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DRY MATTER CONTENT AND ORGANIC ACIDS IN TOMATOES, GREENHOUSE GROWN UNDER DIFFERENT MANURING AND IRRIGATION MODES

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Abstract

The experimental work was carried out during the period 2016-2017 in Bulgaria. Subject of research are tomato Vitelio cultivar, greenhouse grown at three levels of manuring and different irrigation regimes. The purpose of this study is to research the effect of applying three manuring schemes on irrigation with an optimal irrigation regime (M) and a controlled water deficit, with 75% and 50% of the irrigation rate being applied to dry matter and organic acids. From the presented distributions of the tested quality parameters of greenhouse tomatoes, it can be seen that the dry matter and titrimetric organic acids ratios are close to normal, and for the ascorbic acid indicator there are larger variations in the base values. The data is eligible for the sampling representatively requirements. Significant levels of $p < 0.05$ were obtained for the three researched indicators, i. E. the results of multi-variate dispersion analysis could be used in order to develop strategies for irrigation and manuring of tomatoes to reduce environmental risk. Considering the quality indicator: ascorbic acid a decrease in the quantities has been registered with an increase in the manuring norms. The analysis of the results found that when increasing fertilizer levels, the content of ascorbic acid decreased, i.e., there is an increase in the cost of tomato production and a decrease in the quality of tomatoes.
Key words: Tomatoes, irrigation, fertilization, dry matter, organic acids, ascorbic acid.

1. Introduction

In recent years, tomatoes have been the vegetable crop that holds one of the first places in production. The quality of tomatoes is a determinative factor in production. The environmental risk of the manuring factor and the role of irrigated water as an environmental factor are at the base of the current ecological study.

The content of dry matter and organic acids in tomatoes can have a beneficial effect both on the taste qualities of the produce and on the productive potential of the crop. The quantities of dry matter and the ratio of its individual components are essential for the quality of the fruit. A great number of the organic acid representatives are antioxidants that inhibit oxidative processes in animal and human consumption. These compounds not only inhibit the formation of free radicals containing oxygen, but can also be donors of hydrogen needed to increase levels of usable energy in organisms (ATPs).

A team of researchers (Bénard et al., 2009) prove that lower nitrogen levels reduce plant growth and increase the dry matter content in fruits, thus improving the fruit quality.

Potassium is considered to be one of the major biogenic elements due to its vital role in the formation of metabolites and the activation of enzymes that ultimately improve the chemical and sensory properties of tomato fruits.The present study of the effect of different levels of potassium fertilizer on the chemical and sensory properties of tomatoes indicates that the increase in the K-concentration leads to an improvement in the quality parameters of the tomato fruits (Javaria et al. 2012a; Constán-Aguilar et al. 2015).

A linear positive correlation was reported between taste and sugar, total solids, titratable acidity; surface redness with lycopene and hardness with the total amount of solids while the taste pH ratio is negative.

Regression relationships between manuringand macroelements nitrogen, phosphorus and potassium on the growth and reproduction of tomato seedlings have been determined, with a high degree of nitrogen influence on the leaf area index. Excessive use of N leads to a decrease of the tomato quality. of tomatoes (Liu et al. 2009, Patanè C. and SL Cosentino, 2010).

In the research of the effect of various mineral nutrient solutions, it has been found that the source of nutrients plays a major role in determining the levels of titratable acid and antioxidant components in tomatoes (Toor et al., 2006).

More attention is now focused on promoting the health benefits of the regular consumption of fruits and vegetables because fruits contain a wide assortment of antioxidant molecules (carotenoids, phenolics compounds, and ascorbate) that contribute to fruit nutritional quality.

The correlation between quality parameters and dietary regimes in tomatoes is the subject of many authors' research. There are numerous results on the influence of manuring with macroelements and types of nutrient solutions on the levels of chemical indicators and antioxidant properties of tomatoes (Oke et al., 2005, Bernard et al, 2009, Javaria et al. 2012b;, Vassileva et al., 2016).

It is only possible to obtain a good effect of irrigation and the most productive use of irrigated water by applying an optimal irrigation regime that is consistent with crop requirements. A number of authors have found the high degree of influence of the water deficit on the quantity and quality of tomato yields (Zugui L. et al., 2003, Favati F. 2009, Ozbahce et al. 2010, Patanè C. et al., Pevicharova et al. 2013, Kuşçu, 2014).

The purpose of this study is to research the effect of applying three manuring schemes on irrigation with an optimal irrigation regime (M) and a controlled water deficit, with 75% and 50% of the irrigation rate being applied to dry matter and organic acids.

2. Material and Method

2.1. Experimental Data

The experimental work was carried out during the period 2016-2017 in an unheated polyethylene greenhouse in Institute of Vegetable Crops “Maritsa”, Bulgaria. Subject of research are tomato Vitelio cultivar, greenhouse grown at three levels of manuring and different irrigation regimes.

The experience is based on the block method on a flat surface according to scheme 110 + 50 + 35 with the plot size of 10 m^2. To study the impact of different levels of manuring and irrigation with different irrigation regimes on fruit quality, twenty manuring and irrigation options have been set.

The scheme includes three levels of manuring: optimal manuring, 1/2 of manuring norms; 1/3 of the manuring standards. The effect of the basemanuring carried out with P_{23} (in the form of P_2O_5 and K_{25} (as K_2SO_4) and nutrition during vegetation with N_{50} (in the form of NH_4NO_3) and K_{66} (in the form of KNO_3) was studied. Irrigation includes optimal irrigation mode and disrupted irrigation regime with 75% and 50% of the irrigation rate.

Tomatoes are grown in accordance with standard practices in greenhouse production. Irrigation was carried out with a drip irrigation installation with built-in drip irrigation mechanism.

Experimental Variations: 1) disrupted irrigation regime (50% of the irrigation norm) without manuring; 2) disrupted irrigation regime (75% of the irrigation norm) without manuring; 3) optimum irrigation regime (100%) without manuring; 4) disrupted irrigation regime (50% of the irrigation norm) and 50% manuring; 5) disrupted irrigation regime (75% of the irrigation norm) and 50% manuring; 6) optimum irrigation regime (100%) and 50% manuring; 7) disrupted irrigation regime (50% of the irrigation norm) and 75% manuring; 8) disrupted irrigation regime (75% of the irrigation norm) and 75% manuring; 9) optimum irrigation regime (100%) and 75% manuring; 10) disrupted irrigation regime (50% of the irrigation norm) and 100% manuring; 11) disrupted irrigation regime (75% of the irrigation norm) and 100% manuring; 12) optimum irrigation regime (100%) and 100% manuring.

2.2. Biochemical Analysis

The content of basic chemical components in tomato fruit is determined as a result of the biochemical analysis. The dry matter content is determined on average samples of 20 fruit in process maturity of each variant refractometrically (%). The titrable organic acid levels are determined by direct titration of juice with 0.1 n NaOH (%). Ascorbic acid was detected by the Tilman reaction using 2,6-dichlorophenol-indophenol as an indicator (Genadiev et al., 1969).

2.3. Statistical Processing

Statistical data processing involves obtaining the main statistical indicators for all tested features, verifying the distribution normality data, and multivariate dispersion analysis with a LSD (Least Significant Difference) test to determine the impact of different manuring and watering schemes on the dry matter content, ascorbic acid and titratable organic acids in greenhouse-grown tomatoes. For data processing, the IBM SPSS Statistics 17.0 statistical package was used.

3. Results and Discussion

3.1. Analysis of Dry Matter

Table 1 shows the impact of the manuring and irrigation scheme on dry matter, ascorbic acid and titratable organic acid levels for 2016 and 2017. As a result of the multispectral LSD analysis of all manuring and irrigation variants for both years observed p-value = 0.000 <0.05 has been found, proving that the impact of the various manuring and watering variants on the tested features (dry matter, ascorbic acid and titratable organic acids) is statistically significant.

The dry matter in the fruit is one of the most important and easily determinable components of the produce quality. Its normal content in tomato fruit varies between 5 and 7.5% (Heuvelink, E. 2005). Considering the dry matter content, for the optimal irrigation options and different manuring levels, the average values range from 4.2 to 5.1 mg%. When 100% manuring is applied, dry matter ranges from 4.6 to 5.6 mg%.

In the first year of the manuring variants with a 100% manuring rate, an increase in the dry matter content was registered by 9.5% compared to the not menured, and in the second year of the survey the increase was by 14.4%. These results are confirmed by a study by Xiukang Wang et al. (2017), according to which the dissolvable solids (TSS) content increases with increasing manuring levels.

According to Bénard et al. (2009), however, lowering the supply of nitrogen has had a low impact on fruit commercial yield (-7.5%), but has reduced plant vegetative growth and increased dry matter content in fruit. Tringovska (2015) also found that in the excessive manuring the biochemical indicators of the quality of the fruits are of lower values.

Table 1. Influence of Manuring and Irrigation Scheme on Dry Matter Content and Titratable Organic Acid Levels

Variant	$\bar{x} \pm SD$					
	Dry matter [a]		**Ascorbic acid** [b]		**Titratable organic acids** [c]	
	2016	**2017**	**2016**	**2017**	**2016**	**2017**
1	4.21±0.023*	4.31±0.025*	37.93±0.030*	34.07±0.016*	0.29±0.021*	0.33±0.017*
2	4.21±0.020*	4.52±0.035*	34.06±0.024	34.07±0.022*	0.30±0.019*	0.34±0.020*
3	4.29±0.030	4.50±0.029	34.12±0.037	38.45±0.033	0.31±0.017	0.31±0.017
4	4.31±0.025*	4.50±0.029	27.95±0.039*	32.61±0.021*	0.32±0.018	0.39±0.020*
5	4.10±0.019*	4.60±0.037*	30.57±0.039*	33.58±0.032*	0.30±0.019*	0.41±0.026*
6	4.21±0.022*	4.41±0.037*	32.31±0.020*	30.16±0.023*	0.32±0.018	0.32±0.018
7	4.10±0.018*	4.60±0.037*	27.07±0.035*	30.17±0.025*	0.34±0.020*	0.39±0.020*
8	3.91±0.061*	4.60±0.037*	27.95±0.039*	28.24±0.023*	0.31±0.017	0.37±0.027*
9	4.90±0.035*	5.10±0.021*	24.45±0.033*	30.17±0.025*	0.32±0.018	0.36±0.027*
10	4.60±0.037*	5.60±0.037*	26.64±0.031*	32.61±0.022*	0.32±0.018	0.33±0.017*
11	4.70±0.035*	5.00±0.053*	25.33±0.029*	28.23±0.022*	0.33±0.017*	0.32±0.018
12	4.61±0.032*	4.60±0.037*	21.83±0.036*	30.66±0.026*	0.33±0.017*	0.35±0.027*

Based on observed means.
The error term is Mean Square (Error) = 0.000
a. R^2 = 0.987(Adjusted R^2 = 0.987) for 2016; R^2 = 0.990 (Adjusted R^2 = 0.990) for 2017
b. R^2 = 1.000 (Adjusted R^2 = 1.000) for 2016; R^2 = 1.000 (Adjusted R^2 = 1.000)for 2017
c. R^2 = 0.414 (Adjusted R^2 = 0.405) for 2016; R^2 = 0.669 (Adjusted R^2 = 0.663) for 2017
*test: LSD significant mean differences between variant 3 (accepted as Control) and all other variants of tomato fruit treatment at the $p < 0.05$ level

As can be seen from Table 1,statistically significant differences in average dry matter between optimum irrigation and not menured variants (Variant 3) and variants of manuring and irrigation in tomatoes for 2016 exist. The credibility of the difference in the average values of dry matter are proven with the results obtained for 2017with the exception of variants3 and 4, where no statistically significant differences were observed. These results are presented graphically in Fig. 1a and 1b. The figure clearly shows the average values and standard deviations of the dry matter indicator for the various tomato processing options, greenhouse production, and the credible differences between them.

The frequency distribution of the average dry matter content of tomato fruits into the two years of the experiment is shown at Fig. 2a and 2d. As can be seen from the figure, the values of the dry matter have a distribution/diffusion close to the normal value.During the second year, higher values of the indicator were recorded. The upward trend in dry matter volumes in 2016 for 100% manuring variants was also observed in 2017.

3.2. Analysis of Ascorbic Acid

Ascorbic acid (vitamin C) is one of the main quality indicators measured in tomatoes. It is one of the most important organic acids in fruits and vegetables in terms of their nutritional value (Melèndez et al., 2004) The histogram, concerning concentrations of ascorbic acid in 2016 (Fig.2b) reflects the irregular distribution/order of these values in different manuring and irrigation options.

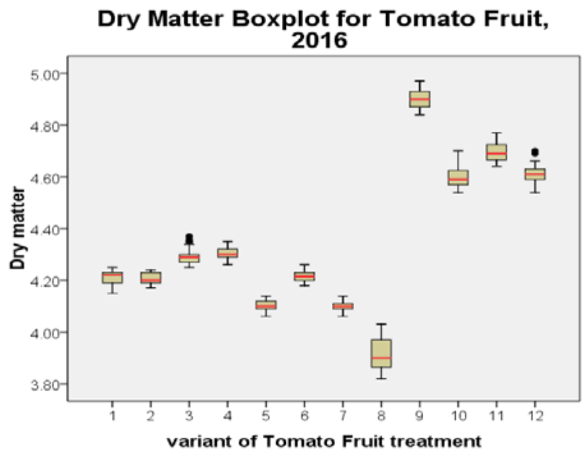
A decrease in the content of ascorbic acid at 100% manuring rate has been registered for various tomatoes with regular irrigation scheme. Limits were set at 21.83-26.64 in the first year and 28.23-32.61 in the second year. Opposed to the background full of different irrigation regimes but without application of manuring the results are the following 34.06-37.93 and 34.07-38.45 (see Table 1). Experimental data show a decrease in the amount of ascorbic acid at higher manuring rates.

As a result of their own study, Stevens and Rick (1986) study it wide ranges of vitamin C content in tomato fruits (8-119 mg. 100g) was also found. Vasileva et al. (2016) found that fractional (three or two times) potassium manuring leads to an increase in the dry matter content, total sugars and vitamin C while researching the fruits of the two varieties of tomatoes ("Atak" and "Nicolina F1").

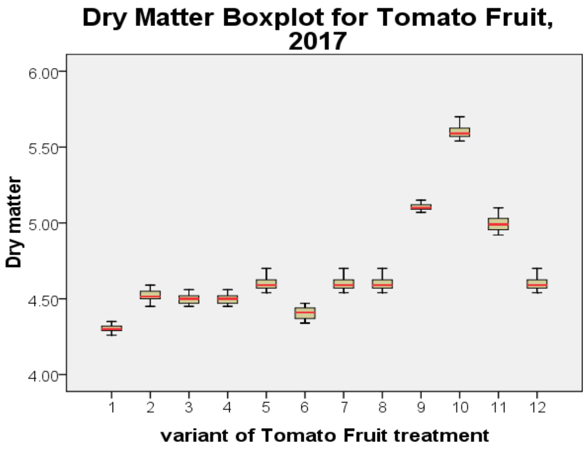
According to a Pevicharova et al. (2013) survey the influence of the irrigation regime on the synthesis of ascorbic acid in tomatoes is relatively low. The content ranges from 19.48 to 60.49 mg per 100 g for irrigated plants and from 12.52 to 85.64 mg per 100 g for not irrigated plants.

The results obtained in this study confirm the insignificant effect of irrigation on the content of ascorbic acid in tomatoes grown under different irrigation regimens. The causing of periodic water deficiency leads to insignificant disturbances in the synthesis of vitamin C.

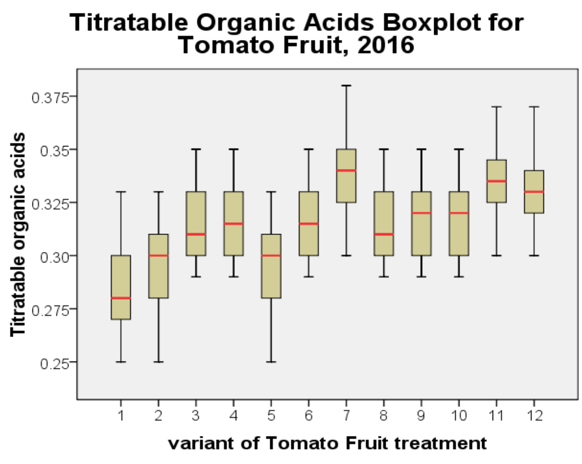
The multivariate analysis of the results of the chemical component: ascorbic acid proves significant differences between manuring and irrigation variants. Except variant 2 for 2016, reliable differences between the averages of the researched index between option 3 (optimal irrigation regime) and all other variants of treatment are reported for both 2016 and 2017.



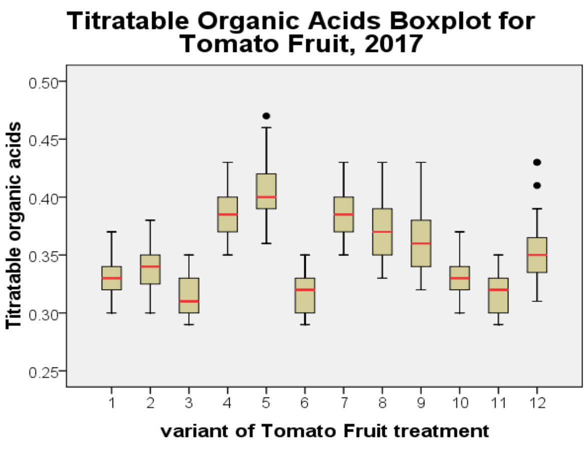
a)



b)



c)



d)

Legend1) disrupted irrigation regime (50% of the irrigation norm) without manuring; 2) disrupted irrigation regime (75% of the irrigation norm) without manuring; 3) optimum irrigation regime (100%) without manuring; 4) disrupted irrigation regime (50% of the irrigation norm) and 50% manuring; 5) disrupted irrigation regime (75% of the irrigation norm) and 50% manuring; 6) optimum irrigation regime (100%) and 50% manuring; 7) disrupted irrigation regime (50% of the irrigation norm) and 75% manuring; 8) disrupted irrigation regime (75% of the irrigation norm) and 75% manuring; 9) optimum irrigation regime (100%) and 75% manuring; 10) disrupted irrigation regime (50% of the irrigation norm) and 100% manuring; 11) disrupted irrigation regime (75% of the irrigation norm) and 100% manuring; 12) optimum irrigation regime (100%) and 100% manuring.

Fig. 1. Boxplot of Significant Differences between all Variants of Tomato Fruit Treatment

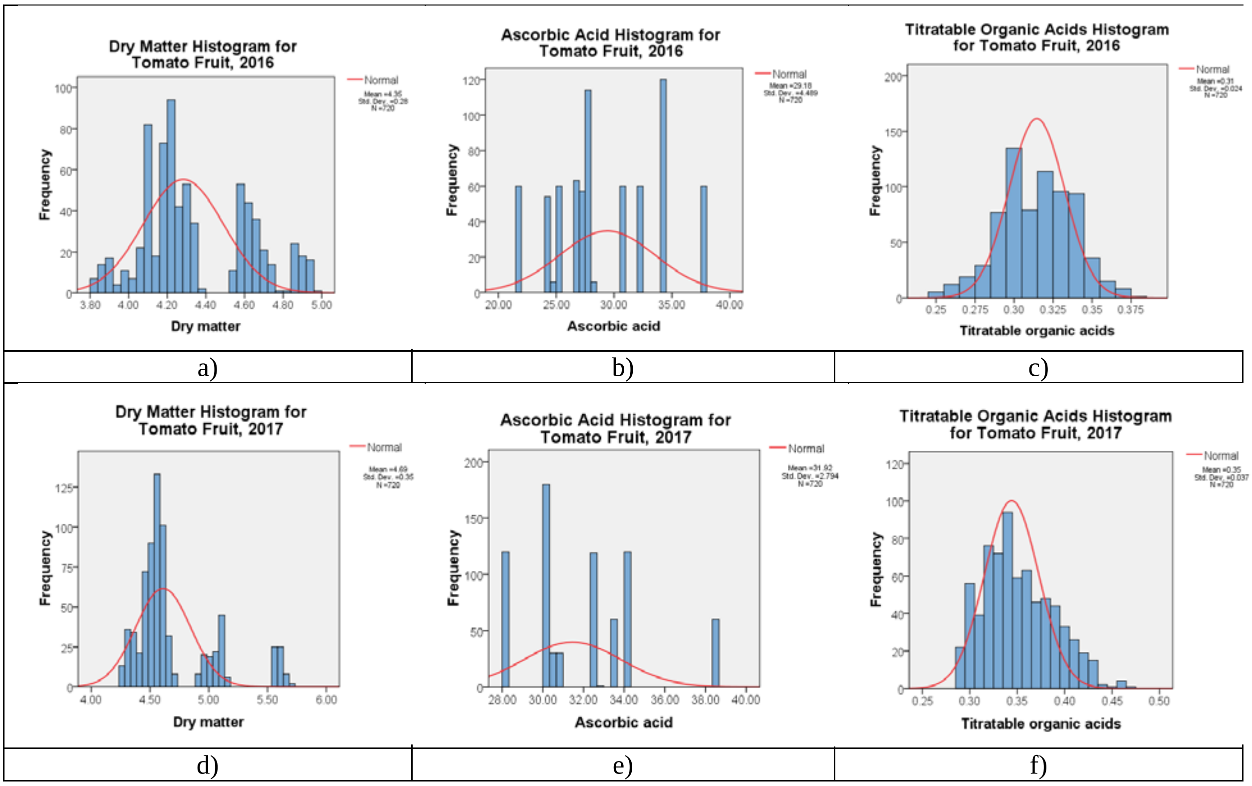


Fig. 2. Histogram of Data Distribution for Dry Matter, Ascorbic Acid and Titratable Organic Acids for 2016 and 2017

3.3. Analysis of Titratable Organic Acids

An important element of plant nutrition is the formation and accumulation of titratable organic acids in tomato fruits. According to Adams et al. (1978), the content of total acidity in tomato fruit has a greater impact on their taste qualities than sugars. Data concerning the total quantity of organic acids (ascorbic, citric, fumaric and malic acids) in tomatoesare presented in this paper.

In Table 1 what makes an impression is that at an optimal manuring rate, the organic acid content ranges within very narrow limits over both years. The highest levels of organic acids are recorded at manuring rates of 50 and 75%. Significant differences were found under the influence of irrigation regimes.With the highest levels of titratable organic acids, variants with impaired/disrupted irrigation regime and reduced manuring levels are distinguished on average. It has been found that when reducing the irrigation rate of 50 and 75% and manuring by 50 and 75%, the parameters for this component range from 0.32 to 0.4 in both years.

Considering the chemical component: Titratable acids (Table 1) statistically significant differences for the year 2016 are recorded between the optimal scheme of watering and manuring (variant 3) and 1, 2, 5, 7, 11 and 12 schemes of irrigation and manuring, and in 2017 the differences between the optimal variant and all other variants except the 6 and 11 are credible.These results are depicted in Fig. 1c and 1d.

As can be seen from Fig. 1c in 2016, the average values of the titratable acid indicator for most treatment regimens are very close or equal, so only some of them have statistically significant differences. In 2017 (Figure 1d) a significant variation in the average values variants for processing options was indicated, with the exception of the options 6 and 11, which justifies the statistical reliability of the differences.

The histogram of the average values for titratable organic acids for 2016 is depicted in Fig. 2c and Fig. 2f for 2017 and indicates that the data has a normal frequency distribution.

3.4. Analysis of the Coefficients of Determinacy for all the Qualitative Indicators Examined

Table 1 shows the coefficients of determinacyof the three quality parameters observed as a result of the analysis. As can be seen from the table, 98.7% (2016) and 99.0% (2017) of variations in the factor: dry matter are due to the impact of different watering/irrigating and manuring options.

Considering ascorbic acid, 100% of variations in both observed years are due to the impact of watering and manuring schemes. Consideringtitratable organic acids, 41.4% for 2016 and 66.9% for 2017 variations are explained by the impact of different manuring levels and different irrigation regimes.

A similar trend is registered by Javaria, et al. (2012) when analyzing the total content of solids, sugars and titratable acidity in samples with different potassium levels. Likewise, lycopene, vitamin C, and total quantity ofdissolvable solids increased significantly with K_2O was increased up to 375 kg but then decreased when K_2O was applied to 450 kg K_2O ha-1.

The results obtained by comparing the impact of different irrigation regimes identify the possibilities for increasing the nutritional qualities of tomatoes by reducing irrigation norms. In support of this, Favatia et al. 2009 reported that the data obtained by regulating irrigation regimes by a reduction of the irrigation rate and an extension of the irrigation interval.

The presented frequency distributions (Figure 2) of the reaearched dry matter qualities and titratable organic acids have a near-normal distribution, and for the ascorbic acid indicator there are larger variations in the base values. Since the data comly with the sample representativeness requirements, and as a result of the analysis, significance levels p-value = 0.000 <0.05 were obtained for the three researched indicators, respectively for both observed years, it can be assumed that the results of the applied multivariate dispersion analysis are common and applicable to the whole aggregation.

The performed multvariate analysis of the influence of the factors manuring and irrigation on the dry matter content and the levels of the organic acids may be used/serve as the basis for developing strategies for irrigation and manuring of tomatoes in order to reduce the environmental risks.

4. Conclusions

From the presented distributions of the tested quality parameters of greenhouse tomatoes, it can be seen that the dry matter and titrimetric organic acids ratios are close to normal, and for the ascorbic acid indicator there are larger variations in the base values.

The data is eligible for the sampling representativity requirements. Significant levels of p <0.05 were obtained for the three researched indicators, i. E. the results of multi-variate dispersion analysis could be used in order to develop strategies for irrigation and manuring of tomatoes to reduce environmental risk.

Significant differences have been found concerning the effects of manuring on the dry matter content of tomatoes, greenhouse production.

Considering the quality indicator: ascorbic acid a decrease in the quantities has been registered with an increase in the manuring norms.

Average variants with disrupted irrigation regime and reduced manuring levels With the highest levels of titratable organic acids are distinguished.

The analysis of the results found that when increasing fertilizer levels, the content of ascorbic acid decreased, i.e., there is an increase in the cost of tomato production and a decrease in the quality of tomatoes.

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