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Evaluation of the influence of irrigation and fertilization on the content of some biochemical colour compounds in tomatoes, greenhouse production by mathematical approach

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Abstract

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Using a mathematical approach (correlation and cluster analysis), assess the similarity and remoteness of different irrigation regimens for tomatoes and group them on the basis of basic biochemical parameters. The objectives of the study was to establish the parameters of the quality indicators (common dyes, lycopene and beta-carotene) in tomato under the influence of the various irrigation and diets; ~~to~~ compare the similarity and remoteness of different irrigation regimes and fertilization regimes for tomatoes, the variety *Vitelio* F1 and to group them on the basis of important quality indicators using cluster analysis and to establish correlation between study quality indicators to make a more objective assessment of the studied factors – irrigation and fertilization. As a result of the analyses the effects of irrigation regimes and the rate of fertilization in tomatoes are found. At all fertilization levels, there is a tendency to increase the lycopene content by decreasing the irrigation rate. The same trend is observed in the content of β-carotene in tomatoes. Increasing the water deficit increases the levels of β-carotene. Cluster analysis divided the similarity in the two main cluster variants. In the first cluster it is comprised of two sub-clusters: the first sub-clusters with variants 2, 3 and 1, the second sub-clusters to the embodiments 5 and 6, similar indicators, common dyes and beta-carotene and variants impaired irrigation regime and with at least Euclidean distance between them. The second major cluster includes variants 7, 10, 8, 9 and 11 where it is allowed a small to moderate water deficit. They are most similar to common dyes, lycopene and extraction. The strongest positive correlation is found between total dye and lycopene, beta-carotene, yield.

Keywords: tomatoes; irrigation; fertilization; cluster; correlation

Introduction

The prevalence and widespread use of tomatoes is due primarily to the excellent food, taste and technological qualities of the fruit. The chemical composition of fruits fluctuates quite widely, depending on the variety, the region, the growing conditions and the farming practices applied.

However, the nutrient content of tomatoes depends mainly on genetic and ecological factors, and Javanmardi et al. (2008) consider maturation. Irrigation is also an agricultural practice that can influence the final content of these parts in the tomato fruit (Dumas et al., 2003). Water supply is limited globally and there is a growing need to reduce the amount of water used during irrigation practices (Zegbe-Domlnguez et al., 2003). The water deficit has a positive influence on the dry matter content, (Shao et al., 2014) and lycopene (Dumas et al., 2003).

The influence of irrigation practices on the processing tomato quality has not been sufficiently studied yet. Here are many studies related to the effects of quantity and frequency of irrigation on the quality of tomatoes (Cahn et al., 2001; Zegbe-Dominguez et al., 2003; Hanson et al., 2004; Machado et al., 2005) but still this question is relevant given the content of antioxidants in tomatoes.

Examining the influence of water deficit there are established parameters of water deficit and productivity of irrigation water which result in stable yields and high quality (Lahoza et al. 2016; Nangare et al. 2016).

Favati et al. (2009) evaluate the relationship between all quality parameters in tomatoes and seasonal water for irrigation. Tested and evaluated are the effects of different irrigation regimes, taking into account the physical and chemical characteristics of fruit and content of antioxidants.

The efficiency of utilization of fertilizers and irrigation water is the subject of study and Du et al. (2017). Studying the impact of irrigation and fertilization with different levels of nitrogen, they set the optimal irrigation regime (75% air humidity) and fertilization norms (250 kg N ha^{-1}) and recommend the best strategy for water and nitrogen management for greenhouse tomatoes grown under drip irrigation conditions. Balanced fertilization can improve the qualitative composition of tomatoes (Dorais et al., 2008; Boteva, 2009).

In recent years, as a result of expanding knowledge about the benefits of carotenoids for health, there is a significantly increasing attention of researchers to food taste and antioxidant properties of tomato fruits. A plurality of medical research has shown that dietary intake of lycopene-rich food limiting cases of some oncological and cardiovascular diseases, cataracts and the like. (Miller et al., 2002; Willcox et al., 2003).

In our country a tomato "Plovdiv carotene" was directly created, combining favorable high in fruits of β-carotene and lycopene (Ganeva et al., 2011). Color is principally associated with the lycopene content of tomato and is generally considered the most important attribute determining the product quality (Garcia et al., 2006a).

In this study we set the following objectives:

1) to establish the parameters of the quality indicators (common dyes, lycopene and beta-carotene) in tomato, under the influence of the various irrigation and diets;

2) to compare the similarity and remoteness of different irrigation regimes and fertilization regimes for tomatoes, the variety *Vittelio* and to group them on the basis of important quality indicators using cluster analysis;

3) to establish a correlation between study quality indicators to make a more objective assessment of the studied factors – irrigation and fertilization.

Such an approach for the characterization is carried out at a sunflower, corn and soybeans (Binohd, et al., 2007; Chambo, 2014; Ilchovska et al., 2014; Matev et al., 2014).

Material and Methods

For the purpose of the study there were used test results of different irrigation regimes and norms of fertilization in tomato cultivar *Vittelio* during the period 2016 – 2018 year. The experiment is based in the region of Plovdiv with geographical coordinates 42° and 09′ north latitude and 24° and 45′ East GMT (GPS). The experiment based on the block method on a flat surface in scheme 110 + 50 + 35 with the size of the parcel plot of 10 m^2 (Barov, 1982).

1. Irrigation regime (50% of the irrigation rate) without fertilization; 2. Irrigation regime (75% of the irrigation norm) without fertilization; 3. Optimal irrigation regime (M-100%) without fertilization (control); 4. Irrigation regime (50% of irrigation rate) and 50% fertilization; 5. Irrigation regime (75% of irrigation rate) and 50% fertilization; 6. Optimal irrigation regime (M-100%) with 50% fertilization; 7. Irrigation regime (50% of the irrigation rate) and 75% fertilization; 8. Irrigation regime (75% of irrigation rate) and 75% fertilization; 9. Optimal irrigation regime M-100%) with 75% fertilization; 10. Irrigated irrigation regime (50% of irrigation rate) and 100% fertilization; 11. Irrigation regime (75% of irrigation rate) and 100% fertilization; and 12. Optimal irrigation regime (M-100%) and 100% fertilization.

Using a mathematical approach (correlation and cluster analysis), assess the similarity and remoteness of different irrigation regimens for tomatoes (*Vitelio* variety) and group them on the basis of main biochemical parameters. Three-year data are used from the field trial including irrigated and optimal variant as well as variants with annulment of irrigations and reduced watering rates.

Greenhouse production is intense and it requires the application of high doses of fertilizers. For the purposes of the experiment, different doses of basic fertilization and feeding during the growing season were tested. The main fertilization was carried out with P 230 $kg.ha^{-1}$ in the form of P_2O_5) and K 250 $kg.ha^{-1}$ (as K_2SO_4). Feeding through vegetation was performed with N 500 $kg.ha^{-1}$ as NH_4NO_3) and K 660 $kg.ha^{-1}$ as KNO_3) according to the experimental methodology.

Submission of irrigation water was realized with the drip irrigation system. During the three years of the study various watering rates have been implemented depending on the requirements of culture and the length of the growing season. During the first year the irrigation rate was 495 mm, realized through 33 watering. In the second one, 27 pots with an irrigation rate of 405 mm were submitted. The number of irrigation in the last year was 29 with an irrigation rate of 435 mm. Reducing watering options in applied according methodical plan.

Basic chemical components in the tomato fruit – On average samples of 20 fruit into a technological maturity of each variant to determine the dry matter content – refractometer (%), ascorbic acid (mg%) – by reaction of Tilmans (Genadiev et al, 1969), titratable organic acids by direct titration of the juice with 0.1 n NaOH (%), common dyes (mg%), lycopene (mg%) and β-carotene (mg%) – according to the procedure of Manuelyan (Manuelyan, 1991).

The evaluation of the tested modes of watering and fertilization is done by comparing the following parameters defining the quality of tomatoes: general dyes – x_1; lycopene – x_2; beta-carotene-x_3; yield – x_4; prematurity – x_5.

The grouping of the 12 tested variants of irrigation scheduling is done through hierarchical cluster analysis. The method of intergroup binding is used (Ward, 1963; Dyuran et al. 1977). Euclidean distance intergroup is used as a measure of similarity:

$$D(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}.$$

Built dendrogram through which generated clusters are graphically represented. The horizontal line of the dendrogram shows the escalated distance at which the clusters are formed. A correlation analysis is conducted to determine the existence of statistically significant correlations between the studied parameters.

Data processing was carried out with the statistical program SPSS.

Results and Discussion

To determine the influence of irrigation regime and fertilization levels on quality of greenhouse tomatoes found the content of the common dyes, lycopene and beta carotene. An important indicator of the quality of tomatoes is the content of common dyes. The two main groups of pigments in the fruit of tomato carotenoids and chlorophylls but the final color is determined by the total quantity and ratio of different carotenoids (Danailov, 2012).

The results of the analysis of the quality of the tomato fruit (*Solanum lycopersicum* L.) are presented in Figure 1, 2 and 3. The content of the common dyes, average research period is greatest in variant 7 with 75% fertilizer and variant 10 with a 100% fertilization rate.

A similar trend was noted in Vasileva et al. (2016) in an analysis of the influence of potassium fertilization (K 240 kg.ha^{-1}) in the form of K_2SO_4 on background nitrogen (K 240 kg.ha^{-1} in the form of NH_4NO_3) and phosphorous (P 120 kg.ha^{-1}) the form of triple superphosphate) fertilization. The subject of the study was two tomato varieties early and mid-early production. The trend was recorded for both varieties in both production directions.

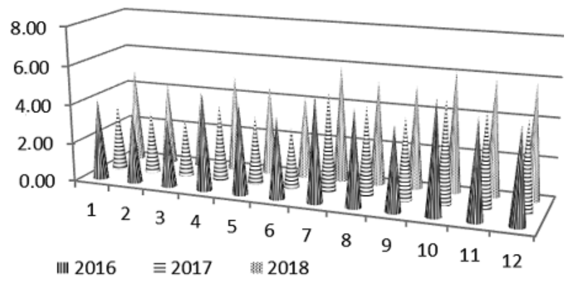

Figure 1. Content of common dyes in tomatoes, greenhouse production

Lycopene is a phytochemical from the group of carotenoid pigments. Its antioxidant activity predetermines the interest in increasing its content in tomatoes. Researchers have found that lycopene accounts for between 75 and 83% of the total content of pigments in tomatoes (Gould, 1992; Abushita et al., 1997) making it an important biochemical quality indicator.

According to some authors the content of lycopene is varietal characteristic and fruit of tomatoes respond to fertilization with potassium by increasing the content of antioxidants (Hartz et al., 2005; Henry et al., 2008). According to the FAO, the lycopene content ranges from 7 to 13 mg. 100 g (Rath et al., 2009). In the present study the content ranges from 2.25 to 5.74. Figure 2 shows that the content of lycopene is higher at a reduced irrigation rate. The trend is observed at all levels of fertilization and fermentation of tomato fruits.

Average for the period with the highest content stands variant 7 with a lycopene content of 4.69. The mowing mode is less than half irrigation. At the same level of fertilization and irrigation 100% lycopene is 3.97. The results are similar in 100% fertilization. Reducing half of the irrigation rate contributed to the formation of 4.49 lycopen, and at 100% irrigation rate the values were 3.67. The water deficit has a positive influence on the content of lycopene as well as Dumas et al. (2003).

The beta (b)-carotene content determines the orange color of the tomato fruit. The good combination of the two components (lycopene and beta (b)-carotene) with an antioxidant

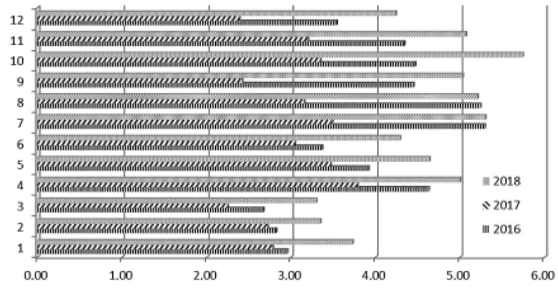

Figure 2. Lycopene content in tomatoes, greenhouse production

effect determines hybrids of tomatoes such as hybrids of high biological value (Pevicharova et al., 2012). The analysis of the results shows trends in Beta-carotene content in different irrigation regimes and fertilization levels. Against a background of a fertilizer regime, a decrease in the carotenoid content was observed when the irrigation rate increased. For zero fertilization, the content ranges from 0.20-0.25 mg% averaged over the years of the experiment.

At a fertilization level of 75% of the fertilizer rate, values from 0.30 to 0.43 mg% were calculated. The higher value was found in reducing the irrigation rate in half. At 100% fertilizer the content of beta-carotene is in the range of 0.32 – 0.51 mg%. Similar findings were reached and other scientists analyzing the impact of nutrients on the quality of tomatoes. According to Mozafar (1994) beta-carotene content in fruit increases with increasing levels of K, Mg, Mn, B, Cu and Zn. Phosphorus may also increase the fruit concentration of phytochemicals such as ascorbic acid, flavonoids and lycopene (Dorais et al., 2008).

The performed cluster analysis shows that the impact of irrigation regime on quality indicators of tomatoes grouped in two main clusters. The results are presented both tabulary

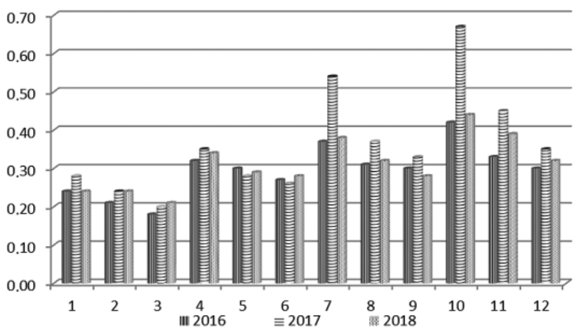

Figure 3. Beta-carotene content in tomatoes, greenhouse production

with the steps of combining cluster and intergroup distances (Table 1) and graphically by dendrogram (Fig. 4).

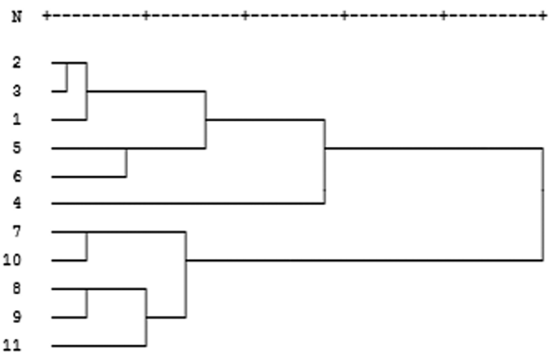

Figure 4. Dendrogram based on the average intergroup distance

The first cluster is more homogeneous and it is comprised of two sub-clusters: the first sub-clusters with variants 2,3 and 1, the second sub-clusters to the embodiments 5 and 6, similar indicators, common dyes and beta-carotene and variants impaired irrigation regime and the most a little Euclidean distance between them. The close distance in the first sub-clusters can be explained by the influence of zero fertilization on the content of qualitative indicators. In this case, more important is the deficiency of nutrients influencing the synthesis of antioxidants. In the second sub-clusters the relative values can be explained by the higher rate of fertilization (50%) but in combination with 75% and 100% irrigation rate.

The second major cluster includes variants 7, 10, 8, 9 and 11 in which a water deficit is carried. They are most similar to common dyes, lycopene and extraction. The grouping is due to the positive impact of nutrients that contribute to the synthesis of a particular dye and reduced irrigation rate. Cluster analysis found that when fertilizing with 75 to 100% fertilizer rate determining influence has irrigation regime.

The results of cluster analysis are consistent with the findings made in the analysis of the appended modes fer-

Table 1. Correlational dependencies

X_i	x_1	x_2	x_3	x_4	x_5
x_1	1.00	0.803**	0.957**	0.770**	-0.626*
x_2		1.00	0.814**	0.670*	-0.291
x_3			1.00	0.688*	-0.505
x_4				1.00	-0.731**
x_5					1.00

tilization and irrigation and their impact on the quality indicators of the tomatoes.

Experimental data are processed by correlation analysis, by means of which it is established and evaluated the relationship between the studied parameters. The same is expressed by the correlation coefficient r, determined by statistical program SPSS 13.

As a result of correlation analysis correlations are established between the studied parameters. The strongest positive correlation was registered between the indicators common dyes and beta-carotene (r = 0.957) and between the provisions of general dyes and lycopene (r = 0.803), beta-carotene, yield. High degree of correlation is calculated between the observed indicators also provisions of general dyes and yield (r = 0.770). In synchronism with these analyzes are the correlations derived from Chen et al. (2013) to study the productivity of tomatoes in water deficit.

Between the maturity and common dyes indicators (r = -0.626) there is a strong negative correlation. The correlation relationship between yield and early maturity is also characterized as negative with high correlation (r = -0.731).

Analyzes and correlations give useful indications of the ability to improve the quality of tomatoes by a regulated water deficit and refinement of rules for basic fertilization and feeding during vegetation.

Conclusions

As a result of the analysis the effects of irrigation regimes and the rate of fertilization in tomatoes are found.

At all fertilization levels there is a tendency to increase the lycopene content by decreasing the irrigation rate. The same trend is observed in the content of β-carotene in tomatoes. Increasing the water deficit increases the levels of β-carotene.

Cluster analysis divided the similarity in the two main cluster variants. In the first cluster it is comprised of two sub-clusters: the first sub-clusters with variants 2,3 and 1, the second sub-clusters to the embodiments 5 and 6, similar indicators, common dyes and beta-carotene and variants impaired irrigation regime and with at least Euclidean distance between them.

The second major cluster includes variants 7, 10, 8, 9 and 11 where it is allowed a small to moderate water deficit. They are most similar to common dyes, lycopene and yield.

The strongest positive correlation is found between total dye and lycopene, beta-carotene, yield.

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