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Quality of tomato production depending on the applied irrigation rate and fertigation

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Abstract

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During the period 2018-2020, on leached Cinnamon forest soil at outdoor irrigation conditions, studies were conducted with determinant tomato variety Nikolina F1 – medium early production. The influence of 50 and 100% irrigation rates and increasing fertilization by fertigation ($N_{15}P_8K_{15}$; $N_{20}P_{1\,2}K_{20}$ и $N_{25}P_{16}K_{25}$) on the quality of the formed production has been established.

The results of the three-year study show higher quality indicators in tomatoes with reduced irrigation compared to 100% irrigation rate – 6.0% higher dry matter content, 12.3% more total sugars, 16.99% higher sugar-acid number, as well as an acid content reduced by 8.3%. In terms of dry matter, total sugars and sugar-acid number, the variant fertilized with $N_{20}P_{12}K_{20}$ is optimal for both irrigation rates. In both irrigation rates, there is a trend for the acid content in the fruits to increase with the fertilizer rate, while in the case of ascorbic acid, there are no pronounced trends over the years.

The regression dependences represented by polynomial equations between the quality indicators for tomatoes and the applied fertilization depending on the irrigation rate show high values of the coefficients of determination (R2 between 0.58 and 0.99), except for the dry matter and total sugars at full irrigation rate in 2020

Keywords: tomato; drip irrigation; mineral fertilization; absolute dry matter; total sugars; mutual acids; ascorbic acid

Introduction

Limited water resources worldwide, as well as the competition among industrial, agricultural and urban consumers becoming increasingly serious, necessitates continuous improvement in irrigation practices, especially in such an intensive sector as vegetable production (Yadan et al., 2017; Tesfay et al., 2020). Uncontrolled exploitation of groundwater has serious consequences, such as lowering its level, reduction of managed areas, as well as intensive processes of salinization and desertification (Kang et al., 2004).

Management of water and nutrients provided by fertilizers are the two main abiotic factors influencing crop growth and productivity (Kuscu et al., 2014; Wang et al., 2015). Tomato quality is the overall result of various individual and combined interactions of factors and indicators (Wang et al., 2011; Zheng et al., 2013). Studies show (Wang et al., 2015) that in all countries, tomato production is increasing, with consumer demand gradually changing from increased quantity of fruit to better-quality fruit. Up-to-date data obtained under various soil and climatic conditions related to irrigation regimes and tomato fertilization are needed as a stable foundation for the production of tomatoes with an achievable balance between high yield and high fruit quality.

The aim of the present study is to determine the influence of increasing irrigation rates and fertilization by fertigation on the formation of high-quality produce.

Material and Methods

The studies were conducted under irrigation conditions on leached Cinnamon forest soil in the Chelopechene Experimental Base of ISSAPP "N. Poushkarov". Medium-early determinate variety Nikolina F1 – selection of the Forest Research Institute of BAS – was used as an experimental culture. The soil in the experimental plot has a low humus content (1.44%) with a slightly acidic reaction – pHH_2O – 6.2; pHKCl – 5.4. The content of mineral nitrogen is low – 16.1 $mg.kg^{-1}$ soil. The accumulation of mobile forms of phosphorus and potassium is average – 11.4 mg $P.100g^{-1}$ and 17.7 mg $K.100g^{-1}$ soil. The scheme with the variants of the experiment is presented in Table 1. The experiment is based on the method of long plots in four replications, with the size of the experimental plot being 7.5 m^2. Irrigation is carried out through a drip irrigation installation. Irrigation wings for drip irrigation are selected depending on the moistening contours in Cinnamon forest soil, the distance between the drippers is 0.30 m, with an outflow of 2 lh^{-1}. Two are placed in each strip next to the stems of tomatoes on the surface of the field.

The plants are planted in a two-row strip according to the scheme 100 + 60 x 30. Nitrogen (ammonium nitrate) and potassium (potassium chloride) fertilizers in all variants with fertilization are introduced three times with the irrigation system. Fertilizer rates are divided equally and introduced to the stage of mass formation of fruit sets. The phosphorus norm, in the form of double superphosphate, is introduced in the autumn by deep plowing.

Studies on tomato fruits are performed at commercial maturity on an average sample of 10 fruits from each replicate of the variants included in the experiment. The analyzes are performed in the laboratory of ISSAPP "N. Poushkarov" and the University of Chemical Technology and Metallurgy. After drying the samples at 65°C with pre-fixation at 110°C, the absolutely dry matter (ADM) was determined. Sugar content in the fruit is determined reflectometrically. The method is based on the conversion of D-glucose and D-fructose to D-glucose-6-phosphate, a product of oxidation with NAD (coenzyme). It in turn is converted to gluconate-6-phosphate. The NADH (coenzyme) formed reduces the tetrazolium salt to blue formazan, the concentration of which is measured reflectometrically on an RQflex® reflectometer using test strips. The content of total acids in the fruit is determined reflectometrically. The method is based on the reaction with an alkaline reagent of all acidic substances (total acidity) contained in the sample. The result changes depending on the pH and corresponds to a change in the color of the pH indicators. It is read on an RQflex® reflectometer using test strips. The content of ascorbic acid in the fruit is determined reflectometrically by the method "after reaction with molybdophosphoric acid to phosphomolybdenum blue". After averaging and straining the samples, the tomato juice is diluted with oxalic acid and is filtered. Polyvinylpolypyrrolidone (Divergan® RS) is added to the filtrate thus obtained and the pH is adjusted to >1 with a few drops of 25% H_2SO_4. After mixing, the sample is filtered and the Vitamin C content is read on a RQflex® reflectometer. The sugar-acid ratio in the fruit is determined by the formula:

The results are processed using the statistical package Statgraphics (Anova). The regression analyzes are prepared with the software product MS Excel.

Results and Discussion

Table 1 presents the results of the biochemical analyzes of the biochemical quality indicators included in the study in the period 2018-2020. Although the literature shows that quality indicators are genetically determined, a number of studies have shown that these traits are influenced to a greater or lesser extent by both growing conditions and environmental factors (Vasileva, 2016; Boteva et al., 2018; Vasileva et al., 2020).

In terms of climate (precipitation, temperature, humidity), the experimental years are very different, which inevitably affects not only the growth processes and productivity, but also the quality indicators.

During the years of research (Table 1), the content of absolutely dry matter in the fruits of tomatoes ranges between 4.25 and 6.6% at 100% irrigation rate and between 4.27 and 6.9% at 50% irrigation rate. The obtained values for dry matter content in tomato fruits in the phase of commercial maturity are completely comparable with those obtained in other experiments with the same variety – Nikolina F1. (Vasileva et al., 2016; Boteva et al., 2018; Vasileva et al., 2020. The average dry matter content of tomatoes for the three-year period in plants with reduced irrigation is 5.48% or 6.0% higher than that in case of 100% field capacity.

At a confidence level of 95.0%, the data on the dry matter in the fruits of plants in the three experimental years are arranged in 2 homogeneous groups at 100% irrigation, and with the reduced irrigation rate in 2018, there are no statistically significant differences between the data on dry matter, the values of the indicator are arranged in 3 homogeneous groups in the next two experimental years. The value of the variable p-value for the measured dry matter during the experimental years at 100% field capacity, as well as at 50% field capacity for 2019 and 2020, is less than the significance level, which by default is 0.05, while in the variants at 50%

Table 1. Influence of fertilization and irrigation rate on the quality of tomato production

Variant	ACB%			Total sugars, %			Mutual acids, %			Ascorbic acid, mg%		
	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
	100% irrigation rate											
T_1. 0	5.03	4.87	5.99	3.2	3.8	4.2	0.67	0.39	0.43	12.16	10.8	15.3
T_2.N15P8K15	4.25	4.31	6.0	4.2	4.0	4.3	0.56	0.42	0.48	14.81	12.7	18.6
T_3.N20P12K20	4.58	4.60	6.6	4.6	4.0	4.8	0.60	0.45	0.50	13.50	15.4	23.7
T_4.N25P16K25	4.99	4.60	6.2	4.6	3.8	4.0	0.73	0.48	0.50	16.00	14.2	24.2
Average	4.71	4.59	6.2	4.15	3.9	4.3	0.64	0.44	0.48	14.12	13.3	20.5
Median	4.61	4.60	6.1	4.40	3.95	4.25	0.66	0.42	0.48	13.91	13.55	21.55
St dev P	0.393	0.256	0.284	0.591	0.200	0.318	0.105	0.039	0.107	1.521	1.771	3.720
F- Ratio	5.26	4.20	8.32	40.31	0.89	16.80	1.67	9.02	0.23	21.60	43.81	181.90
P- Value	0.0270	0.0465	0.0077	0.0000	0.4872	0.0008	0.2503	0.0060	0.8741	0.0003	0.0000	0.0000
LSD-95.0%	0.525	0.369	0.322	0.339	0.399	0.272	0.190	0.043	0.236	1.163	0.978	1.031
LSD-99.0%	0.765	0.537	0.469	0494	0.581	0.395	0.277	0.063	0.344	1.692	1.424	1.501
	50% irrigation rate											
T_1. 0	4.27	4.6	6.2	3.8	3.9	4.6	0.51	0.39	0.42	10.55	11.6	17.9
T_2.N15P8K15	5.07	4.8	6.5	5.9	4.2	5.1	0.49	0.4	0.50	13.62	14.5	22.6
T_3.N20P12K20	5.15	5.1	6.9	5.8	4.0	5.3	0.55	0.45	0.46	10.43	16.8	29.1
T_4.N25P16K25	5.45	5.3	6.4	4.2	3.9	4.8	0.61	0.48	0.50	8.25	14.9	21.5
Average	4.99	4.94	6.50	4.93	4.01	4.94	0.54	0.43	0.47	10.71	14.45	22.78
Median	5.11	4.9	6.45	5.05	4.0	4.9	0.51	0.45	0.48	10.39	14.9	22.1
St dev	0.601	0.278	0.268	0.947	0.189	0.275	0.051	0.046	0.043	1.937	1.890	4.053
F- Ratio	2.98	16.89	12.29	116.92	1.63	20.06	10.18	4.80	3.91	102.17	85.23	623.12
P- Value	0.0963	0.0008	0.0023	0.0000	0.2589	0.0004	0.0042	0.0338	0.0536	0.0000	0.0000	0.0000
LSD-95.0%	0.952	0.237	0.261	0.326	0.344	0.217	0.054	0.060	0.063	0.712	0.759	0.610
LSD-99.0%	1.385	0.345	0.379	0.412	0.500	0.316	0.079	0.081	0.092	1.036	1.104	0.888

field capacity in 2018, the variable p-value is greater than the significance level – 0.05, where all measured values of the indicator are grouped in one row. The low p-value corresponds to high values of the Fisher criterion – F (except for 2018 – the variants with reduced irrigation). This fact is considered proof that the difference between the population and the sample mean is significant.

During the first two experimental years, as the fertilizer rate increases, so does the dry matter in the tomato fruit, regardless of the irrigation rate. In 2020, in which the highest contents of the indicator were reported (6.6% at 100% field capacityand 6.9% at 50% field capacity), at both irrigation rates, the highest content of dry matter was measured in the fruits of variant T_3 fertilized with $N_{20}P_{12}K_{20}$. The relationships between the absolutely dry matter in tomato fruit and the fertilization at different irrigation rates are well described by polynomial equations. With the high irrigation rate in the first two experimental years, the coefficients of determination are high (2018 – $R^2 = 0.99$; 2019 – $R^2 = 0.82$), in contrast to 2020, when the coefficient of determination shows a significantly weaker relationship between the studied indicators ($R^2 = 0.31$). In the case of reduced irrigation, the trends are maintained (2018 – $R^2 = 0.99$; 2018 – $R^2 = 0.98$), but in 2020, the coefficient of determination is higher ($R^2 = 0.58$).

The multifactor analysis (for LSD – 95.0%) shows that the main influence on the synthesis of dry matter in tomato fruits in 2018 is of the combined effect of fertilization and irrigation – 33.71%, followed by fertilization – 19.3%, and 6.73 % for irrigation; in 2019, the dominant combined influence of the two tested factors remains – 32.13%. The impact of irrigation that year increases to 30.0%, and fertilization is 20.24%. In the last experimental year, the combined effect of fertilization and irrigation is reduced to 4.6%, and irrigation is dominant with 42.11%, followed by fertilization with 36.91%.

The measured total sugars in the commercial maturity phase are between 3.2 and 4.8% at 100% irrigation rate and between 3.8 and 5.9% at 50% irrigation rate. The average content of sugars in tomatoes for the three-year study period in plants with reduced irrigation is 4.63% or 12.3% higher than in 100% field capacity. The literature cites data on correlation between dry matter and sugars in tomatoes which are due to the so-called “dilution effect” (Anthon et al., 2011). In the performed experiments, such dependences are

observed in all three experimental years at the full irrigation rate and in 2020 at the reduced irrigation.

The obtained values for total sugar content in both types of irrigation, depending on the applied fertilization in 2018, are arranged in 3 homogeneous groups, and in 2020, at 100% field capacity – in 2 and at 50% field capacity – in 3 homogeneous groups. In 2019, at both irrigation rates, there are no statistically significant differences between the measured sugar contents at different fertilization, at a confidence level of 95.0%.The value of the variable p-value in both irrigation rates in the experimental 2019 with the total sugars indicator is significantly higher that the significance level (0.05).

At both irrigation rates, only in 2020, in the plants of the variant with $T_3.N_{20}P_{12}K_{20,}$ the sugar content is proven higher than in the other variants, as the content of total sugars in the fruits with reduced irrigation rate is 10.4% higher in comparison with 100% field capacity.

With the high irrigation rate in the first two experimental years, the coefficients of determination showing the dependence of synthesized sugars on fertilization are high (2018 – $R^2 = 0.99$; 2019 – $R^2 = 0.93$), in contrast to 2020, when the coefficient of determination shows a significantly weaker relationship between sugars and fertilization ($R^2 = 0.33$). In the case of reduced irrigation, the coefficients of determination for all three experimental years are high (2018 – $R^2 = 0.97$; 2019 – $R^2 = 0.90$; 2020 – $R^2 = 0.82$).

The multifactor analysis (for LSD < 95.0%) shows that in the first year, the main impact on the synthesis of sugars is that of fertilization – 37.57%, followed by irrigation – 32.75%. The influence of the combined effect of the two studied factors is 26.12%. In 2019, the influence of the tested factors is weaker, as 17.4% is the influence of irrigation and 15.4% – of fertilization, and their combined effect is only 3.19%. In the last experimental year, the impact of irrigation on the accumulated total sugars is significant – 52.43%, the participation of fertilization is also high – 36.42%, and the combined effect of irrigation and fertilization is only 5.02%.

The acid content in tomato fruits during the years of the experiment ranges between 0.39 and 0.73% at the high irrigation rate and between 0.40 and 0.61% at the reduced one. The average acid content in tomatoes with 100% irrigation rate for the three-year period is 8.3% higher than that of the fruits with reduced irrigation.

The results for acid content regardless of irrigation rate in 2017 are combined into 3, and in 2019 – into 2 homogeneous groups. In the case of reduced irrigation in 2018, the acid content is arranged in 2 homogeneous groups, and at the full irrigation rate, there are no proven differences in the acid content at different fertilizer rates. The variable p-value is greater than the significance level – 0.05 at the full irrigation rate for 2017 and 2019.

In both irrigation rates during the experimental years, there is a trend without statistically proven differences for increase in the acid content in tomato fruits with increasing fertilizer rate. The role of the form, method and rate of fertilization and especially of nitrogen and potassium fertilization on the quality of production has been proven in many studies (Agostini et al., 2010; Mitova et al., 2010; Vasileva et al., 2016; Ankush et al., 2017; Tesfay et al., 2020). Regression equations show a positive dependence of the acid content in fruits on the applied fertilization in both irrigation regimes. With the high irrigation rate in all three experimental years, the coefficients of determination are high (2018 – $R^2 = 0.98$; 2019 – $R^2 = 0.99$; 2020 – $R^2 = 0.99$), and with reduced irrigation, the trend are preserved (2018 – $R^2 = 0.99$; 2019 – $R^2 = 0.97$; 2020 – $R^2 = 0.71$).

The multifactor analysis in 2018 with a significance level of LSD 95.0% shows that fertilization has main influence on the synthesis of acids in tomato fruits – 29.01%, followed by irrigation – 26.74%, and a weak combined effect of the two factors – 4.95%. In 2019, the influence of fertilization increases – 68.48%, at the expense of irrigation – 0.49%, and the combined effect of the factors is 0.94%. In 2019, participation of the tested factors in the formation of the studied indicator is also low: irrigation – 13.3%, fertilization – 0.17%, and combined effect – 1.76%.

The ratio between total sugars and acids in tomatoes is an important quality indicator determining the taste of fruits. Some earlier studies accept as optimal a sugar-acid ratio between 5.6 and 8.7 (Raykova, 1977), but with the development and improvement of selection methods and farming techniques, many researchers have already pointed out that the optimal ratio defining tomatoes as "tasty" is over 10-11 (Kader et al., 1978; Ganeva, 2007; Mitova et al., 2010) . In the studied samples over the years, this ratio ranges between 4.78 (in the controlled variant with 100% field capacity in 2018) and 12.04 (for fruits with reduced irrigation and fertilization with $N_{15}P_8K_{15}$ in 2018). In fertilized plants with 100% field capacity in 2018, and in 2020, regardless of irrigation rate, variant $T_3.N_{20}P_{12}K_{20}$ has formed fruits with the highest sugar-acid ratio, while in the reduced irrigation in 2018, as well as in both irrigation rates in 2019, the fruits from variant $T_2.N_{15}P_8K_{15}$ have the highest value of the total sugars / titratable acids ratio. It is noteworthy that the sugar/acid ratios in tomato fruits at 50% field capacity are 16.99% higher than those in plants with 100% field capacity.

Figure 1 shows the ratios between total sugars and titratable acidity in tomato fruits during the experimental years as a function of the applied fertilization and irrigation rate.

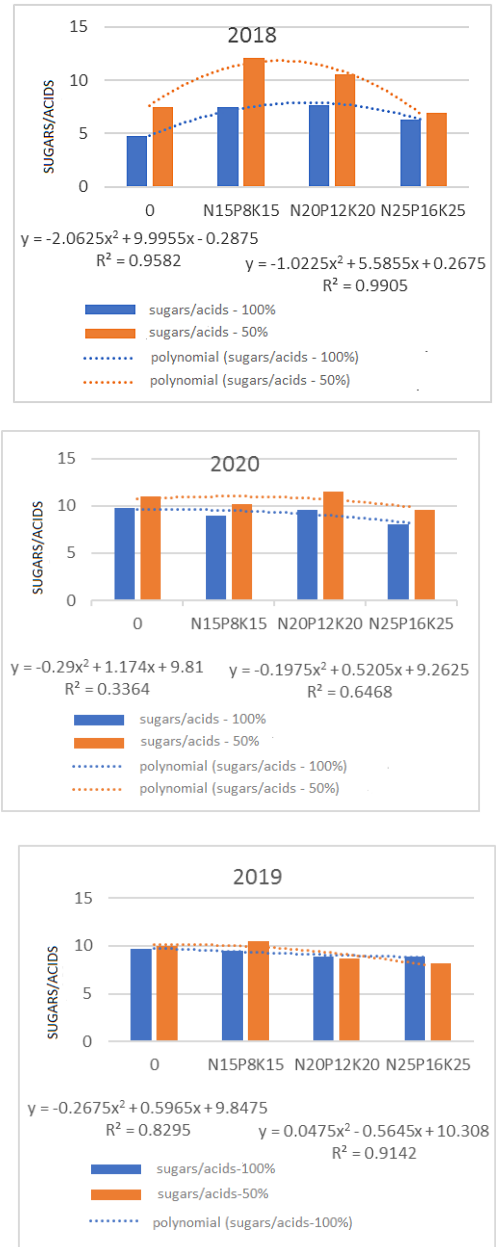

Fig. 1. Ratio between total sugars and titratable acidity in tomato fruitsas a function of the applied fertilization and irrigation rate

The dependence of the ratios of total sugars and titratable acidity on fertilization at the two irrigation rates is expressed by polynomial equations. In 2018 and 2019, the coefficients of determination expressing the indicated dependences between the sugar-acid number and the applied fertilization at full ($R^2 = 0.99$ for 2018 and $R^2 = 0.91$ for 2019) and reduced irrigation rate ($R^2 = 0.96$ for 2018 and $R^2 = 0.83$ for 2019) are very high. In 2020, these ratios are significantly lower – $R^2 = 0.65$ at full and $R^2 = 0.34$ at reduced irrigation rate, which means that only 65% and 34% of cases will have similar dependencies between the sugar-acid number and the applied fertilization.

The content of ascorbic acid in tomatoes in the period 2018-2020 is between 10.8 and 24.2mg% at full irrigation rate and between 8.25 and 29.1 mg% at the reduced rate. In the first experimental year, the average content of ascorbic acid in the fruits of plants with 100% field capacity is higher than in plants with reduced irrigation, and in the next two years, there is a reverse trend, as the final result of the average content of vitamin C in the experimental years is the same regardless of irrigation rate (Table 1). Despite the fact that there are no differences in the average content of vitamin C in the three experimental years due to irrigation rates, if we consider the individual years, it will be seen that this result is due to too low measured vitamin levels in the samples from the variants with reduced irrigation in 2018.

At a confidence level of 95.0%, the data for ascorbic acid in the fruits of plants at 100% irrigation for 2018 and 2019 are arranged in 4, and in 2020 – in 3 homogeneous groups, and with the reduced irrigation rate in 2018 and 2019 – in 3, and in 2020 – in 4 homogeneous groups. The variable p-value in all years of research at both irrigation rates is less than the significance level with proven differences between the variants.

At the full irrigation rate in 2018 and 2020, the plants with high fertilizer rate – $T_4.N_{25}P_{16}K_{25}$ – have the highest vitamin content, while in 2018 at 100% capacity, as well as in 2019 and 2020 at the reduced irrigation, fruits fertilized with $T_2.N_{15}P_8K_{15}$ have the highest content of ascorbic acid.

The coefficients of determination showing the relationship between ascorbic acid and fertilization at 100% field capacity are high in all experimental years (2018 – $R^2 = 0.71$; 2019 – $R^2 = 0.80$; 2020 – $R^2 = 0.92$). In the case of reduced irrigation, the trends are maintained for2018 – $R^2 = 0.93$ and 2019 – $R^2 = 0.83$, and in 2020, the coefficient of determination is lower – $R^2 = 0.58$.

The results of the multifactor analysis (for LSD 95.0%) show that the main influence on the synthesis of vitamin C in tomato fruits in 2018 is by irrigation – 48.87%, the combined effect of fertilization and irrigation is next with 28.58%, followed by fertilization -19.60%, while in 2019, the dominant factor is fertilization with 85.41%. The influence of irrigation that year is low – 9.33%, and the combined effect of the two tested factors is only 1.37%. In the last experimental year, the greatest influence on the synthesis of vitamin C is by irrigation – 46.11%, slightly weaker is the influence of

fertilization – 38.82%, the combined effect of the two factors is 14.25%.

The results obtained from the three-year study show higher quality indicators – absolutely dry matter, total sugars, ascorbic acid (except for 2018), sugar-acid number, as well as reduced acid content in the variants with reduced irrigation. These results are confirmed by a number of foreign studies (Kuscu et al., 2014; Yadan et al., 2017; DUYa-dan et al.; Jiang et al., 2019), which found ;that at the expense of yields, the quality of tomato production increases with a moderate water deficit. Jinliang et al. (2013) prove that when applying 1/3 (T3) of full irrigation at the stage of flowering and fruit development (stage II) and 1/3 (T5) or 2/3 (T6) full irrigation at the stage of fruit ripening (stage III), the content of total soluble solids (TSS), reducing sugars (RS), organic acids (OA), vitamin C (VC) and sugar/acid ratio (SAR) are significantly increased.

Conclusion

The studied biochemical indicators for the quality of tomatoes are influenced by two groups of factors: agrotechnical (irrigation and fertilization) and meteorological.

The average dry matter content of tomatoes for the three-year study period in plants with reduced irrigation was 5.48%, or 6.0% higher than in 100% field capacity. During the first two experimental years, as the fertilizer rate increases, so does the dry matter in the tomato fruit, regardless of the irrigation rate. In 2020, in which the highest contents of the indicator were reported (6.6% at 100% field capacityand 6.9% at 50% field capacity), at both irrigation rates, the highest content of dry matter was measured in the fruits of variant with $N_{20}P_{12}K_{20}$.

The average sugar content of the variants of fertilization in tomatoes for the three-year study period with reduced irrigation is 4.63%, or 12.3% higher than that in 100% field capacity. In both irrigation rates, only in 2020 with the variant with $N_{20}P_{12}K_{20}$, sugar content is statistically proven to be higher in comparison with the other variants.

The acid content in tomato fruits during the years of the experiment ranges on average between 0.39 and 0.73% at the high irrigation rate and between 0.40 and 0.61% at the reduced one. The average acid content in tomatoes with 100% irrigation rate for the three-year period is 8.3% higher than that of the fruits with reduced irrigation. In both irrigation rates during the experimental years, there is a trend without statistically proven differences for increase in the acid content in tomato fruits with increasing fertilizer rate.

Sugar/acid ratios in the experimental years range between 4.78 (in the controlled variant with 100% field capacity in 2018) and 12.04 (for fruits with reduced irrigation and fertilization with $N_{15}P_8K_{15}$ in 2018). In fertilized plants with 100% field capacity in 2018, and in 2020, regardless of irrigation rate, variant $T_3.N_{20}P_{12}K_{20}$ has formed fruits with the highest sugar-acid ratio, while in the reduced irrigation in 2018, as well as in both irrigation rates in 2019, the fruits from variant $T_2.N_{15}P_8K_{15}$ have the highest value of the total sugars/titratable acids ratio. Sugar/acid ratios in tomato fruits at 50% field capacity are 16.99% higher than those in plants with 100% field capacity.

The content of ascorbic acid in tomatoes in the period 2018-2020 is between 10.8 and 24.2 mg% at full irrigation rate and between 8.25 and 29.1 mg% at the reduced rate, as the average content of vitamin C in the experimental years is the same (15.97 mg% and 15.98 mg%) regardless of the irrigation rate. At the full irrigation rate in 2018 and 2020, the plants with high fertilizer rate – $T_4.N_{25}P_{16}K_{25}$ – have the highest vitamin content, while in 2019 at 100% capacity, as well as in 2019 and 2020 at the reduced irrigation, fruits fertilized with $T_2.N_{15}P_8K_{15}$ have the highest content of ascorbic acid.

The regression dependences represented by polynomial equations between the quality indicators for tomatoes and the applied fertilization depending on the irrigation rate show high values of the coefficients of determination (R2 between 0.58 and 0.99), except for the dry matter and total sugars at full irrigation rate in 2020.

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