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Research Article

Assessment of Some Agrochemical Types on the Biochemical Composition of Tomato's Cultivars (*Solanum lycopersicum* L.)

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Abstract

Enhancing fruit quality through the application of contemporary agrochemicals that regulate physiological and biochemical processes in plants is a pressing concern in present circumstances. The effect of foliar application of 04 agrochemicals (Agricola, Aminofol, Aminovit, Speefol) on the quality of 04 plum-shaped tomato varieties (Cobra26F_1, Heinz3402F_1, SisterF_1, Rio Grande) cultivated on light chestnut soils under drip irrigation was carry out in the north of the Astrakhan region within a strongly continental climate zone from 2018 to 2020. The study revealed that varying agrochemicals have an impact on the quality parameters of tomato fruit. In the Cobra 26 F_1 hybrid, foliar treatments led to a rise in the fruit's dry matter content, from 0.24% in the aminofol variant to 0.49% in the Agricola variant. Additionally, sugar content increased by 0.20-0.23% in the Agricola treatments and by 0.06-0.33% in the Aminovit treatments, for both the Cobra 26 F_1 and Sister F_1 hybrids. Application of various agrochemicals on leaves resulted in an increased mass fraction of vitamin C in Heinz 3402 F_1 hybrids, specifically on variants treated with Aminovit and Agricola by 2.21 and 3.81 mg/100 g respectively. For hybrid Sister F_1, only the variant treated with Agricola showed an increase of 1.79 mg/100g. In the case of variety Rio Grande, all variants showed an increase in vitamin C, ranging from 0.03 on the Aminovit-treated variant to 8.84 on the Aminofol-treated variant. The fruit of both the Heinz 3402 F_1 hybrid and the Rio Grande variety exhibited an increase in carotene content, from 0.10 to 0.24 mg% and 0.02 to 0.04 mg%, respectively. Additionally, fruit acidity was reduced. As a conclusion the applied agrochemicals have different effects on the content of dry matter.

Keywords

Tomato (*Solanum lycopersicum*), Biochemical Composition, Agricola, Aminovit, Leaf Treatment

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1. Introduction

Tomato is one of the world's favorite vegetables and the most widely cultivated crop [1]. World produces around 190 million metric tons of tomatoes per year (FAOSTATS 2023). Tomato fruits contain organic acids, pectin substances, B vitamins, nicotinic and folic acids, K vitamins, have low energy value, insignificant amount of carbohydrates and can be used as a dietary product [2]. Epidemiological evidence suggests that consumption of tomatoes and tomato products is associated with a reduced risk of prostate cancer and other chronic diseases [2-3]. Tomato carotenoids are the main source of lycopene in the human diet [6]. High productivity, good taste, large variety of varieties which differ in fruit color, shape and size, as well as in mechanical resistance and biochemical composition have made tomato one of the most widely cultivated crops [7, 8].

Tomato cultivation in modern conditions is based not only on the traditional application of mineral fertilizers, which in various doses increase the sugar content of fruits, dry matter and vitamin C [9-11], During growth and fruit production, tomato plants assimilate nutrients from the soil and generate extensive organic matter which corresponds to the nutritional composition of their fruits in terms of minerals. Improving the nutrition conditions of tomato plants increases the content of dry matter, sugars and ascorbic acid, as stated by Grigorov and Kuznetsov (2009) [12]. Leaf treatments using various agrochemicals had different effects on the dry matter content of tomato fruits of different varieties. It is mainly their excessive use that gives chemical fertilizers a bad reputation. For the first time was studied the effect of different agrochemicals (Agricola, Aminovit, Aminofol, Speedfol) on the quality of plum-shaped tomatoes under drip irrigation on light chestnut soils. Hence this work was aimed to assess the effect of leaf treatment with various agrochemicals on the biochemical composition of plum-shaped tomato varieties. Tomato fruits contain organic acids, pectin substances, B vitamins, nicotinic and folic acids, K vitamins, have low energy value, insignificant amount of carbohydrates and can be used as a dietary product [13]. Good taste qualities, multiple uses, wide distribution and high productivity have made tomato one of the most widely used crops [14]. In the world, a large number of tomato varieties and hybrids have been developed for industrial processing and hobby vegetable production, which differ in bush structure, yield, disease resistance, fruit color, shape and size, as well as in mechanical strength and biochemical composition of fruits [8]. The main factors of intensification of vegetable growing in dry-steppe zones are irrigation with the application of mineral fertilizers, as well as leaf application of various agrochemicals capable of levelling stresses arising during the growth and development of tomato plants. A scientifically substantiated combination of different methods of tomato cultivation, providing optimization of irrigation regimes and plant nutrition contributes to obtaining high yields of quality fruits [15-17]. Leaf treatments with various biologically active substances (Mzibra Abir et al, 2021), growth stimulants (Alimova R. et al, 2023), organomineral fertilizers (Selivanova M. et al, 2020) and other substances (Suliman A. A., Abramov A. G., Shalamova A. A., 2020), [20-22] are capable of leveling stresses occurring during the growth and development of tomato plants, increasing yield and improving their quality by improving the content of sugars, vitamin C and dry matter in the fruit (Chanthini K. M.-P. et al, 2019; Guo Jun et al, 2018; Zhu, Zhu et al, 2018) [23]. Therefore, the study was aimed to evaluate the effect of leaf application of agrochemicals on the quality of plum-shaped tomato varieties under cultivation in light chestnut soils with drip irrigation.

2. Materials and Methods

2.1. Site Description

The experiments were carried out between 2018 and 2020 on irrigated fields of the Caspian Agrarian Federal Scientific Centre of the Russian Academy of Sciences (FGBNU) in Southern Russia under arid conditions at Astrakhan region, located at 42°58′ N, 47°28′ E with an altitude of 130m, on light chestnut soils. The trials were conducted in accordance with generally accepted methods along with the Methodological guidelines for state variety testing of agricultural crops including potato, vegetable, and melon varieties in Moscow [25, 28].

2.2. Plant Seeds

Four varieties of plum-shaped tomatoes (Cobra 26 F_1, Heinz 3402 F_1, Sister F_1, Rio Grande, were experimented. The hybrid *Cobra26*F_1 is a hybrid variety developed by Technisem and marketed on local markets in Cameroon. *Heinz 3402 F1* – plum-shaped fruits, with red color weighing 90 grams, transportable. It’s the No. 1 tomato hybrid in the world for whole-fruit canning and processing into tomato products, manufactured in USA with a yield 120-130 t/ha^{-1}. *Sister* F_1 is a hybrid developed in the Russian Federation and sold in the supermarkets. Hybrid value: resistance to tobacco mosaic virus and Alternaria, heat and drought, high fruit setting and abundant fruiting, long preservation of mature fruits on the plant and in natural storage conditions. It is recommended for fresh consumption, home cooking, canning, pickling, drying and freezing" [29].

Rio Grande: variety has several positive advantages: excellent taste of fruits; widely used in culinary dishes as a salad, sauce, and puree, as well as in canning; tomatoes are not fastidious to any conditions and agronomic techniques; fruits are well stored; low bushes absolutely do not need garter; good large yield throughout the time.

Advantages of the variety: resistance to diseases and unfavorable growing conditions, heat resistance, abundant fruiting, early ripening of fruits, excellent transportability" [14].

2.3. Experimental Design

The study had a two-factorial design and aimed to investigate how foliar application of different agrochemicals, which stimulate plant growth, development, and enhance crop adaptability to changes in growing conditions. Tomato seedlings aged 35-40 days were planted in rows on both sides of the drip tape, which were lined with film and staggered at 30 cm intervals. The distance between the drip tapes was 1.4 m, and the experiment was carried out in three replicates. Each treatment was conducted on an experimental plot of 30 m^2, and each variety was tested on a plot of 150 m^2. The accounting plot was 10 m^2, and the total area of the trial was 600 m^2. The planting density was 24000 plants per hectare.

2.4. Irrigation

The irrigation was carried out using a drip irrigation system. The researches of A. S. Ovchinnikov, V. S. Bocharnikov and I. I. Azarieva (2014) found that increasing the irrigation rate from 100 to 160 m^3/ha promotes an increase in tomato yield by 31.5% [6]. The experimental plots underwent regular irrigation, receiving 27 irrigations in 2018, 25 irrigations in 2019, and 30 irrigations of 3-4 hours duration in 2020, with an irrigation rate of 154 m^3/ha^{-1}. During the tomato growing seasons of 2018, 2019, and 2020, the irrigation norm was 4954 m^3/ha^{-1}, 4711 m^3/ha^{-1}, and 4902 m^3/ha^{-1}, respectively. Scientists of VNIIOB have established that the irrigation norm in tomato cultivation can be reduced from 4350 to 2850 m^3/ha, which allows reducing costs by 18-23% allowing to obtain more than 56.7 tonnes/ha of fruits against the background of mineral nutrition [6].

2.5. Fertilizers Used Characteristics and Their Application

Agricola for tomatoes "is a preparation that is water-soluble, acts in a complex manner and is specially designed for most vegetables, including tomatoes. It contains potassium, phosphorus, nitrogen fertilizers, microelements and plant components. The use of fertilizer promotes root growth, plant rooting and immunity. Agricola increases; vitamin content, resistance to; fungal, bacterial and viral diseases, unfavorable weather conditions. Timely fertilization increases yields and improves flavor. Agricola is an environmentally friendly fertilizer, does not contain chlorine and heavy metals. All this ultimately leads to an increase of yield.

Ingredients: NPK 13:20:20 + microelements boron (B), copper (Cu), manganese (Mn), zinc (Zn), magnesium (MgO). To obtain a treatment mixture, dissolve 25 g of fertilizer in 10 liters of water. During the growing period 3 foliar applications were carried out.

Foliar feeding: Spray the leaves with the prepared solution until they are evenly wet with a sprayer. The first feeding is carried out 2 weeks after planting seedlings, the subsequent repeated at intervals of 10-14 days. Spraying is better in the morning or evening. Consumption of the working solution: 3 liters/100 sq.m. [4]. *Aminovit.* "The role of microelements in plant life is huge. For full development they need iron, manganese, copper, cobalt, molybdenum, boron, zinc. Micronutrients provide synthesis of enzymes responsible for the possibility of effective utilization by plants of the energy of the sun, water and nutrients contained in the soil. Aminovit is a liquid complex mineral fertilizer designed for foliar feeding of agricultural crops throughout the entire vegetation period. The microelement and amino acid series allow the crop to tolerate unfavorable weather conditions and diseases less destructively, fully covering its need for microelement nutrition. Aminovit contains 90 g/liter of Sulphur and should be used not only as a supplement to dry NPK nutrition, but also as a supplement to Sulphur nutrition of the plant. The product formula is a balanced set of macronutrients as well as trace elements in chelate form. Composition: macronutrients - N - 8%, P_2O_5 - 1%, K - 1.2%, MgO - 0.24%, S - 9%, Fe - 0.02%; trace elements - B - 0.1%, Mo - 0.05%, Mn - 0.04%, Cu - 0.38%, Zn - 0.34%, Co - 0.03%. Aminovit is intended for the formation of a more powerful epicotyl, narrowing the germination time period, better overwintering, increasing the overall immunity of the plant. The microelement and amino acid series allow the crop to endure unfavorable weather conditions and diseases less destructively, fully covering its need for microelement nutrition.

Schedule of application: vegetable crops of open and closed ground - 0.5-1.5 l/ha, consumption of working solution 100-200 l/ha - 2-3 times with an interval of 10-15 days, during the period of active growth on well-developed leaf surface [18].

Aminofol NPK - "a special anti-stress agrochemical containing macronutrients NPK with a high percentage of amino acids. Application of Aminofol NPK helps to overcome not only stress situations by stimulating metabolism, growth and development of plants, but also increases resistance to many diseases, because phosphorus and potassium are present in the form of potassium phosphide, which has a preventive fungicidal effect by stimulating the synthesis of phytoalexins. Aminofol NPK can be effectively applied in a wide range of temperatures in contrary to conventional foliar fertilizers, because amino acids: Tyrosine; Arginine; Alanine; Lysine; Proline; Serine; Threonine; Valine and Glutamine stimulate plant physiology and growth, providing a ready energy reserve for biological processes in stress situations (frost, low or high temperature, hail storm, chemical burn, osmotic stress, etc.) and are good transport agents. Application of Aminofol NPK significantly increases yield and quality of production.

Composition (w/v - in 1 liter of product): amino acids -

43.5%, Nitrogen (N) organic - 6.8%, phosphorus (P_2O_5) - 20.4%, potassium (K_2O) - 13.6%. Leaf fertilization of vegetable crops (cucumber, pumpkin, melon, courgette, watermelon, tomato, pepper, aubergine) - 1.0-3.0 l/ha, before planting seedlings, after planting (or after 2 pairs of leaves) and further 5-7 times at intervals of 10-12 days, Consumption of working solution - 200-400 l/ha [19].

Speedfol amino calmag SL (Speedfol cal mag) - "is a liquid fertilizer containing a complex of amino acids of plant origin, calcium and magnesium. Amino acids of fertilizer have a powerful anti-stress immunomodulating effect, and calcium and magnesium strengthen cell membranes.

It is used for normalization of plant metabolism after the impact of stress factors (adverse weather conditions, pesticide use, damage). The composition of Speedfol contains humectants that reduce evaporation from the surface of plants and reduce the risk of drying and curling of leaves, as well as increase the time and efficiency of absorption of nutrients by plants.

Application of Speedfol calmag increases resistance to diseases and stresses; acts as a preventive measure against calcium and magnesium deficiency; increases yield; improves quality and shelf life of products. Amino acids act as a source of energy for accelerated plant growth, improve the process of plant absorption of all nutrition elements. Composition: amino acids - 33.5% (43.6 g/l), MgO - 2.7% (35 g/l), CaO - 6.7% (87 g/l). Amino acids in the composition of the fertilizer activate the entry of nutrients into the plant and their transport through the vascular system (90% of nutrients and amino acids from Speedfol Amino Kalmag enters the plant in 2-3 hours after feeding); stimulate protein synthesis; increase resistance to adverse environmental factors; provide rapid recovery from stress factors.

All amino acids included in the fertilizer are free a-amino acids obtained by enzymatic hydrolysis from plant material. Speedfol is used as a foliar fertilizer, as a supplement to the main fertilizer application and fertigation. Application recommendations - 1-4 liters/ha (10-40 ml/10 liters of water per 100 m^2). Maximum concentration of the working solution is 2%. Fertilization - after exposure to stress factors, before flowering. The following fertilizers at intervals of 1-2 weeks, if necessary.

2.6. Harvest and Biochemical Analysis

2.6.1. Harvest

The fruit was randomized harvested as it matured. Biochemical analysis was carried out in the VIR Laboratory of Biochemistry and Molecular Biology in the Biological Ripeness of the Fruits. The juice of 1/2 part of at least five fruits of each accession, in two replications was used for analysis. The analysis and processing of the material were carried out according to methods of Ermakov et al., 1987). [21]

2.6.2. Assessment of Biochemical Composition Analysis of Tomato Fruits

1) Determination of dry matter

a. To assess the biochemical parameters of tomato fruits, it is necessary

b. to determine their dry matter content by measuring it by a gravimetric method; *Determination of nitrates*

c. Mass fraction of nitrates was calculated by electrochemical detection method according to MU 5048-89(mg/kg),

2) Determination of vitamin C

The mass fraction of vitamin C (%) was determined according to GOST 24556-89,

3) Mass fraction of sugars, the tomato extract is spiked with lactose and tricarballylic acid as internal standards and loaded into a NH_2 solid phase extraction (SPE) column. The sugars appear in the flow-through and are subsequently analyzed by HPLC using a Nucleodur NH_2 column and a refractive index detector %.

4) A carotene mass fraction in mg% (in accordance with GOST 8756.22-80) UV-VIS spectrophotometry is the most convenient method [2, 7, 11], by measuring the absorbance at different wavelengths. High-performance liquid chromatographic (HPLC) methods [12, 14], carotenoids were isolated with 100 % acetone and their absorption was measured on an Ultrospec II spectrophotometer at different wavelengths (nm): 454 – for carotenes.

5) Titratable acidity (total titratable acidity – by titrating with 0.1 n of alkali, was calculated as malic acid) expressed in mol H^+/100 cm^3.

2.6.3. Assessing the Quality of Tomatoes Fruits

Determination of the relationship between the biochemical composition indicators of the fruit was conducted as described by [22-23]. Thus, the sugar-acid index (K_{SA}) was expressed as the ratio of the fruit's sugar content to its acidity using the following formula:

$$K_{SA} = \frac{S}{A} \quad (1)$$

Where *S* represents the sugar content of the fruit and *A* refers to the fruit's acidity. The sugar-acid index is biologically significant as it indicates that the higher the index than the standard sugar-acid index for tomatoes [3, 31], the sweeter and more delicious the fruit. The vitamin-nitrate index (K_{VN}) was expressed as the ratio of the fruit's vitamin C content to its nitrates, and calculated using the formula:

$$K_{VN} = \frac{V}{N} \quad (2)$$

Where the content of vitamin C in the fruit is denoted as *V* and the content of nitrates as *N*, the vitamin-nitrate index holds biological significance. The higher the index, the greater the vitamin value and environmental safety of the product. The ratio of sugar content index (K_{SV}) measures to vitamin C content in fruit using the formula (3), where S is the sugar content and V is the vitamin C content.

$$K_{SV} = \frac{S}{V} \quad (3)$$

A lower K_{SV} index indicates a higher nutritional value and dietary benefit of the product. Therefore, it is a useful biological indicator of fruit quality.

2.6.4. Statistical Analysis

Results were presented as mean value ± standard deviation and analyzed by analysis of variance (ANOVA) using XLSTAT 2016. Significant differences between means were determined by($p<0.05$).

3. Results and Discussion

Tomato fruits are renowned for their high nutritional, organoleptic and dietary value. Typically, the fruits possess 4-8% dry matter, 1.5-6% sugars, and 15-45 mg per 100 g raw weight of ascorbic acid, in addition to carotene, an array of vitamins, acids and minerals such as K, Mg, Na, Ca, P, Fe. The nutrient content of fruit is predominantly influenced by various factors, including the variety characteristics, place of cultivation, and agro technical methods [24-26].

As a result of studying the most important indicators of the biochemical composition of tomato fruits, were established and represented in figures.

3.1. Dry Matter Content

In the hybrid Cobra 26 F_1, leaf treatments had significantly (LSD_{05}=0.02) contributed to an increase in the dry matter content of the fruit from 0.24% in the Aminofol variant (5.97%) to 0.49% in the Agricola variant (6.22%) as shown in Figure 1. The figure below shows that the average dry matter content of the tomato fruit in the control variant was 5.73%. In the control, the dry matter content in tomato fruits averaged 5.73%. In the variant with application of Speedfol, dry matter in fruits decreased on mean by 0.52% in compare with the control and was 5.20%.

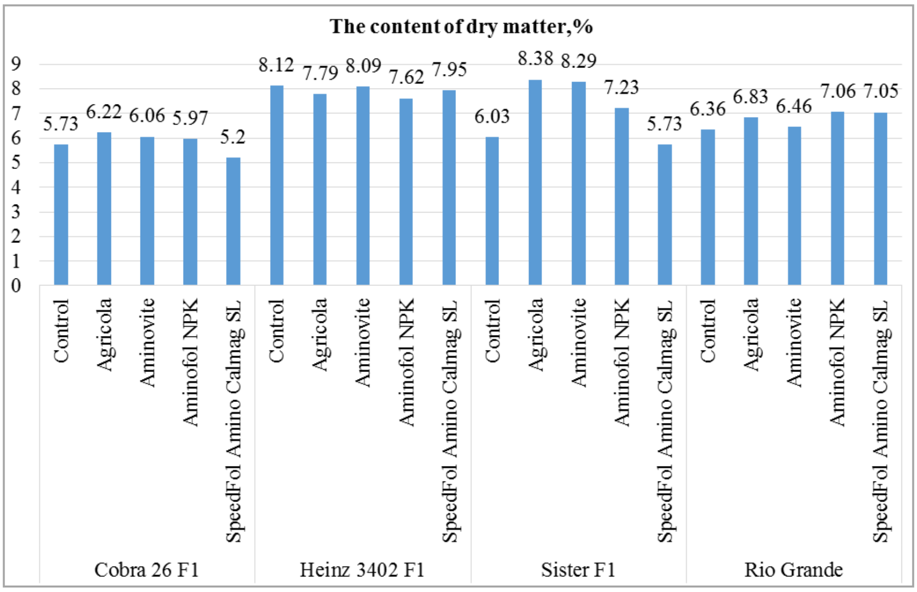

Figure 1. *Impact of Treatment on Dry Matter Content of Tomato Fruit.*

This study investigated the impact of treatment on the dry matter content of tomato fruit. Hybrid Heinz 3402 F_1 on all variants of the experiment with leaf treatments showed a decrease in dry matter content relative to the control (8.12%) by 0.03...0.50%. In hybrid Sister F_1, the indicators of dry matter content in fruits increased in variants with application of Agricola up to 8.38 %, Aminovit - 8.29 %, Aminofol - 7.23 %. These results on the dry matter content are similar with the results of other studies (Gupta et al., 2011; Nour et al., 2013; Kondratyeva, Engalychev, 2019; Ignatova et al., 2020) [29, 31, 32], which reported on the dry matter content in tomato fruits within 5.55–8.80 %. In the variant with application of Speedfol the index decreased by 0.30% and was 5.73%. In the variety Rio Grande on all treatments the dry matter content increased on mean by 0.10...0.69% relative to the control (6.36%). The maximum values were observed in the variants with application of Aminofol - 7.06% and Speedfol - 7.05%. The sugar content in tomato fruits depends not only on the physiological and biochemical characteristics of the variety, but also on the growing conditions of the plants, in particular, on the use of fertilizers and irrigation [31]. As mentioned by Yu. O. Akimova [31], the largest amount of sugar in tomato fruits is formed when the threshold of pre-watering soil moisture during the fruiting period is maintained at the level of 70% NV and the corresponding calculated norms of mineral nutrition [30]. According to the academician A. A. Pokrovsky (1976), the average sugar content in tomatoes from open ground is 4.2%. In our experiment, foliar application of different agrochemicals did not equally affect the accumulation of sugars in tomato fruits (Figure 2).

3.2. Sugar Content

In hybrids Cobra 26 F_1 and Sister F_1 on mean for years of study there was an increase in the content of sugars on variants with application of Agricola by 0.20-0.23% and on variants with Aminovit by 0.06-0.33% (LSD_{05}=0.5). Hybrid Cobra 26 F_1 had a lower sugar content compared to the other hybrids. Sugar content in the control did not exceed 3.39%, and in the released variety with Agricola, it was 3.59%. In hybrid Sister F_1 sugar content on the control was higher and made up 4.14%, and on released variants with application of Agricola and Aminovit was 4.37...4.46%. In hybrid Heinz 3402 F_1 and variety Rio Grande, leaf treatments with different agrochemicals contributed to an increase in sugar content in all variants from 0.09 to 0.65%. In hybrid Heinz 3402 F_1 relative to the control (3.93%) the best variant was the variant with the application of Agricola - 4.32%, and in variety Rio Grande relative to the control (3.06%) variant with the application of Speedfol was 3.71%. Vitamins are unstable substances that are easily degraded by various factors. The main factors that affect the extent and rate of change of vitamins are the action of light and temperature. According to the biochemical analysis of tomato fruits for ascorbic acid content, changes were observed in the experiment variants. Thus, in hybrid Cobra 26 F_1 foliar application of different agrochemicals decreased the mass fraction of vitamin C from 1.89 mg/100 g in the variant with Agricola to 8.76 mg/100 g in the variant with Aminofol (LSD_{05}=0.01) (Figure 2).

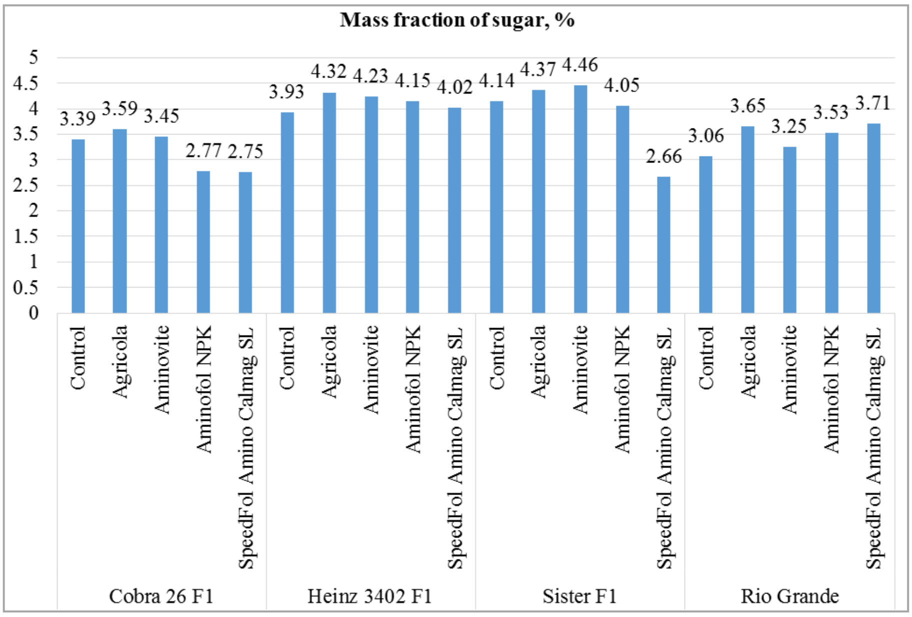

Figure 2. *Sugar content in tomato fruit as a function of the treatment, averaged over three years.*

3.3. Vitamin Content

In hybrid Heinz 3402 F_1 only on variants with Aminovit and Agricola, the vitamin C content increased by 2.21 and 3.81 mg/100 g and was 31.64 and 33.25 mg/100 g, respectively. In hybrid Sister F_1, only in the variant with Agricola, the content of vitamin C increased by 1.79 mg/100 g of fruit, while in the other variants, a decrease from 5.30 to 13.97 mg/100 g was observed. In the variety Rio Grande on all variants with treatments there was an increase in vitamin C content from 0.03 in the variant with Aminovit to 8.84 in the variant with Aminofol and was from 19.31 in the control to 28.15 in the variant with Aminofol. Carotenoids, are oxidation products of lycoline and are plant pigments that give vegetables, flowers and fruits their red to yellow pigment coloration. One of the main carotenoids is beta- carotene. Tomatoes and tomato products are important sources of beta-carotene.

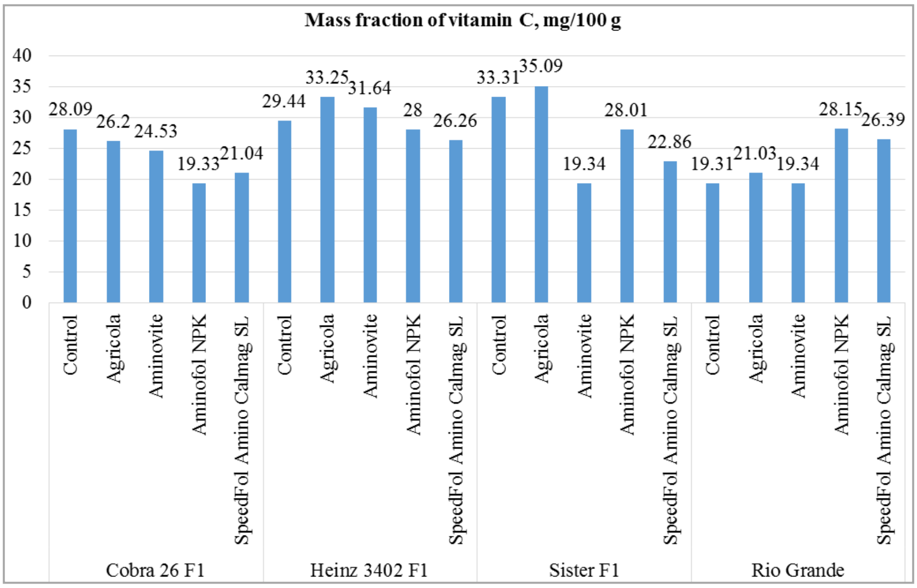

Figure 3. *Vitamin C content in Tomato Fruit as a Function of Treatment, Averaged over Three Years.*

3.4. Carotene Content

In our experiment, the mass fraction of carotene in hybrids Cobra 26 F_1 and Sister F_1 reduced by 0.05...0.24 mg% (LSD_{05}=0.02) in all variants with leaf treatments refer to (Figure 4). And in hybrid Heinz 3402 F_1 treatments on the opposite had a positive effect on the carotene content increasing its values relative to the control from 0.10 to 0.24 mg%, while the highest content was observed in the variant with Agricola - 0.4669 mg% and in the variant with the application of Speedfol - 0.4073 mg%. In the variety Rio Grande treatments also had a positive effect on carotene content, although the gains relative to the control were insignificant and varied from 0.02 to 0.04 mg%, and the highest content was observed in the variant with Aminovit - 0.4260 mg%. Indicators of total (titratable) acidity fluctuate within a fairly wide range. These fluctuations depend on variety, maturity, climatic conditions, level of agrotechnics and other factors.

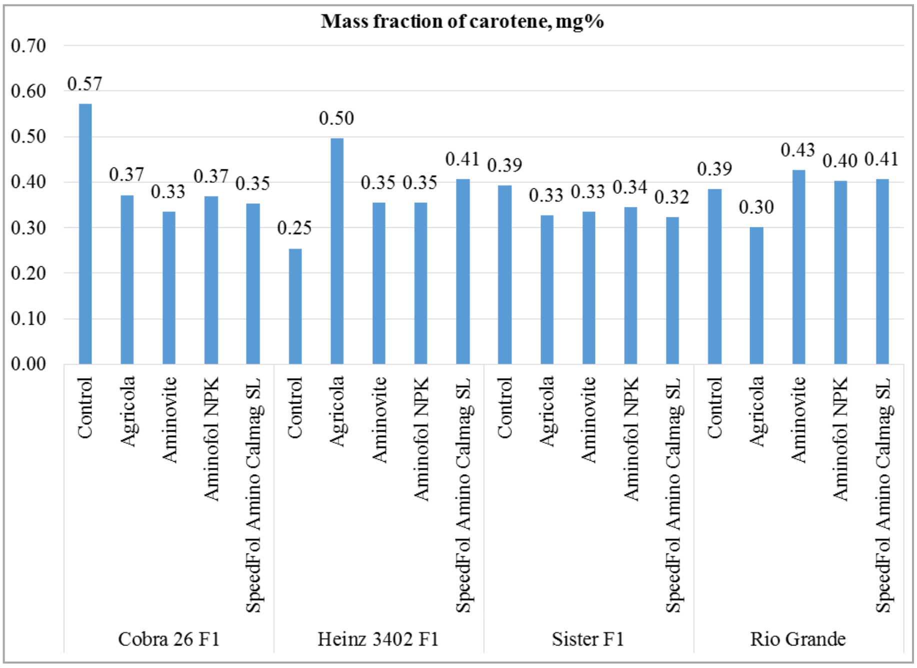

Figure 4. *Mean carotene content in tomato fruit over three years, dependent on different treatments.*

3.5. Titratable Acidity Content

In our study, titratable acidity varied with hybrid/variety and with the applied leaf treatments with agrochemicals. So, in hybrid Cobra 26 F_1 titratable acidity significantly (LSD_{05}=0,8) decreased on variants with treatments with the exception of variant with Aminofol on which the acid content increased by 000, 60 mmol and was 6,1 mmol. In the control, the acid content was at the level of 5.5 mmol, the lowest content was observed in the variants with Aminovit and Speedfol - 4.0 mmol. In hybrid Heinz 3402 F_1 on variants with Agricola and Aminovit the acid content increased relative to the control (8.2 mmol) by 0.20 mmol and was 8.4 mmol, and on variants with Aminofol and Speedfol the acid content decreased by 1.20... 1.90 mmol and was 7.0 and 6.3 mmol, respectively. In hybrid Sister F_1 on all variants with treatments acid content decreased by 0.20... 1.70 mmol, the minimum content was observed in the variant with Agricola 5.0 mmol. In the variety Rio Grande on variants with Agricola and Aminovit acid content relative to the control (5.6 mmol) increased by 0.10-0.20 mmol and was 5.7-5.8 mmol, the minimum was observed on the variant with Aminofol - 4.7 mmol. Similar results on the level of titratable acidity were obtained in other studies. In R. V. Nour et al. (2013) and J. Owusu et al. (2012) studies titratable acidity varied from 0.10 to 0.41 %.

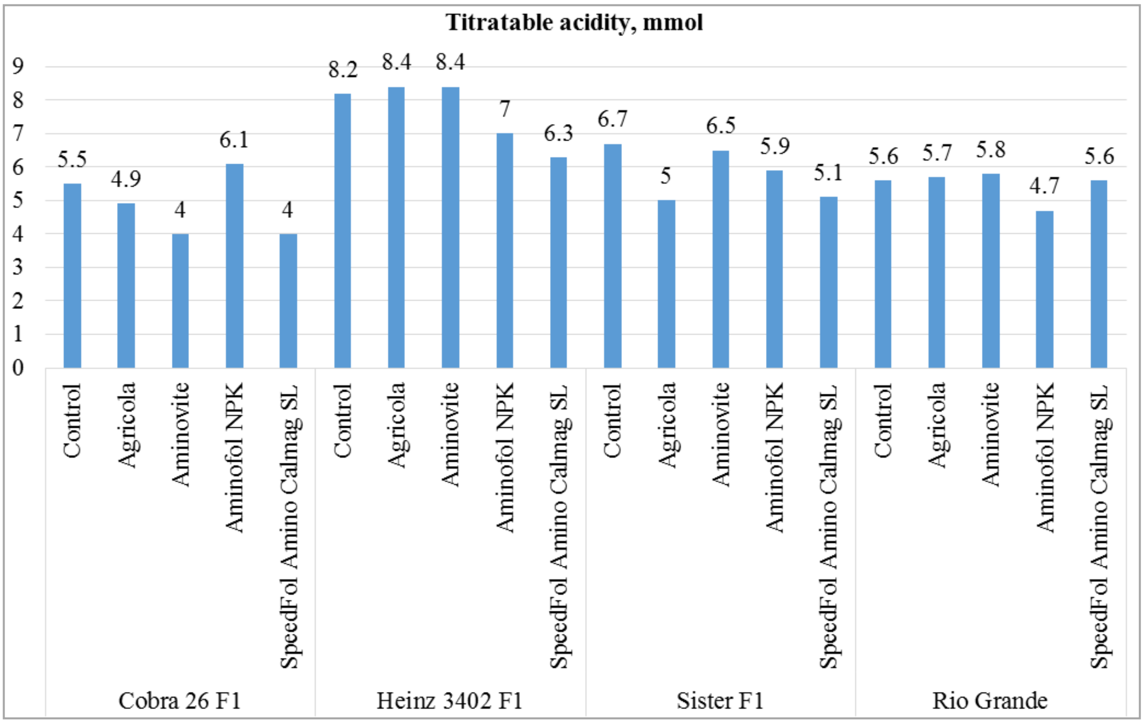

Figure 5*. Titratable Acidity content in tomato fruits across three years.*

Ecological safety of vegetable products is an important quality category. Maximum allowable concentrations of nitrate content in tomato fruits are not more than 150 mg/kg. In our experiment on all hybrids and varieties all studied variants were significantly lower than MPC. So, in hybrid Cobra 26 F_1 the content of nitrates in the control was 30 mg/kg (LSD_{05}=2.4).

3.6. Nitrates Content

Leaf treatments with different agrochemicals contributed to a non-significant increase in nitrate content in fruits by a mean of 10-26.5 mg/kg, while the highest content was observed in the variant with Aminofol - 56.5 mg/kg.

In hybrid Heinz 3402 F_1 also on all variants with treatments slightly increased nitrate content relative to the control (30.0 mg/kg), and the highest content was registered on the variant with Aminofol - 88.0 mg/kg. Nitrate content in hybrid Sister F_1 on the control was - 82.0 mg/kg, while on variants with Agricola and Speedfol it decreased by 52 mg/kg and was - 30 mg/kg, while on the variants with Aminovit and Aminofol it increased by 16.5 and 38.5 mg/kg, and was 98.5 and 120.5 mg/kg, respectively. In the Sister F_1 hybrid, the nitrate content measured 82.0 mg/kg under standard conditions. The Rio Grande variety had the same nitrate content in all variants and did not exceed 35 mg/kg.

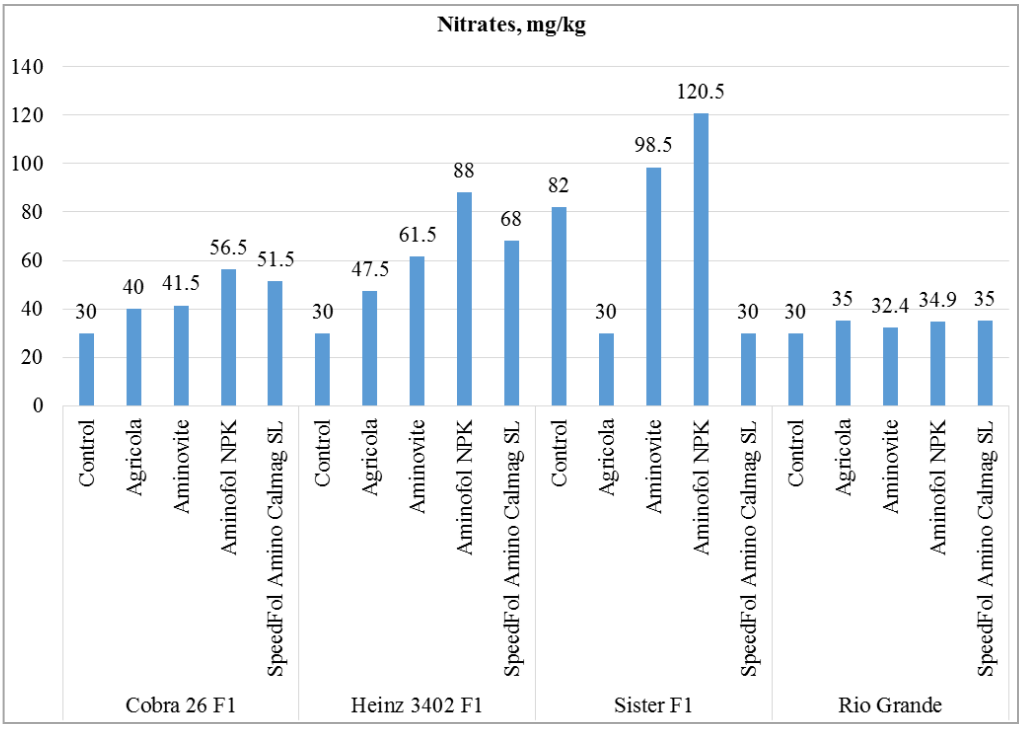

***Figure 6**. Nitrate content in tomato fruits during three years.*

According to the results of calculations of fruit quality indices, based on the ratio of sugar content in fruits to acid content (sugar-acid index - K_{SA}), ratio of vitamin C content to nitrate content in fruits (vitamin-nitrate index - K_{VN}) and ratio of sugars to vitamin C content (sugar-vitamin index - K_{SV}) to sodium indices, the following data in the table were obtained.

***Table 1**. Results of assessing the quality of tomato fruits, on mean for 3 years.*

Hybrid/variety	Variants	Mean of fruit quality indices		
		Sugar acid (K_{SA})	Vitamin-Nitrate (K_{VN})	Sugar- vitamin (K_{SV})
Cobra 26 F_1	Control	6.16	9.36	0.12
	Agricola	7.33	6.55	0.14
	Aminovit	8.63	5.91	0.14
	Aminofol	4.54	3.42	0.14
	Speedfol	6.88	4.09	0.13
Heinz 3402 F_1	Control	4.79	9.81	0.13
	Agricola	5.14	7.00	0.13
	Aminovit	5.04	5.14	0.13
	Aminofol	5.93	3.18	0.15
	Speedfol	6.38	3.86	0.15
Sister F_1	Control	6.18	4.06	0.12
	Agricola	8.74	11.70	0.12
	Aminovit	6.86	1.96	0.23
	Aminofol	6.86	2.24	0.14

Hybrid/variety	Variants	Mean of fruit quality indices		
		Sugar acid (K_{SA})	Vitamin-Nitrate (K_{VN})	Sugar- vitamin (K_{SV})
	Speedfol	5.22	7.62	0.12
	Control	5.46	6.44	0.16
	Agricola	6.40	6.01	0.17
Rio Grande	Aminovit	5.60	3.10	0.17
	Aminofol	7.51	8.07	0.13
	Speedfol	6.63	7.54	0.14
LSD_{05}		1.9	1.1	0.02

As indicated by several authors sugar-acid index (K_{SA}) depends on variety and accumulation of sugars and acids in fruits (Machulkina V. A. et al. 2020) [21]. The higher the index value the sweeter and more flavorful the fruit. For tomatoes the standard sugar-acid index is at least 7. The variants with Agricola and Aminovit treatments on hybrid Cobra 26 F_1 stood out in terms of sugar-acid index - 7.33 and 8.63 respectively. Furthermore. In hybrid Heinz 3402 F_1 the best for this indicator was the variant with Speedfol treatments - 6.38 and in hybrid Sister F_1 on the variant with Agricola - 8.74 in variety Rio Grande the highest was the variant with Aminofol treatments - 7.51 for the variety Rio Grande. The highest vitamin value and environmental safety on the basis of vitamin-nitrate index (K_{VN}) was observed in hybrids Cobra 26 F_1 and Heinz 3402 F_1 on control variants - 9.36 and 9.81 also high index of this indicator was registered on the variant with Agricola 6.55 and 7.0. The hybrid Sister F_1 variant with Agricola application was also the best with an index of 11.7. In the variety Rio Grande, the best vitamin-nitrate index values were observed in the variants with Aminofol and Speedfol application - 8.07 and 7.54 respectively. The vitamin value and dietary usefulness of tomato fruits which is shown by the sugar-vitamin index (K_{SV}) in the hybrid Cobra 26 F_1 was distinguished by the control variant where the ratio of sugars in the fruit to the content of vitamin C was minimal as the lower the index the higher the vitamin value and dietary usefulness of the product The minimum indices in hybrid Heinz 3402 F_1 were observed in variants Agricola. Aminovit and control. The best variants of Sister F_1 hybrid were Agricola, Speedfol and the control. The variety Rio Grande had variants with Aminofol and Speedfol that excelled on the sugar-vitamin index. The obtained data in general indicate that the biochemical composition of tomato fruits depends primarily on the variety as well as on the applied agrochemicals as confirmed in other experiments (Kurina A. B. et al. 2021; Kondratyeva I. Yu. and Pavlov L. V. 2009). [22, 23]. Notably, the results are based on objective assessments without subjective opinions.

Table 2. Analytical results of treatments and varieties on mean for 3 years.

Parameters	Treatments	Cobra 26 F1	Heinz 3402 F1	Sister F1	Rio Grande	Means
	Control	5.73 ± 0.06^{ij}	8.12 ± 0.03^{def}	6.03 ± 0.07^{i}	6.36 ± 0.13^{ghi}	6.31 ± 0.90^{C}
	Agricola	6.22 ± 0.11^{hi}	7.79 ± 0.18^{abcd}	8.38 ± 0.05^{a}	6.83 ± 0.05^{efgh}	7.31 ± 0.85^{A}
Dry mater content%	Aminovite	6.06 ± 0.05^{i}	8.09 ± 0.08^{ab}	8.29 ± 0.03^{ab}	6.46 ± 0.10^{fghi}	7.22 ± 1.00^{AB}
	Aminofol	5.97 ± 0.15^{i}	7.62 ± 0.05^{bcd}	7.23 ± 0.07^{cde}	7.06 ± 0.08^{defg}	6.97 ± 0.63^{B}
	Speedfol	5.20 ± 0.02^{j}	7.95 ± 0.08^{abc}	5.73 ± 0.20^{ij}	7.05 ± 0.05^{defg}	6.48 ± 1.11^{C}
	Means	5.84 ± 0.37^{D}	7.71 ± 0.73^{A}	7.13 ± 1.12^{B}	6.75 ± 0.31^{C}	
	Control	28.09 ± 0.01^{ef}	29.44 ± 0.01^{d}	33.31 ± 0.03^{b}	19.31 ± 0.02^{l}	27.54 ± 5.23^{B}
Mass fraction of vitamin C. mg/100 g	Agricola	26.20 ± 0.01^{h}	33.25 ± 0.01^{b}	35.09 ± 0.03^{a}	21.03 ± 0.33^{k}	28.89 ± 5.74^{A}
	Aminovite	24.53 ± 0.02^{i}	31.64 ± 0.01^{c}	19.34 ± 0.05^{l}	19.34 ± 0.02^{l}	23.71 ± 5.15^{E}
	Aminofol	19.33 ± 0.01^{l}	28.00 ± 0.01^{f}	28.01 ± 0.01^{ef}	28.15 ± 0.02^{e}	25.87 ± 3.86^{C}

Parameters	Treatments	Cobra 26 F1	Heinz 3402 F1	Sister F1	Rio Grande	Means
	Speedfol	21.04 ±0.02^{k}	26.26 ±0.01^{gh}	22.86±0.04^{j}	26.39±0.01^{g}	24.13 ±2.33^{D}
	Means	23.84 ±3.28^{C}	29.71 ±2.54^{A}	27.72 ±6.09^{B}	22.85 ±3.77^{D}	
Mass fraction of sugar. %	Control	3.39 ±0.01^{j}	3.93 ±0.11^{f}	4.14±0.02^{d}	3.06±0.04^{l}	3.63 ±0.43^{C}
	Agricola	3.59 ±0.02^{hi}	4.32 ±0.03^{b}	4.37±0.02^{b}	3.65±0.03^{gh}	3.98 ±0.37^{A}
	Aminovite	3.45 ±0.01^{j}	4.23 ±0.03^{c}	4.46±0.04^{a}	3.25±0.03^{k}	3.84 ±0.52^{B}
	Aminofol	2.77 ±0.02^{m}	4.15 ±0.03^{d}	4.05±0.04^{e}	3.53±0.02^{i}	3.63 ±0.56^{C}
	Speedfol	2.75 ±0.03^{m}	4.02 ±0.02^{e}	2.66±0.03^{n}	3.71±0.02^{g}	3.28 ±0.61^{D}
	Means	3.18 ±0.36^{D}	4.13 ±0.15^{A}	3.94 ±0.67^{D}	3.44 ±0.25^{C}	
Mass fraction of carotene. mg%	Control	0.57 ±0.00^{a}	0.25 ±0.00^{m}	0.40 ±0.00^{e}	0.38 ±0.00^{f}	0.40 ±0.11^{A}
	Agricola	0.37 ±0.00^{g}	0.50 ±0.00^{b}	0.33 ±0.01^{k}	0.30 ±0.00^{l}	0.37 ±0.07^{B}
	Aminovite	0.33 ±0.00^{j}	0.35 ±0.00^{h}	0.33 ±0.00^{j}	0.43 ±0.00^{c}	0.36 ±0.03^{D}
	Aminofol	0.37 ±0.00^{g}	0.35 ±0.00^{h}	0.34 ±0.00^{i}	0.40 ±0.00^{d}	0.37 ±0.02^{CD}
	Speedfol	0.35 ±0.00^{h}	0.41 ±0.00^{d}	0.32 ±0.00^{k}	0.41 ±0.00^{d}	0.37 ±0.03^{BC}
	Means	0.40 ±0.08^{A}	0.37 ±0.08^{D}	0.34 ±0.02^{D}	0.38 ±0.04^{B}	
Titrable Acidity. mmol	Control	5.50 ±0.51^{fghhij}	8.20 ±0.30^{a}	6.70 ±0.25^{bc}	5.60 ±0.66^{efghi}	6.51 ±1.18^{A}
	Agricola	4.90 ±0.35^{ij}	8.40 ±0.50^{a}	5.00 ±0.20^{hij}	5.70 ±0.20^{defgh}	6.00 ±1.49^{BC}
	Aminovite	4.00 ±0.32^{k}	8.40 ±0.34^{a}	6.50 ±0.45^{bcd}	5.80 ±0.51 ^{defgh}	6.20 ±1.63^{B}
	Aminofol	6.10 ±0.30^{cdef}	7.00 ±0.23^{b}	5.90 ±0.41^{defg}	4.70 ±0.40 ^{jk}	5.91 ±0.91^{B}
	Speedfol	4.00 ±0.63^{k}	6.30±0.43^{bcde}	5.10 ±0.52^{ghij}	5.60 ±0.51^{efghi}	5.25 ±0.98^{C}
	Means	4.88 ±0.91^{D}	7.67 ±0.93^{A}	5.84 ±0.79^{B}	5.50 ±0.59^{C}	
Nitrates content. mg/kg	Control	30.00±9.45^{i}	30.00 ±1.59^{i}	82.00 ±2.95^{c}	30.00 ±4.11^{i}	43.29 ±23.41^{C}
	Agricola	40.00±8.50^{h}	47.50 ±4.25^{de}	30.00 ±0.83^{i}	30.00 ±5.37^{i}	37.08 ±8.70^{D}
	Aminovite	41.50±3.68^{h}	61.50 ±7.96^{def}	98.50 ±3.60^{b}	30.00 ±1.86^{i}	57.95 ±26.83^{B}
	Aminofol	56.50±6.72^{ef}	88.00 ±2.27^{c}	120.50 ±4.30^{a}	30.00 ±2.25^{i}	73.83 ±34.76^{A}
	Speedfol	51.50±3.48^{fg}	68.00 ±5.28^{d}	30.00 ±1.058^{i}	30.00 ±1.61^{i}	45.01 ±16.54^{C}
	Means	44.01±10.92^{C}	59.11±20.17^{B}	72.37±37.15^{A}	30.24 ±2.80^{D}	

$^{a-m}$ Values with different superscript letters differ significantly ($p < 0.05$)
$^{A-E}$ Values with uppercase and superscript letters differ significantly ($p < 0.05$) regardless of variety (column) and treatment (row)

4. Conclusion

As a result of biochemical evaluation of tomato fruits, we can conclude that applied agrochemicals have different effects on the content of dry matter. Sugars and vitamin C. which primarily in our opinion depends on the variety or hybrid as well as on the growing conditions. The findings cannot unambiguously distinguish certain agrochemicals but the most effective treatments for a number of indicators are Aminovit and Aminofol which contribute to the accumulation of more dry matter, carotene and reduce the acidity of fruits, increase the flavor quality of fruits while not significantly affecting the nitrate content.

Abbreviations

K_{SA}: Sugar-acid index
K_{VN}: Vitamin nitrate index
K_{SV}: Ratio of sugar content index

Ethical Approval

As per international standard or university standard written ethical approval has been collected and preserved by the authors.

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Authors' Contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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