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Influence of different doses of mineral fertilizer and the controlled water deficit on the antioxidants parameters in tomatoes (*Solanum lycopersicum L.*) irrigated with a drip irrigation system

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Abstract

Stoyanova, A., Veleva, P., Valkova, E. & Georgiev, M. (2020) Influence of different doses of mineral fertilizer and the controlled water deficit on the antioxidants parameters in tomatoes (*Solanum lycopersicum L.*) irrigated with a drip irrigation system. *Bulg. J. Agric. Sci., 26 (Suppl. 1), 19-29*

The main objective of this study is to analyze the mutual influence of different irrigation schemes and fertilization rates on the greenhouse tomato yield, and the irrigation water usage efficiency for a period of three years (2016-2018). Different irrigation schemes have been examined, achieved by reducing the irrigation depth at different levels. Fertilization plays an important role in the technological process with different rates. This experiment was focused on the effect of both factors (the fertilization rate and the irrigation regim) on the main quality parameters of the greenhouse tomatoes. Multivariate data analysis was applied to process the data, including Scheffe and Dunnett's tests (depending on the Levene's test of equality of variances) were used to find the significant differences ($P < 0.05$) between the control variant and all other irrigation and fertilization schemes based on the investigated quality parameters (Dry matter, %; Ascorbic acid, mg%; Titrable organic acids, %; General dyes, mg%; Lycopene, mg% and β - carotene, mg%) in greenhouse-grown tomatoes. The analysis showed a medium to a high correlation (R^2 = 0.988, 0.990, and 0.062 for the three investigated years) between Dry matter content and the two investigated factors (the fertilization rate and the irrigation depth) and a very strong correlation (R^2 = 0.999, and 1.000) between Ascorbic acids and both factors of influence for the first two years and a weak correlation (R^2 = 0.287) for the third experimental year. A weak to moderate correlation between Titrable organic acids (R^2 = 0.414, 0.669, and 0.079), β – carotene (R^2 = 0.252, 0.673, and 0.471), and both influencing factors were found, and a moderate correlation between General dyes (R^2 = 0.532, 0.815, and 0.590), Lycopene (R^2 = 0.685, 0.796 and 0.643), and the variants of irrigation and fertilization for the three experimental years.

Keywords: antioxidants; fertilization; greenhouse tomato; irrigation regime

Abbreviations: FAO – Food and Agriculture Organisation in the United Nations, FC - Field capacity, GLM - General Linear Model, LFMC - Limited field moisture capacity, PRD - Partial root zone drying, RID - Regulated irrigation capacity, SD - Standard Deviation, TSS - Total soluble solid

Introduction

The cultivated tomato (*Solanum lycopersicum* L.) is the world's most highly consumed vegetable due to its status as a basic ingredient in a large variety of raw, cooked, or processed foods. This culture has gained immense popularity, especially in recent years with the discovery of the antioxidant activities and anti-cancer functions of Lycopene (Wu et al., 2011; Raiola et al., 2014). Tomatoes are rich in protein, amino acids, mineral salts, but their antioxidant properties are especially important.

Within their nutritional composition, tomatoes stand out as an important source of antioxidants, such as vitamin C and Lycopene, compounds that provide benefits to human health, protect against oxidative damage, reduce the risks associated with cancer and prevent cardiovascular disease (Story et al., 2010).

Influenced by the growing interest of consumers of natural antioxidants, one of the tasks of the selection in tomatoes is to create varieties and hybrids with increased biological value (Danailov, 2002; Pevicharova & Ganeva, 2004; Dorais, 2008).

The content of nutrients in tomatoes depends on the agro-technological factors in cultivation, harvest time, and method of storage. The possibility of delivering the fertilizers simultaneously with the irrigation water allows ensuring an appropriate and balanced diet of the plants during the different phases of their development and better distribution of nutrients, reduction of labor costs, and reduction of the amount of the fertilizers.

Bernard et al. (2009), examining the impact of fertilization with different nitrogen levels, found that a decrease in nitrogen supply had a small effect on fruit yield (-7.5%). This established a decrease in plant vegetative growth and an increase in Dry matter content in fruits, thus improving their quality. The quality of the fruit is improved due to the lower acidity (10-16%) and the increased content of soluble sugar (5-17%). Nutrient sources also play a key role in studying the levels of titratable acidic and antioxidant components in greenhouse tomatoes. The average content of phenolic and Ascorbic acids in tomatoes grown with chicken manure and clover mulch was 17.6% and 29% higher than tomatoes grown with mineral nutrient solutions (Toor et al., 2006).

Potassium fertilization, in order to increase the yield and quality of tomato fruits, is most effective if applied in the period when the size of the fruit is 2-3 cm in diameter and until 10% of them acquire a characteristic color, according to research by Hartz (2007). A number of authors link the biochemical parameters of tomato fruits with the varietal characteristics (Hartz et al., 2005), but with the same background of N and P the differences reported could be due to the different scheme for introduction of the potassium norm.

According to Vasileva et al. (2016) fractional (triple and double) potassium fertilization leads to an increase in the content of Dry matter, Total sugars and vitamin C in the fruits of the two tested varieties ("Atak" and "Nikolina F1"), when growing plants in the conditions of early and middle-early production.

The application of fertilizers to the soil, both natural and artificial, must be in accordance with generally accepted norms, rules, and technologies. Violation of the fertilization systems can lead toundesirable ecological and social consequences expressed in the destruction of the environment and the soil structure, deterioration of the quality of agricultural products, and health status of the population (Harizanova et al., 2019; Kostadinov et al., 2019; Naskova et al., 2019).

A number of authors have established the degree of influence of water deficit on the quantity and quality of tomato yields (Zugui et al., 2003; Ozbahce et al., 2010; Patanè et al., 2011; Pevicharova et al., 2013; Kuşçu et al. , 2014; Du et al., 2017; Yang et al., 2017). The main advantage of regulated water deficit according to Nangare et al. (2016) is an improvement in quality with respect to Total soluble solids, Ascorbic acid, and Lycopene.

The effect of reducing the irrigation dose was studied by Favati et al. (2009) taking into account the physical and chemical characteristics of the fruit as well as the content of the antioxidant parts. In addition, the relation between all quality parameters and the seasonal amount of irrigation water is assessed. In this regard, it should be emphasized that the irrigation water quality is also important for the quality of crop products (Kostadinova et al., 2013).

Developing new irrigation strategies given global water scarcity Jensen et al. (2010) found that partial root drying (PRD) induced hydraulic and chemical signals from the root system resulting in partial stomatal closure, an increase in photosynthetic water use efficiency, and a slight reduction in top vegetative growth. PRD significantly increases the antioxidant content by approximately 10% in both potatoes and fresh tomatoes.

The positive health properties of tomatoes are a result of the antioxidants and other useful nutrients in them. Ascorbic acid is one of the most important organic acids in fruits and vegetables in terms of their nutritional value (Melèndez et al., 2004) and has powerful antioxidant properties, thus limiting the effects of free radicals in the body (Davey et al., 2000).

Lycopene is the main carotenoid and powerful antioxidant present in tomatoes (Silva, 2012), whose content depends on genetic factors, temperature, water quantities, light, varieties used and the ripening state of the fruit, with levels that increase significantly in more advanced stages of growth (Palomo et al., 2010). Lycopene is a carotenoid whose levels increase from an early green state to the full ripening state of the fruit. Its insignificant or basic synthesis would mainly involve the varietal factor (Kotiková et al., 2009) and the environmental factor (solar radiation and temperature) (Toor et al., 2006).

Intensive cultivation of agricultural crops requires the introduction of intensive agricultural factors such as irrigation, fertilization, intensive tillage, incl. and improving the species and varietal composition of crops. An important condition is the refinement of the individual elements of technology.

The main purpose of this study is to analyze the influence of different fertilization rates and irrigation regimes on some basic quality indicators (Dry matter, Ascorbic acid, Titrable organic acids, General dyes, Lycopene, and β - carotene) in greenhouse-grown tomatoes.

Material and Methods

Experimental staging

The object of the study was a hybrid greenhouse tomatoes variety Vitellio F1 cultivated in an unheated polyethylene greenhouse, situated in the region of Plovdiv, Bulgaria for three-year period (2016-2018).

The area is flat, with an altitude of 160 m and geographical coordinates N 42° 09', E 24°45' (GPS).

Tomatoes were grown according to the following scheme 110 + 50 + 35, in four replications. The block method is applied, with a 10 m^2 harvest plot (Barov, 1982).

Two factors from the agricultural technique of tomatoes were studied – fertilization rate and irrigation regim. Therefore, the characteristic of the soil type - alluvial-meadow soil - is also important. This soil type is characterized: by a weak humus horizon (average 0.25 m), in which the humus content varies within a narrow range of 1.5 - 2.0%; high water permeability, with low water-retaining capacity; good aeration and limited field moisture capacity (LFMC) - about 14-16%; with total porosity in the range of 30 - 42% (Koinov et al., 1962).

In the soil layer of 0-30 cm the nutrient reserves content 117.19 mg/1000 g of mineral nitrogen; 6.67 mg/100 g mobile phosphorus and 20.09 mg/100 g digestible potassium. (according to the author).

For the purpose of the study, twelve variants with different levels of fertilization and different irrigation rate were set.

Factor A – irrigation regim: Irrigation of plants is carried out with a drip irrigation system. Drip irrigation pipes with built-in drippers have been used for watering. The irrigation wings have built-in 0.2 m drippers, with a flow rate of 1,110 L / h. Pre-irrigation humidity of 75% - 80% FC is maintained, and the irrigation rate is calculated for active soil layer 0 - 30 cm.

Factor B – fertilization rate: the experiment contained basic fertilization at three nutrition rates: 50%, 75%, and 100%. The 100% nutrition rate contained P23 (as P_2O_5), K25, and S9.2 (as K_2SO_4). The reduction of nutrition rate was 50% (P11.5, K12.5, S4.6) and 75% (P17.25, K18.75, S6.9). During the vegetation, feeding is carried out at three levels of N (as NH_4NO_3), and K (as KNO_3) on the background of basic fertilization. When realizing 100% fertilizer norm for feeding, N50, and K23 are used respectively. As a result of the reduced norms for feeding the tomatoes, N25, K11, and N37.5, K17.25 were imported at 50 and 75% fertilizer norms, respectively.

The following variants were tested:

Variant 1 (V1): Deficit irrigation (50% of the full irrigation depth) without fertilization;

Variant 2 (V2): Deficit irrigation (75% of the full irrigation depth) without fertilization;

Variant 3 (V3): Full irrigation without fertilization (Control);

Variant 4 (V4): Deficit irrigation (50% of the full irrigation depth) and 50% of the full fertilization rate;

Variant 5 (V5): Deficit irrigation (75% of the full irrigation depth) and 50% of the full fertilization rate;

Variant 6 (V6): Full irrigation with 50% of the full fertilization rate;

Variant 7 (V7): Deficit irrigation (50% of the full irrigation depth) and 75% of the full fertilization rate;

Variant 8 (V8): Deficit irrigation (75% of the full irrigation depth) and 75% of the full fertilization rate;

Variant 9 (V9): Full irrigation with 75% of the full fertilization rate;

Variant 10 (V10): Deficit irrigation (50% of the full irrigation depth) and full fertilization;

Variant 11 (V11): Deficit irrigation (75% of the full irrigation depth) and full fertilization; and

Variant 12 (V12): Full irrigation and full fertilization.

Determination of chemical components in tomatoes

During the three-year study of greenhouse tomatoes, the total yield and quality of the fruit as well as the basic chemical components in the tomato fruits (Dry matter, %; Ascorbic acid, mg%; Titrable organic acids, %; General dyes, mg%; Lycopene, mg% and β – carotene, mg%) were determined.

On average samples of 20 fruits at the technological maturity of each variant, the Dry matter content was determined - refractometrically (%) alongside the levels of titratable organic acids by direct titration of juice with 0.1 n NaOH (%).

The content of Ascorbic acid (mg%) was determined by the Tillmans reaction (Genadiev et al., 1969),

titratable organic acids - by direct titration of juice with 0.1 n NaOH (%), total dyes (mg%), lycopene (mg%) and β-carotene (mg%) - according to the method of Manuelyan (Manuelyan, 1991).

Statistical data analysis

Data analysis included obtaining the main statistics (mean values - $\bar{x}$, Standard Deviations - SD and Coefficients of determination - R^2), normality distribution verification of the samples and multivariate data analysis to establish the influence of different fertilization and watering schemes on the studied tomato quality parameters. Based on that, a General Linear Model (GLM) was developed, given as $Y = \bar{x} + G + e$, where Y are the measurements of the particular quality parameter, $\bar{x}$ are the average values, G are the factors of influence (the variants of tomatoes fruit treatment) and *e* are the random residual errors.

Furthermore, Scheffe and Dunnett's tests (depending on the Levene's test of equality of variances) were used to find the significant differences between the investigated groups where p-values < 0.05 were considered statistically significant. The data have been processed with statistical package IBM® SPSS® Statistics 17.0 WinWrap Basic, Copyright 1993 – 2007 (SPSS Statistics, 2017).

Table 1. Effect of different fertilization and watering schemes on the Dry matter content and levels of Ascorbic acids in greenhouse-grown tomatoes for the three investigated years

Variants of treatment	$\bar{x} \pm SD$					
	Dry matter, % [a]			Ascorbic acid, mg% [b]		
	First experimental year	Second experimental year	Third experimental year	First experimental year	Second experimental year	Third experimental year
1	4.21±0.023*	4.30±0.025*	4.60±0.290 ns	37.92±0.099*	34.07±0.016*	30.97±1.796*
2	4.21±0.020*	4.52±0.035*	4.58±0.282 ns	34.06±0.083*	34.07±0.021*	30.98±1.844*
3	4.29±0.030*	4.50±0.029*	4.59±0.295*	34.12±0.011*	38.45±0.033*	32.57±1.273*
4	4.30±0.025 ns	4.50±0.029 ns	4.60±0.290 ns	27.95±0.013*	32.61±0.021*	29.87±1.082*
5	4.11±0.019*	4.60±0.037*	4.70±0.329 ns	30.57±0.202*	33.58±0.032*	29.88±1.172*
6	4.22±0.022*	4.41±0.038*	4.41±0.414*	32.31±0.187*	30.16±0.023*	30.43±1.604*
7	4.10±0.018*	4.60±0.037*	4.80±0.378*	27.07±0.059*	30.17±0.025*	28.81±1.129*
8	3.91±0.059*	4.60±0.037*	4.60±0.308 ns	27.95±0.135*	28.23±0.030*	30.43±1.604*
9	4.90±0.035*	5.10±0.021*	4.70±0.370 ns	24.45±0.121*	30.17±0.025*	29.33±0.840*
10	4.60±0.037*	5.60±0.037*	4.69±0.467 ns	26.64±0.140*	32.61±0.022*	29.88±0.963*
11	4.69±0.035*	5.00±0.053*	4.61±0.411 ns	25.33±0.233*	28.23±0.022*	30.42±3.844*
12	4.61±0.032*	4.60±0.037*	4.62±0.364 ns	21.83±0.108*	30.66±0.026*	28.25±1.079*

a. Dry matter, %: R^2 = 0.988 for the First experimental year; R^2 = 0.990 for the Second experimental year; R^2 = 0.062 for the Third experimental year; b. Ascorbic acid, mg%: R^2 = 0.999 for the First experimental year; R^2 = 1.000 for the Second experimental year; R^2 = 0.287 for the Third experimental year. *Equal superscripts within the same column represent significant differences in the mean values of the Dry matter, % or Ascorbic acid, mg% between Variant 3 (accepted as Control) and all other variants of tomato fruit treatment at the level of significance $P < 0.05$; ns - shows not significant differences ($P > 0.05$); R^2 - Coefficients of determination based on observed mean values through Scheffe test for sets with equal variances and Dunnett's T3 test for sets with unequal variances

Analysis of Ascorbic acids, mg%

When analyzing the results for the quality indicator - Ascorbic acids, statistically significant differences were found between the average values of the control variant V3 and all other variants of the studied factors for all of the three studied years. The Coefficients of determination (R^2) (Table 1) showed a very strong correlation between Ascorbic acids and both factors of influence for the first two years and a weak correlation for the third experimental year.

The significant differences between V3 and all other variants of irrigation and fertilization based on the mean values of Ascorbic acids for the three experimental years can be seen in Fig. 1 (d, e, f). The results showed that on average for the studied period, against the background of increasing fertilization rates, a decrease in the content of Ascorbic acid is reported with increasing irrigation rate. At an irrigation rate of 50%, the values of the indicator are 29.87 mg% on average, while at the optimization of the irrigation regime the content of Ascorbic acids is 30.16 mg%. The influence of the irrigation regime on the synthesis of Ascorbic acid in tomatoes is relatively low, according to Pevicharova et al. (2013). The content varies 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 non-irrigated plants. Ascorbic acid (vitamin C) is one of the most important organic acids in fruits and vegetables in terms of their nutritional value, according to Melèndez et al. (2004). The results of the study reveal that regulated water deficiency leads to minor disturbances in the synthesis of vitamin C.

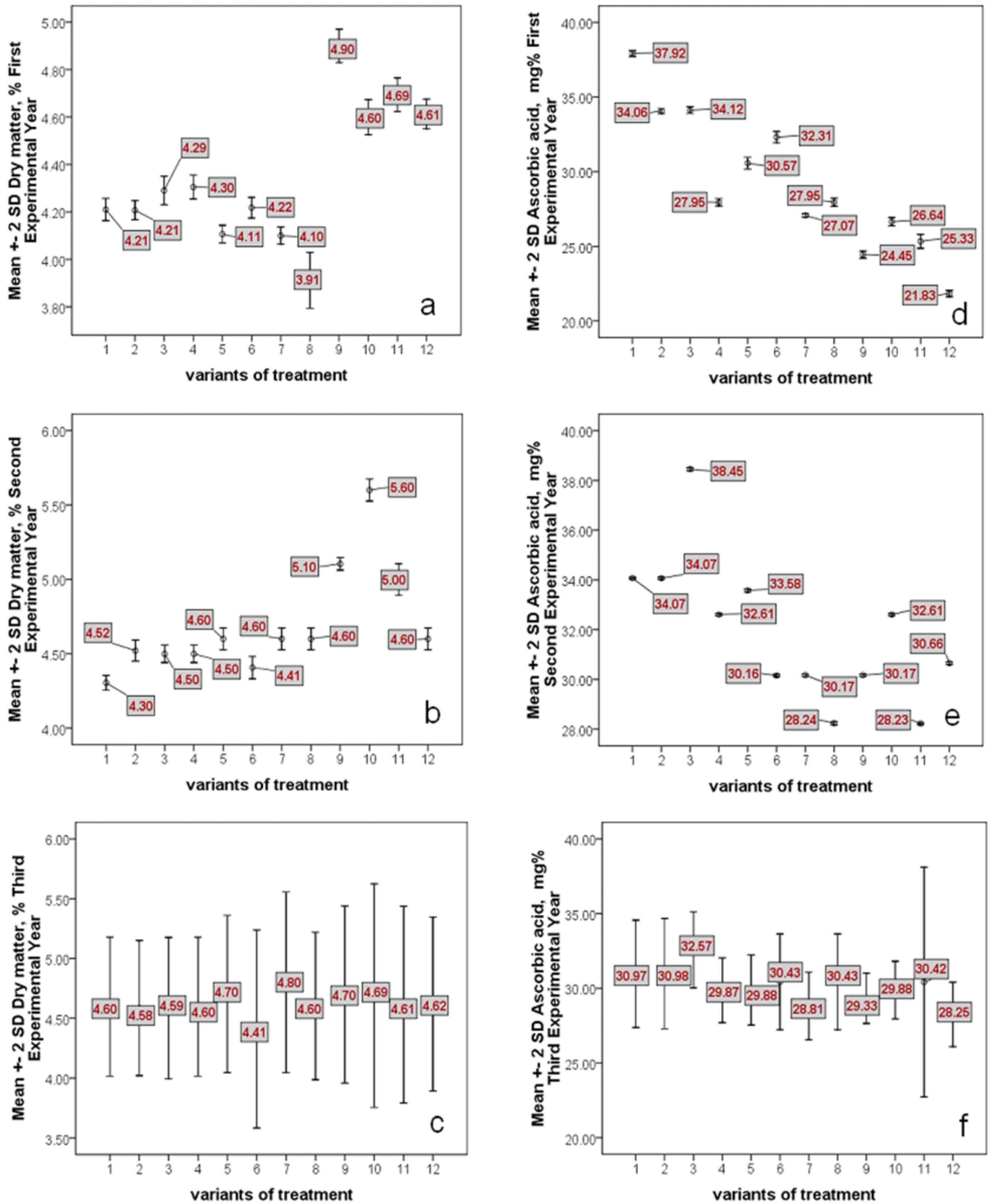

Figure 1. (a,b,c,d,e,f). Plots of the significant differences between fertilization and watering schemes of greenhouse-grown tomatoes for the investigated quality parameters (Dry matter ,% and Ascorbic acid, mg%) for the three experimental years

Analysis of Titrable organic acids, %

The results of the analysis of Titrable rganic acids are presented in Table 2. During the second and third years of the experiment, significant differences ($P < 0.05$) were registered for most treatment options. The analysis shows that in the third year lower values of the indicator were obtained, which vary from 0.21% (at zero levels of fertilization) to 0.31% (at 100% of fertilization). On average for the study period at zero fertilization, the values of Titrable organic acids were 0.28%. With an increase in nutrition, there is a tendency to increase the values of the indicator. A moderate relation (R^2) between Titrable organic acids and both influenced factors (fertilization and watering) for the first two years and a weak correlation for the third studied year was found (Table 2). In Fig. 2 (a, b, c) are presented averaged values of Titrable organic acids, where the narrow limits of variation of the studied parameter can be clearly seen. According to Adams et al. (1978) the content of total acidity in tomato fruits has a greater impact on their taste than sugars.

Table 2 Effect of different fertilization and watering schemes on the levels of Titrable organic acids and the General dyes content in greenhouse-grown tomatoes for the three investigated years

Variants of treatment	$\bar{x} \pm SD$					
	Titrable organic acids, % [a]			General dyes, mg% [b]		
	First experimental year	Second experimental year	Third experimental year	First experimental year	Second experimental year	Third experimental year
1	0.29±0.021*	0.33±0.017*	0.22±0.059 ns	4.17±0.752*	3.38±0.025*	4.88±0. 302*
2	0.30±0.019*	0.34±0.020*	0.21±0.062 ns	3.63±0.069 ns	3.16±0.051 ns	4.29±0.666 ns
3	0.31±0.017*	0.31±0.017*	0.22±0.059*	3.41±0.023*	2.93±0.192*	3.95±0.239*
4	0.32±0.018 ns	0.39±0.020*	0.21±0.062 ns	4.95±0.309*	3.89±0.245*	4.95±0.309*
5	0.30±0.019*	0.41±0.026*	0.25±0.062*	4.58±0.672*	3.47±0.018*	4.57±0.106*
6	0.32±0.018 ns	0.32±0.018 ns	0.22±0.059 ns	4.11±1.269*	3.07±0.015 ns	4.19±1.179 ns
7	0.34±0.020*	0.39±0.020*	0.25±0.059*	5.36±0.744*	5.04±0.685*	5.93±0.372*
8	0.31±0.017 ns	0.37±0.027*	0.23±0.062*	4.88±0.551*	4.54±0.537*	5.24±1.070*
9	0.32±0.018 ns	0.36±0.027*	0.27±0.067*	4.27±0.618*	4.17±0.342*	5.30±0.690*
10	0.32±0.018 ns	0.33±0.017*	0.27±0.084*	5.69±0.024*	5.21±0.682*	6.14±0.494*
11	0.33±0.017*	0.32±0.018 ns	0.26±0.090*	5.02±0.679*	4.85±0.398*	5.92±0.414*
12	0.33±0.017*	0.35±0.027*	0.24±0.070*	4.81±0.345*	4.59±0.245*	5.81±0.305*

a. Titrable organic acids, %: $R^2 = 0.414$ for the First experimental year; $R^2 = 0.669$ for the Second experimental year; $R^2 = 0.079$ for the Third experimental year; b. General dyes, mg%: $R^2 = 0.532$ for the First experimental year; $R^2 = 0.815$ for the Second experimental year; $R^2 = 0.590$ for the Third experimental year. *Equal superscripts within the same column represent significant differences in the mean values of the Titrable organic acids, % or General dyes, mg% between Variant 3 (accepted as Control) and all other variants of tomato fruit treatment at the level of significance $P < 0.05$; ns - shows not significant differences ($P > 0.05$); R^2 - Coefficients of determination based on observed mean values through Scheffe test for sets with equal variances and Dunnett's T3 test for sets with unequal variances

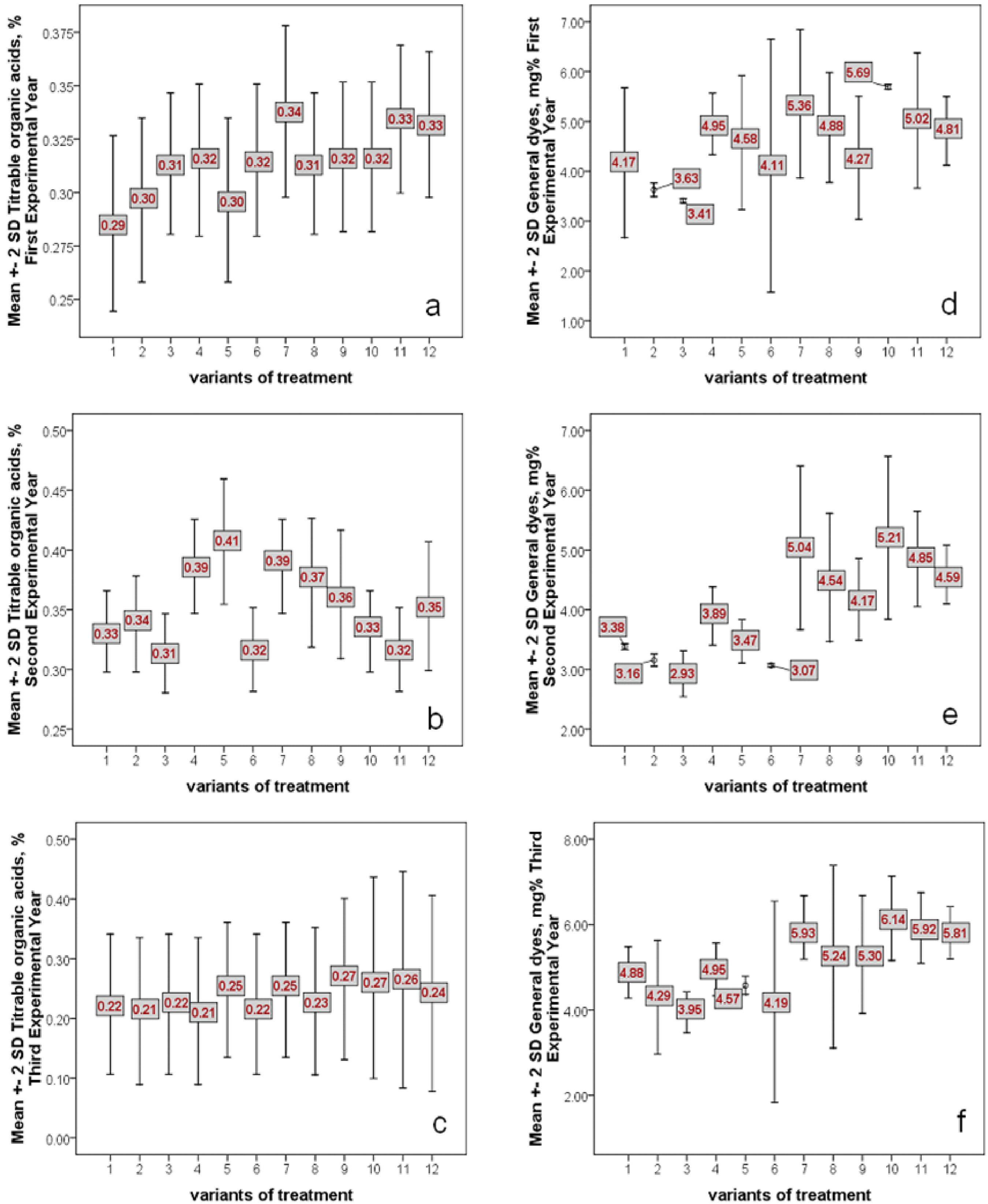

Figure 2. (a,b,c,d,e,f). Plots of the significant differences between fertilization and watering schemes of greenhouse-grown tomatoes for the investigated quality parameters (Titrable organic acids, % and General dyes, mg%) for the three experimental years

Analysis of General dyes, mg%

The content of total dyes, on average for the studied period, is highest in V7 (75% fertilization rate) and V10 (100% fertilization rate), in which 50% irrigation rate was realized (Table 2). The same trend was registered by Vasileva et al. (2016) in the analysis of the influence of the method of fertilization with potassium (24 $kgK.da^{-1}$) in the form of K_2SO_4 on the background of nitrogen (24 $kgN.da^{-1}$ in the form of NH_4NO_3) and phosphorus (12 kgP.da-1 under the form of triple superphosphate) fertilization. Multivariate data analysis showed significant differences at ($P < 0.05$) between V3 and all other tested variants, except on V2 for the whole period and V6 for the second and third experimental years (Fig. 2 d, e, f). A moderate correlation (R^2) between General dyes and the variants of irrigation and fertilization for the three experimental years was found (Table 2). Determining the content of common dyes is important in determining the quality of tomatoes. Danailov (2012) is of the same opinion and believes that the two main groups of pigments in the fruit of the tomato are carotenoids and chlorophyll, but the final color is determined by the total amount and ratio of different carotenoids.

Analysis of Lykopene, mg%

Lycopene values ranged from 2.76 mg% (V3) to 4.69 mg% (V7), on average over the experimental period (Table 3). According to the FAO (2006) the Lycopene content varies from 7 to 13 mg.100g (Rath et al., 2009). Results of data analysis revealed significant differences ($p < 0.05$) in the Lycopene values under the influence of different levels of fertilization and irrigation norms except on V1 and V2 for the first and the third experimental year, and V9 and V12 for the second experimental year. As the parameters reported above, a moderate correlation (R^2) between the influencing factors and the levels of Lycopene in tomatoes was calculated (Table 3). The results are presented graphically in Fig. 3 (a, b, c). The graph very well shows the average values and standard deviations of the parameter in the different variants, as well as the significant differences between them. The analysis shows a tendency to decrease the pigment content with increasing irrigation rate. Dumas et al. (2003) underlined that water deficiency has a positive effect on Lycopene content. Regulated water deficiency leads to an increase in the content of carotenoids and total phenols is the opinion of Coyago-Cruz et al. (2019).

The downward trend was registered in the three years, against the background of different levels of fertilization. As nutrients increase, Lycopene levels increase. Lycopene content is a varietal feature and tomato fruits respond to potassium fertilization by increasing the content of antioxidants (Hartz et al., 2005).

Table 3 Effect of different fertilization and watering schemes on the Lycopene and β - carotene content in green-

Variants of treatment	$\bar{x} \pm SD$					
	Lycopene, mg% [a]			β - carotene, mg% [b]		
	First experimental year	Second experimental year	Third experimental year	First experimental year	Second experimental year	Third experimental year
1	2.96±0.531 ns	2.78±0.181*	3.73±0.249 ns	0.24±0.102 ns	0.28±0.086*	0.24±0.101 ns
2	2.82±0.248 ns	2.72±0.098*	3.30±0.104 ns	0.21±0.125 ns	0.24±0.102 ns	0.24±0.101 ns
3	2.67±0.287*	2.25±0.190*	3.35±0.173*	0.18±0.109*	0.20±0.117*	0.21±0.100*
4	4.63±0.022*	3.79±0.446*	5.00±0.269*	0.32±0.084*	0.35±0.067*	0.34±0.090*
5	3.92±0.668*	3.47±0.110*	4.64±0.025*	0.30±0.076*	0.28±0.060*	0.29±0.021*
6	3.37±0.444*	3.05±0.468*	4.29±1.098*	0.27±0.080*	0.26±0.081*	0.28±0.020*
7	5.30±0.690*	3.49±0.325*	5.30±0.690*	0.37±0.073*	0.54±0.015*	0.38±0.075*
8	5.24±1.070*	3.16±0.084*	5.26±0.657*	0.31±0.060*	0.37±0.081*	0.32±0.050*
9	4.45±0.103*	2.42±0.120 ns	5.03±0.055*	0.30±0.076*	0.33±0.117*	0.28±0.020*
10	4.37±0.797*	3.35±0.230*	5.74±0.093*	0.42±0.067*	0.67±0.173*	0.44±0.068*
11	4.45±0.680*	3.21±0.086*	4.24±1.085*	0.33±0.017*	0.45±0.021*	0.39±0.047*
12	3.54±0.643*	2.39±0.075 ns	5.07±0.686*	0.31±0.242*	0.35±0.021*	0.32±0.018*

a. Lycopene, mg%: R^2 = 0.685 for the First experimental year; R^2 = 0.796 for the Second experimental year; R^2 = 0.643 for the Third experimental year; b. β - carotene, mg%: R^2 = 0.252 for the First experimental year; R^2 = 0.673 for the Second experimental year; R^2 = 0.471 for the Third experimental year. *Equal superscripts within the same column represent significant differences in the mean values of the Lycopene, mg% or β - carotene, mg% between Variant 3 (accepted as Control) and all other variants of tomato fruit treatment at the level of significance $P < 0.05$; ns - shows not significant differences ($P > 0.05$); R^2 - Coefficients of determination based on observed mean values through Scheffe test for sets with equal variances and Dunnett's T3 test for sets with unequal variances

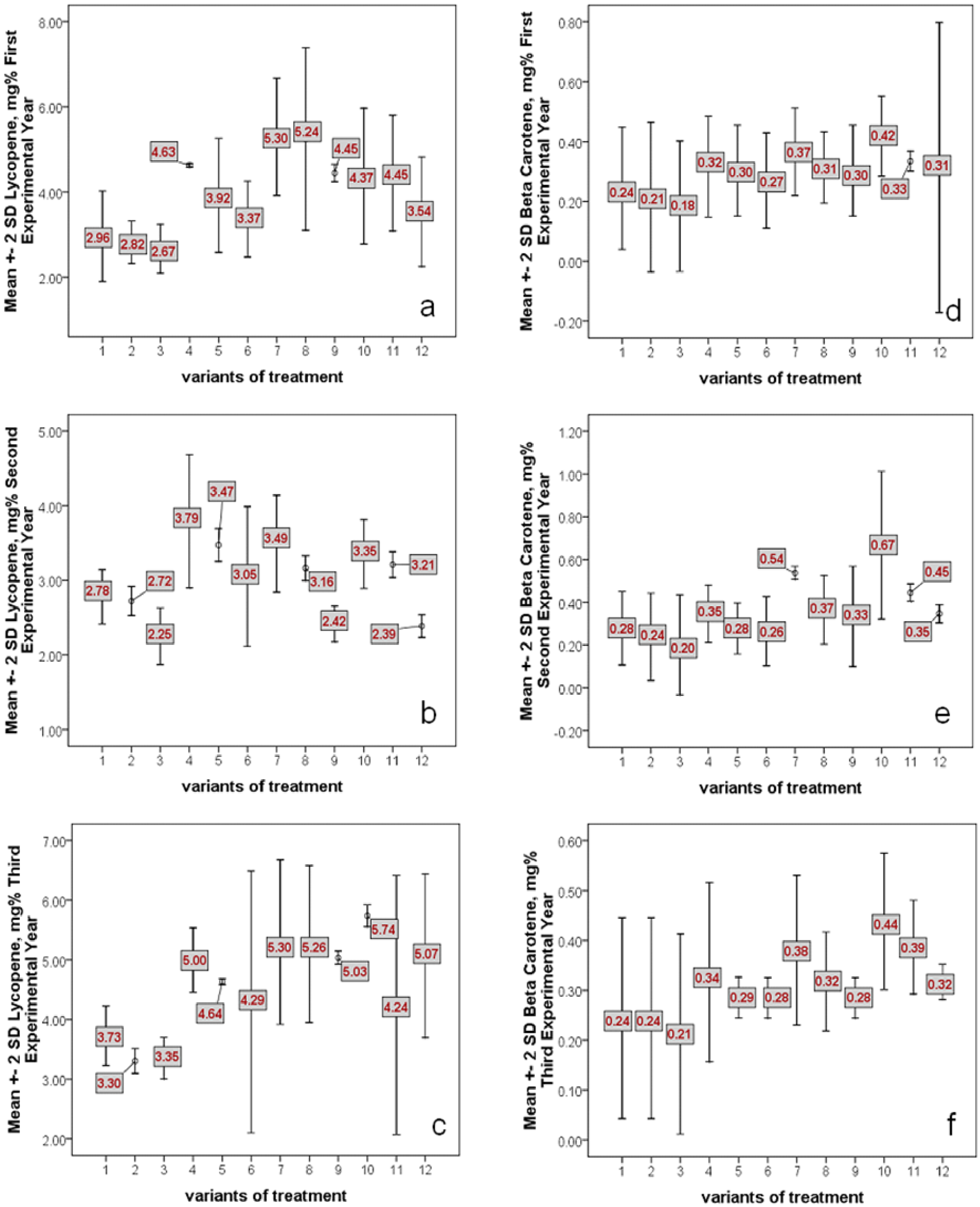

Figure 3. (a,b,c,d,e,f). Plots of the significant differences between fertilization and watering schemes of greenhouse-grown tomatoes for the investigated quality parameters (Lycopene, mg% and β - carotene, mg%) for the three experimental years

Analysis of β – carotene, mg%

The content of β - carotene determines the orange color of tomatoes. The good combination of the two components (Lycopene and β - carotene), with antioxidant effect, define tomato hybrids as hybrids with high biological value (Pevicharova et al., 2012). The results in Table 3 show the existing significant differences in the average values of the parameter β - carotene, and the variants with different levels of fertilization and irrigation rates. A weak to moderate correlation (R2) was found between them.

Only in V1 and V2 for all three studied years no statistically significant differences were observed. Graphically, the significant differences between the treatment options based on the average values of the β - carotene parameter are presented in Fig. 3 (d, e, f). The analysis shows a tendency to increase the determined values with increasing fertilizer rates.

Against the background of zero fertilization, the values of the parameter are 0.23 mg% on average for the three years, under the different irrigation regimes. In conditions of higher agrophone (100% fertilizer norm) the content of β - carotene was found to be on average 0.41 mg% at different soil moisture content. A balanced nutritional regime increases pigment content. This thesis is also supported by Mozafar (1994), who found that the content of β - carotene in fruits increases with increasing levels of K, Mg, Mn, B, Cu, and Zn. According to Dorais et al. (2008), phosphorus can also increase the concentration of phytochemicals in fruits, such as Ascorbic acid, flavonoids, and Lycopene.

The multilayer analysis of the results takes into account trends in the studied parameters of the quality of tomatoes, greenhouse production. Regulated irrigation deficit and a precise and balanced nutritional regime are the keys to obtaining tomatoes with high-quality indicators. The obtained experimental results and analyzes can be used to update the technologies. Preserving soil fertility and reducing the loss (inefficient use) of nutrients are part of the agricultural strategy.

Conclusions

Based on the results obtained it was found that: (i) the Dry matter content in greenhouse tomatoes variety Vitellio F1 varies by variants and years, but an increase has been registered in the variants with higher fertilization rates and lower irrigation rates; the irrigation suspension at the beginning of fruit maturation increased soluble solids accumulation, providing higher quality; (ii) the Ascorbic acid content decreases with increasing irrigation rate; regulated water deficiency leads to minor disturbances in the synthesis of vitamin C; (iii) a tendency to decrease the pigment content with increasing irrigation rate was observed; (iv) the nutrients increasing leads to an increase in Lycopene levels in greenhouse tomatoes variety Vitellio F1.

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