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Yield structure formation of Tomato (*Solanum lycopersicum* Mill.) influenced by leaf treatments with growth-stimulating fertilizers

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Abstract

Tomato fruits have great interest for human health as they are a source of a large amount of nutrients, micronutrients, acids, etc. Climate changes in the last few years, accompanied by an increase in average daily air temperatures, increasing dry periods of varying intensity led scientists all over the world to search for new technologies of plant cultivation. One of modern and actual technics can be leaf application of various growth-regulating fertilizers composed with amino acids and chelate forms of macro and micro fertilizers. The experiment was conducted in the north of the Astrakhan region in the zone of sharply continental climate within 2018-2020. The study revealed that various growth stimulants have a positive effect on the formation of tomato productivity, increasing the number of fruits per plant from 11...22 (Aminovit) to 13...27 pieces (Aminofol) depending on the variety. Leaf treatments with various growth stimulants having in their composition chelate forms of mineral fertilizers and amino acids, such as Aminovit, Aminofol and Speedfol contribute to the improvement of tomato productivity, increasing the average weight of fruits and their number on one bush, increasing the average weight of one fruit, increasing the marketable yield of tomatoes.

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Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops worldwide. Modern technology of cultivation of tomato and other vegetable crops for obtaining stable high yields requires the creation of optimal nutritional conditions for plants. Many studies have proved that for normal activity of vegetable crops it is necessary to have small amounts of boron, molybdenum, manganese, copper, zinc and cobalt, which have a great influence on photosynthetic activity of plants, metabolism, fertilization and ripening processes (Borisov, 2016, Selivanova, 2017).Lack of easily assimilable forms of trace elements in the soil can lead to the deterioration of plant growth and development, the appearance of some diseases, and in case of significant deficiency to a decrease in yield. The need for micro fertilizers is actively manifested at high supply of macronutrients in soils (Borisov, 2016; Selivanova, 2017). Recently, biologically active substances (amino acids, epibrassinolide) play an important role in increasing yields of vegetable crops. Amino acids affect the general physiological activity of the plant and participate in the processes of protein synthesis (Maach, 2020; Kloki´c, 2020). When they are applied together with macro- and micronutrients, their transport and uptake by plants is facilitated. Epibrassinolides in turn increase plant resistance to abio- and biotic stresses (Basiev, 2017; Sheujen, 2003).Tomato is very responsive to the use of micro fertilizers and biological active substances, which contribute to increase yields and accelerate fruit ripening, improved biochemical composition without compromising agroecology and product quality *(*Selivanova, 2017; Ksenzova, 2005; Sakharchuk, 2013*)*. Therefore, interest in the search for preparations with biological active substances that will stimulate the mechanisms of the immune system of plants, increasing their resistance to unfavorable environmental factors and productivity *(*Sakharchuk, 2013, Alfosea-Simón, 2020*)* is not dying out. In this regard, we aimed to study the effect of various preparations containing amino acids and chelate forms of macro and microfertilisers on the formation of tomato productivity in soil and climatic conditions of southern Russia.

Materials and methods

Experimental site location

Experiments were laid according to generally accepted methods in 2018-2020 on irrigated fields of Caspian Agrarian Federal Scientific Centre of the Russian Academy of Sciences (FGBNU), which is located in the arid conditions of southern Russia, on the territory of Astrakhan region 42°58′ N, 47°28′ E, altitude 130 m above sea level. *(*Belik, 1992; Dospehov, 1985; Methodology, 2015; Kutlusurina, 2016*)*.

Soil characteristics of the experimental site

The soils of the experimental plot are light chestnut soils with a low content of humus. These soils are strongly dried out and enriched with salts during summer (Nibhavanti, 2006). The soils of the experimental site contain 0.9% humus on average in the 0-20 cm soil layer, the amount of mobile forms of phosphorus does not exceed 28.5 mg/kg of soil, the proportion of exchangeable potassium is very high - 265.0 mg/kg of soil, nitrate nitrogen in the soil is very low - 3.0 mg/kg of soil, ammonium nitrogen is also insufficient - 5.25 mg/kg of soil. The reaction of salt extract (pH) of the soil of the experimental plot is slightly alkaline - 7.6.

Climatic conditions

The climate of the meta-study site is arid and continental. Air temperature has sharply expressed annual course with amplitude of extreme temperatures 70...80°C. The duration of the warm period is 230-260 days.

Precipitations are low, ranging from 160 to 180 mm on the Caspian Sea coast and from 240 to 260 mm in the north-west of Astrakhan region. Small amount of precipitation and high temperatures determine the dryness of air and soil.

Weather conditions during the period of the experiment varied greatly. In 2018, the sum of active temperatures during the vegetation period of tomato was 3561.5°C, precipitation was 107.4 mm. Weather conditions in 2019 were not quite favorable for tomato plants, as the fall of a large amount of precipitation in July and a decrease in average daily air temperatures on their background led to delayed ripening and the development of diseases. During the vegetation period of tomato, the sum of active temperatures in 2019 was 3489.9ºC, precipitation fell 135.0 mm. The year 2020 was more favorable for the growth and development of tomato plants. During the vegetation period of tomato, the sum of active temperatures in 2020 was 3556.5ºC, precipitation was 73.0 mm.

Experimental materials

The experiment was two-factorial, consisted in studying the effect of leaf application of various growth stimulants that promote the stimulation of growth and development of plants and increase their productivity on four varieties of plum-shaped tomatoes - Cobra 26 F1, Heinz 3402 F1, Sister F1, Rio Grande.

Planting

Tomato seedlings at the age of 35-40 days were planted on both sides of the drip tape in rows littered with film in a staggered order of 30 cm apart, the distance between the drip tapes 1.4 m in a threefold repetition, the area of the experimental plot under each treatment 30 m2, under each variety was occupied 150 m2, the area of the accounting plot 10 m2. The total area of the experiment was 600 m2. Standing density was 24000 thousand plants per ha.

Weeding and irrigating the plants

Weeding during the period of growth and development of tomato plants was carried out manually. Treatment against major pests was carried out - Karate Zeon, MKS (50 g/l lambda-cyhalothrin) - 0.2 l/ha and Belt, KS (Flubendiamide) - 0.15 l/ha, and against diseases - Kurzat, P (copper chloroxide, 689.5 g/kg Cymoxanil, 42 g/kg) - 2.0 kg/ha, Phytoplasmin (macrolide tylosin complex) - 3-4 l/ha first spraying at the beginning of flowering, then 2-3 treatments in 10-14 days. Watering was carried out through a drip irrigation system for 3...4 hours each irrigation rate - 154 m3/ha. During the vegetation period of tomatoes, an average of 25...27 irrigations were carried out. Irrigation norm for the years of study was from 4711 to 4954 m3/ha.

Fertilizer application and mulching

In the experimental plots, mineral fertilizers were applied by fertigation at the rate of N200P135K90. Azofosk 200 kg/ha (NPK 16:16:16) was applied to the soil before the main tillage. Nitrogen fertilization (N50) was made three times during the growing season in the phases of budding - beginning of flowering, in the period of full flowering and beginning of fruit formation by ammonium nitrate with the content of active substance N - 34.5%. The remaining phosphorus (P103) and potassium (K58) rates were applied during fruit formation and the beginning of single fruit ripening by applying monoammonium phosphate (N - 12%, P2O5 - 61%) and potassium sulfate (K - 53%).

Treatments of experimental plots with the studied preparations three times according to vegetation phases (beginning of tassel formation, flowering - beginning of fruit formation, milk ripeness) were carried out manually with a knapsack sprayer at the rates recommended by the manufacturers (Aminovit - 1.5 l/ha, Aminofol NPK - 3.0 l/ha, Speedfol Calmag - 7 l/ha).

Harvesting handling

Harvesting and accounting of yield were carried out manually in the experiment variants as the fruit ripened massively.

Data analysis

The data gathered were subjected to Analysis of Variance (ANOVA) in Randomized Complete Block Design using SAS and MSTAT-C computer programs. Mean separations were performed by Least Significant Difference (LSD) test. Differences at P> 0.05were illustrated as significant.

Results and discussion

The formation of tomato productivity is significantly influenced by the vegetation period and the duration of interphase periods. By the way, the vegetation period and the duration of interphase periods are strongly influenced by varietal characteristics, meteorological conditions of the year and cultivation technologies used.

The growth stimulants studied in the experiment influenced the duration of interphase periods to an insignificant extent reducing them relative to the control by 2...5 days. The most significant effect of growth stimulants was observed on yield formation.

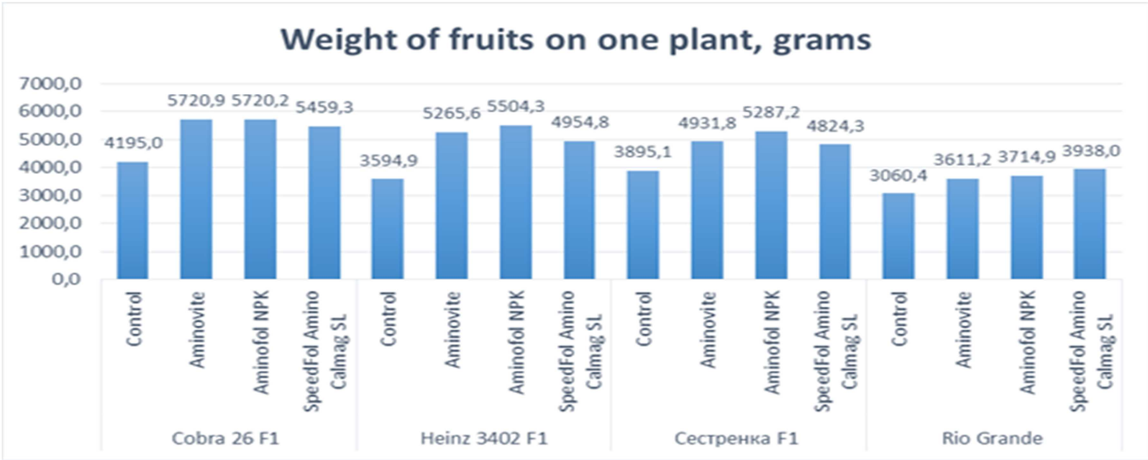

Fig. 1. Fruit weight per plant based on applied growth stimulants, 3-year mean.

The growth stimulants studied in the experiment had a positive effect on fruit weight per plant. In hybrid Cobra 26 F_1, concerning the mean of the years of study, fruit weight in variants with application of growth regulators Aminovit and Aminofol was higher than the other variants and was 5720.9 and 5720.2 g, which is higher than the control by 1525.9 and 1522.2 g, respectively (Fig. 1). The variants with application of Speed folium were also productive with fruit weight exceeding the control by an average of 1264.3 g.

In hybrid Heinz 3402 F_1, variants with application of Aminovit and Aminofol were also the most productive with 5265.6 and 5504.3 g above the control by 1670.7 and 1909.5 g, respectively. Sister F_1 hybrid was more responsive to Aminofol application with fruit weight per bush - 5287.2 g, higher than the control by 1392.1 g. Rio Grande variety on all variants of treatments showed increases in fruit weight per bush, were less significant than in the studied hybrids - from 550.8 g in the variant with Aminovit to 877.6 in the variant with the application of Speedfol.

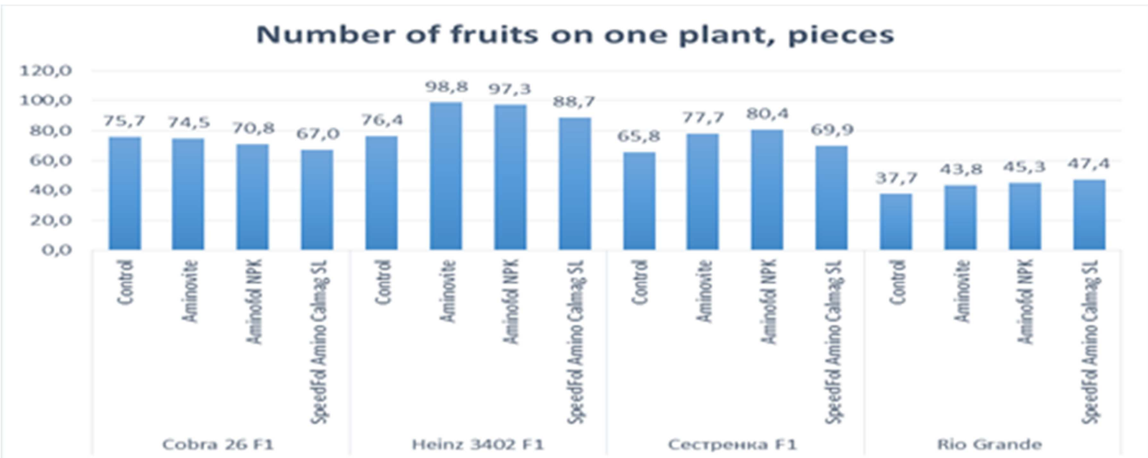

Fig. 2. Number of fruits per plant based on applied growth stimulants, 3-year mean

Leaf treatments with growth regulators resulted in a decrease in the number of fruits per bush in the hybrid Cobra 26 F1 with a mean of 3...11 pieces (Fig. 2), but their average weight of fruit increased by 11.6...21.1 g. The highest mean weight of one fruit was observed during the study years on the variants Speedfol - 81.6 g and Aminofol - 81.2 g, while on the control the average weight of fruit did not exceed 60.5 g.

In hybrids Heinz 3402 F_1 and Sister F_1 the variants with application of Aminovit - 99 and 78 pieces and Aminofol - 97 and 80 pieces, respectively, were distinguished by the number of fruits (Fig. 2). Thus, due to leaf application of growth regulators, the increase of the number of fruits from one bush in hybrid Heinz 3402 F_1 was 22 pieces in the variant with Aminovit and 21 pieces in the variant with Aminofol, and in hybrid Sister F_1 the number of fruits was higher with 11 pieces in the variant with Aminovit and with 13 pieces in the variant with Aminofol.

In the variety Rio Grande, the number of fruits was not high in all variants from 39 pieces in the control to 48 pieces in the variant with application of Speedfol. The greatest increase in the number of fruits per bush was in the variant Speedfol - 9 pieces and Aminofol - 8 pieces. Application of different growth stimulants also affected the mean of fruit weight per plant. As can be seen in Fig. 3, the mean of weight of one fruit increased in all hybrids and in all variants with leaf treatments.

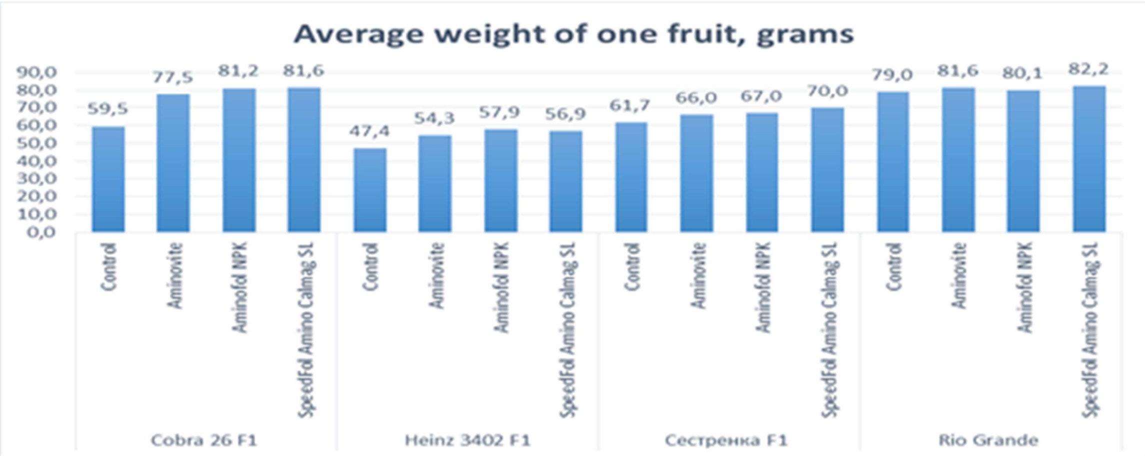

Fig. 3. Average weight per fruit based on growth stimulants applied, 3-year mean

So, the average of fruit weight of the Rio Grande variety increased insignificantly on variants with leaf treatments as compared to the control - 1.0...3.2 g. In hybrid Sister F_1, the weight of one fruit increased from 4.2 g in the variant with Aminovit to 8.3 g in the variant with Speedfol.

The hybrids Cobra 26 F_1 and Heinz 3402 F_1, showed themselves to be the most responsive to leaf treatments with growth stimulants, the weight of one fruit increased maximally in the variants with Aminofol - 20.79 for Cobra 26 F_1 and 10.5 g for Heinz F_1, with Speedfol - 21.1g for Cobra 26 F_1 and 9.5 g for Heinz 3402 F_1 (Fig. 3).

Thus, based on the conducted study, it is evident that leaf treatments with growth stimulants of tomato plants contributed to the increase in the number and weight of fruits per plant and increase the average weight of one fruit.

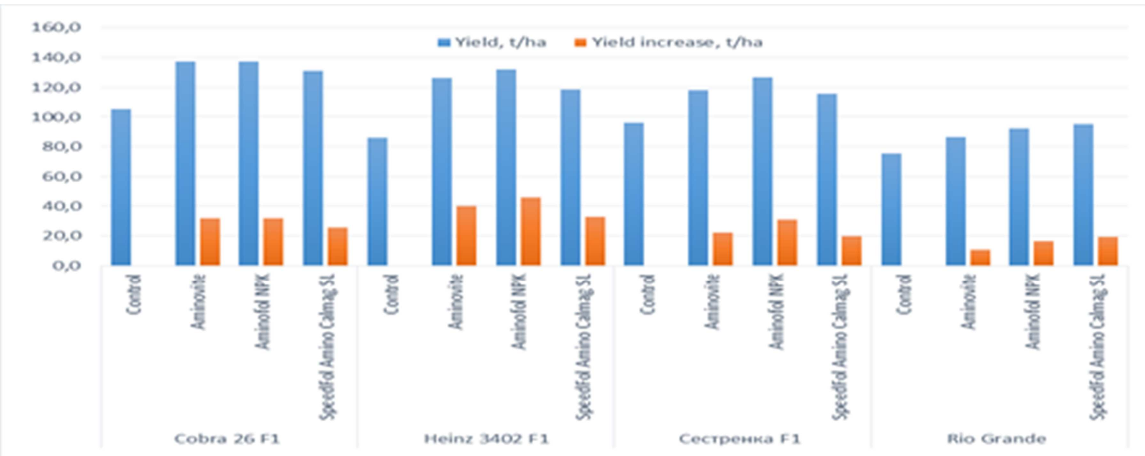

Fig. 4. Tomato yield and yield increase based on applied growth stimulants, 3-year mean

Application of different growth stimulants had a significant effect on tomato yield, and was significantly higher than the control variants, as confirmed in the results of analysis of variance, this is in accord with the data obtained by (Nibhavanti, 2006; Raj, 2012). Yield in 2018 compared to 2019 and 2020 was generally lower in all variants. Therefore, in the control variant the hybrid Cobra 26 F_1 the biological yield was 91.4 t/ha^{-1}, the minimum yield increase was observed in the variant with Speedfol - 19.9 t/ha^{-1}. The highest indicators were observed in the variant Aminovit - 136.7 t/ha^{-1}, with a yield increase of 45.3 t/ha^{-1}. Marketable yield on all variants with leaf treatments was 6-10% higher than the control and was 70...74% (Table 1). In hybrid Heinz 3402 F_1 in 2018, the highest yield increases were observed in variants with the application of Aminovit - 51.8 t/ha^{-1}and Aminofol - 50.9 T/ha^{-1}.

Table 1. Yield and marketability of tomato fruits based on the experiment variant 2018-2020

Varieties	Treatment	yield, t/ha^{-1}					Marketable yield, %				
		2018	2019	2020	Mean	Increasement	2018	2019	2020	Mean	Increasement
Cobra 26 F1	Control	91,4	108,4	116,2	105,3	-	64	63	80	69	-
	Aminovite	136,7	136	139,2	137,3	+32,0	70	70	87	76	+7
	Aminofol NPK	126,5	148,7	136,7	137,3	+32,0	71	65	84	73	+4
	SpeedFol Amino Calmag SL	111,3	148,8	133	131,0	+25,7	74	67	86	76	+7
Heinz 3402 F1	Control	72,0	88,8	98	86,3	-	75	73	80	76	-
	Aminovite	123,8	123,7	131,6	126,4	+40,1	82	81	85	83	+7
	Aminofol NPK	122,9	122,4	151	132,1	+45,8	84	80	86	83	+7
	SpeedFol Amino Calmag SL	112,1	111,6	133	118,9	+32,6	81	80	85	82	+6
SisterF1	Control	73,8	96,8	117,8	96,1	-	65	68	78	70	-
	Aminovite	93,8	123	138,2	118,3	+22,2	75	89	84	83	+12
	Aminofol NPK	100,1	130,9	149,7	126,9	+30,8	73	90	85	83	+12
	SpeedFol Amino Calmag SL	96,4	117,9	133	115,8	+19,6	73	91	88	84	+14
Rio Grande	Control	56,8	48,6	121,7	75,7	-	70	63	84	72	-
	Aminovite	63,0	61,0	135,4	86,5	+10,8	79	70	89	79	+7
	Aminofol NPK	64,8	54,3	157,1	92,1	+16,4	78	72	85	78	+6
	SpeedFol Amino Calmag SL	65,4	62,7	157,5	95,2	+19,5	78	70	86	78	+6
LSD(05) General		16,2	22,6	21,2	-	-	-	-	-	-	-
LSD (05)A		7,2	10,1	9,5	-	-	-	-	-	-	-
LSD (05)B		8,1	11,3	10,6	-	-	-	-	-	-	-
LSD (05)AB		6,3	8,7	8,2	-	-	-	-	-	-	-

The highest marketability was visible in all variants with the application of growth regulators - 81...84%. In the hybrid Sister F_1, the yield increases were lower than in other hybrids and ranged from 20.0 t/ha^{-1} (Aminovit) to 26.3 t/ha^{-1} (Aminofol). Yield marketability on all variants with leaf treatments ranged from 73% to 75%. Rio Grande variety was noted as the lowest responsiveness to leaf treatments with the studied growth stimulants in the experiment. The yield of this variety was low from 56.8 to 65.4 t/ha^{-1}, while yield increases in the others variants with the application of growth stimulants were from 6.2 to 8.6 t/ha^{-1}. Yield marketability on the control variant was 70% and was higher by 2...9% on the variants with treatments. In 2019, the yield of the studied hybrids increased. The hybrid Cobra 26 F_1 had a yield of 108.4 t/ha^{-1}on the control, the highest yield increases were observed on the variants Aminofol and Speedfol - 40.3 and 40.5 t/ha^{-1}with yields of 148.7 and 148.8 t/ha^{-1}. Marketability varied from 63% in the variant control to 70% in the variant with Aminovit. The highest yield increases of 33.5(Aminofol) and

34.9 t/ha^{-1} (Aminovit) for hybrid Heinz 3402 F_1 were observed in the variants with Aminofol and Aminovit, with yields of 122.4 and 123.7 t/ha^{-1}respectively. At the same time, marketability was higher compare to the control on variants with Aminovit, Aminofol and Speedfol - 80 ... 81%, which is higher than the control by 7-8%.

In the hybrid Sister F_1, the greatest yield increase compare to the control was in the variant with Aminofol - 34.1 t/ha^{-1}, with a yield of 130.9 t/ha^{-1}. The productivity of the yield of this hybrid varied greatly from one treatment to another and was the biggest in the variant with the application of Speedfol - 91%.

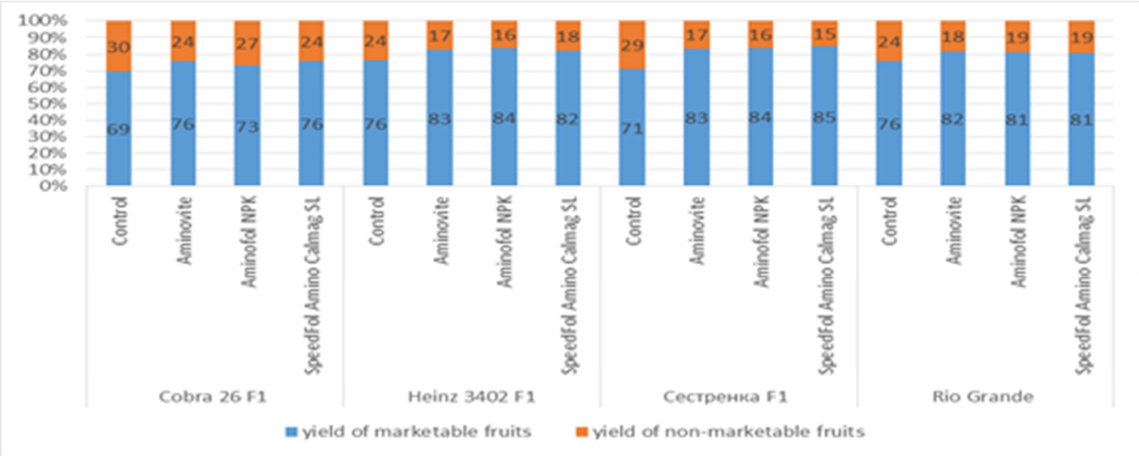

Fig. 5. Proportion (%) of marketable and non-marketable tomato based on growth regulators, 3-year mean

In the variety Rio Grande, no significant yield increases were observed. The yield of this variety in the control was 48.6 t/ha^{-1}. The highest yield was observed in the Speedfol variant - 62.7 t/ha^{-1}. Productivity of the variety did not exceed 72% (Aminofol). Yields in 2020 were higher in a number of variants compared to 2018 and 2019. The hybrid Cobra 26 F_1 in 2020 had lower yield gains, as yields were higher at 116.2 t/ha^{-1} in the control in that year. Only the variant with Aminovit having a yield of 139.2 t/ha^{-1}and a yield gain of 23.0 t/ha^{-1}was significantly higher than the control. Productivity of the yield of Cobra 26 F_1 on the control was 80% and variants with treatments were 4-7% higher. The highest marketability was shown in the treatments with Aminovit - 87% and Speedfol - 86% (Table 1). In hybrid Heinz 3402 F_1 all variants were significantly higher than the control. The highest yield (151.0 t/ha^{-1}) and yield increase (53.0 t/ha^{-1}) was observed in the variant with Aminofol treatment. Marketability, as well as in hybrid Cobra 26 F_1, was at the level of 80...86%. The highest marketability was observed in the variant with Aminofol treatment.

In the hybrid Sister F_1 yield increases was counted from 15.2 to 31.9 t/ha^{-1}, with a reliable increase compare to the control was noted in the variant with Aminofol - 31.9 t/ha^{-1} with a yield of 149.7 t/ha^{-1}. Marketable yield varied greatly from 78% in the control to 88% in the variant with application of Speedfol.

The Rio Grande variety in 2020 had a record yield compared to other years of the study, this is primarily due to the fact that this variety matured later than hybrids during the study, this may be due to frosts which did not allow the entire crop to be harvested the others years. The year 2020 was characterized by a warm and dry autumn, so the harvest was harvested in full. Thus, on the control the yield was 121.7 t/ha^{-1}. Yield increases ranged from 13.7 in the variant with Aminovit to 35.8 in the variant with Speedfol. Variants with Aminofol and Speedfol treatment had yields of 157.1 and 157.5 t/ha^{-1} which is significantly higher than the control. The variety Rio Grande in 2020 had high marketability from 85 to 89%. The variant with the application of Aminovit stood out in terms of marketability.

The average yield of Rio Grande variety was low from 75.7 to 95.2 t/ha^{-1}. The highest yield increase compared to the control was observed in the variant with leaf application with Speedfol - 19.5 t/ha^{-1} (Fig. 4). The obtained data are in agreement with the results obtained by a number of scientists Maach *et al.* (2020) *(4)*, Kloki´c *et al.* (2020) *(5)*, Uddain (2009), Alfosea-Simón *et al.* (2020).

As mean of the years of study, the yield of hybrid Cobra 26 F_1 varied from 105.3 to 137.3 t/ha^{-1}, yield increases were maximum on variants with Aminovit and Aminofol - 32.0 t/ha^{-1} (Fig. 4).

In hybrid Heinz 3402 F_1, the average during the years of study, the maximum yield was observed in the variant with application of Aminofol - 132.1 t/ha^{-1} with an yield increment of 45.8 t/ha^{-1}. Also, high gains were noted on variants with Aminovit 40.1 t/ha^{-1} and Speedfol - 32.6 t/ha^{-1}. The yield of hybrid Sister F_1 varied on average over the years of study from 96.1 t/ha^{-1} in the control to 126.9 t/ha^{-1} in the variant with Aminofol. The maximum yield increase was observed in the variant with Aminofol - 30.8 t/ha^{-1}.

The proportion of marketable yield on all varieties increased with the application of growth stimulants (Fig. 5). At the same time, the best variants of Cobra 26 F_1 hybrid were Aminovit and Speedfol where the share of marketable yield was 76% and the share of non-marketable yield decreased to 24% compare to the control. The highest marketable yield was obtained in the variant with Aminovit - 103.9 t/ha^{-1}, which is 30.7 t/ha^{-1}higher than the control. In hybrid Heinz 3402 F_1 the best was the variant with Aminofol - 110.5 t/ha^{-1} or 84% of marketable fruits per hectare, which is higher than the control by 44.7 t/ha^{-1}. In hybrid Sister F_1, the share of marketable yield was almost the same in all variants - 83...85%, while the maximum fruits yield was obtained in the variant with Aminofol - 106.3 t/ha^{-1}, which is 38.0 t/ha^{-1} higher than the control. In the variety Rio Grande the share of marketable yield in the variants with treatments varied from 81% in the variants Aminofol and Speedfol to 82% in the variant Aminovit, but the maximum yield of marketable fruits was obtained in the variant Speedfol - 76.8 t/ha^{-1}, which is higher than the control by 18.4 t/ha^{-1}.

As can be seen in Fig. 5, the non-commodity part of the yield in all variants with treatments decreased relatively to the control by 16...27% depending on the variety. When evaluating the variants of the experiment on average for all hybrids and variety, the variant with application of Aminofol was the best. With it, the mean weight of fruits from one bush was 5087.0 g, the number of fruits 74, with an average weight of one fruit 71.6 g, marketable yield of 98.0 t/ha^{-1}, and non-marketable - 24.1 t/ha^{-1}. Also the indicators were high on variants with Aminovit and Speedfol, which were slightly inferior in terms of fruit weight per bush - 4880.1 and 4801.1 g, number of fruits 74 and 68 pieces, average weight of one fruit 69.9 and 72.7 g, marketable yield 94.3 and 92.9 t/ha^{-1}, and non-marketable yield 22.8 and 22.3 t/ha^{-1}, respectively.

Conclusion

Leaf treatments with various growth stimulants having in their composition chelate forms of mineral fertilizers and amino acids, such as Aminovit, Aminofol and Speedfol contribute to the improvement of tomato productivity, increasing the average weight of fruits and their number on one bush, increasing the average weight of one fruit, increasing the marketable yield of tomatoes.

Recommendation(s)

The result suggests that farmers in Astrakhan region can use for foliar treatments of tomato cultivation growth stimulants with anti-stress action, amino acids and chelate forms of macro and micro fertilizers for a better productivity of tomato. Carrying out foliar treatments three times per vegetation in the phases of the beginning of brush formation, flowering - the beginning of fruit formation, ripening with growth stimulants at the rate of 300 liters of water with Aminofol NPK - 3.0 l/ha or Aminovit - 1.5 l/ha will help to obtain tomato yield at the level of 127...137

t/ha-1 depending on climatic conditions of the year and hybrid, and yield increases at the level of 31-46 t/ha-1.

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