonstrate the benefits of using these products to increase the immune responses of plants and reduce crop losses as a result of reducing disease development in crops and more efficiently digesting nutrients from the soil. Humates have long been used as a soil conditioner, fertilizer, soil supplement. Humus contains not just micronutrient metal ions, but also the essential macronutrients: nitrate, phosphate, and potassium. The significance of humic acids is not just limited to its function as a reservoir of mineral plant nutrients and regulator of their liberation (Senn, 1991). According to Piccolo et al. (1992) humic acid can be used as a growth regulator to regulate hormone level, improve plant growth and enhance stress tolerance. In this connection, Tan and Nopamorubodi (1979) indicated that humic acid (HA) was in general beneficial to shoot and root growth of corn plants. Dry matter yield in corn shoots was stimulated by HA, especially when the plants were treated with HA at a concentration of 640 ppm. Fagbenro and Agboola (1993) noted that HA was not only beneficial to the growth but also nutrient uptake of teak seedlings. The uptake of N, P, K, Mg, Ca, Zn, Fe, and Cu by the seedlings was increased with application of HA. Humic acid produced a proliferation of roots at optimum concentration of 0.05%. These results showed that HA can stimulate plant growth and nutrients uptake at relatively low concentration. The stimulating effects of HA may be related to its hormone activity.

Conclusion

Bioorganic fertilizers and growth regulators based on humic acids Nagro and Stimix have a very functional effect on the growth and development of tomatoes. Seed treatment with organic products Nagro and Stimix increases the seed germination by 16-19% and the percentage of germinated plants in tomatoes. Processing of seeds with Nagro and Stimix at concentration 1:100 for 4 hours affects positively the biometric indicators of tomato seedlings. The mass of the plants increases by 18.72-52.06%, mass of the root by 30.68-44.54%, the number of leaves by 11.86-23.73%, respectively. Treatment of seeds with Nagro and Stimix and fertilization with these bioorganic fertilizers at phase flowering increases the earliest yield by 33-45% and the total yield by 38-40%. The application of the technological complex of activities including fertilization with mineral fertilizers $N_{16}P_{20}K_{22}$, treatment of seeds with organic fertilizers Nagro and Stimix, fertilization with them at the phase of blooming and spraying of plants with conventional plant protection products leads to reduction of attack by *Phytophthora infestans* and *Alternaria solani* in tomatoes by 55-62%.

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