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THE COMBINED EFFECT OF TEMPERATURE AND LIGHT VARIATION ON SOME QUALITY PARAMETERS IN CHERRY TOMATOES

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Abstract

The study was conducted under controlled conditions in a greenhouse during a crop cycle during September-April. The culture was established on a coconut substrate. All parameters of vegetation, temperature, light, humidity, carbon dioxide content in the greenhouse were monitored. Fruit mass determinations were performed on each inflorescence, as well as carbohydrate and nitrate content. The production obtained by fruiting stages was determined as well as the total production. The aim of the study was to analyze the influence of some parameters of growth and fruiting on the total production and its quality.

Key words: *tomatoes, cerise, Cheramy F1, soilless.*

INTRODUCTION

Tomatoes are plants that can be grown both in the field and in protected space. In this way, we can systematize the plantings to obtain harvests throughout the year. An important advantage for greenhouse crops is that the microclimate is ensured both during the period of vegetative growth and fruiting. Thus, by ensuring the specific climatic conditions of the plant requirements for each stage of vegetation regarding temperature and light we can count on the achievement of sustained production but also quality for fruits. The fruits are rich in vitamins, minerals, amino acids and pigments (Dinu et al., 2017) and poor in calories, being considered very healthy for the human body (Soare et al., 2015).

In the soilless system, in heated greenhouses, tomato production ensures high-quality performance. Manufacturers are constantly looking to improve their competitiveness through fine-grained control of climate parameters (Becherescu et al., 2018).

Studies conducted in the cultivation of tomatoes in the greenhouse have shown that both temperature and humidity are evenly distributed inside the greenhouses. Legast et al., (2020) note that the distribution of greenhouse temperature in tomato cultivation has a significant impact on fruit growth and development. One of the major factors affecting the growth and productivity of tomatoes is the very high temperature in the growing space. In general, very high temperatures lead to some physiological disorders but also to a decrease in production.

Temperature variations also have a negative effect on plant vegetative growth (Hurd and Graves, 1984), nutrient absorption (Kramer and Boyer, 1995), and production (Falah et al., 2010). Temperature is one of the important factors in maintaining postharvest quality and storage capacity. Kader (2002; 2013) mentions that temperatures above 30ºC speed up the fruit ripening process to the detriment of the ability to preserve the aspects mentioned by Adams et al. (2001) and Alex et al. (2021) estimate that plant density in hydroponic crops can influence the production and quality of tomatoes. Numerous authors studied the effect of temperature on plant nutrition by finding direct relationships associated with light intensity Gent et al. (1998); Giaglaras et al. (1999) and the favourable effect of CO_2, Wacquant (1990), Morison (1993).

Pokluda and Kobza (2019) analyzed the effect of climatic conditions in the greenhouse (air temperature, light intensity, relative air humidity (Redmond et al., 2018) and CO_2 level of the air), on the pH dynamics of the nutrient solution and the electrical conductivity (EC), found insignificant correlations of pH and EC with climatic conditions. However, they identified positive correlations of EC with light intensity.

The growth rate of the fruit depends on the temperature values (Li et al., 2014). Thus, Shamshiri et al. (2017), estimate that the growth rate of fruits is much lower at temperature values of 5.7ºC compared to 26ºC, this aspect was also noticed by Adams et al., 2001. Kawasaki et al. (2014), Shishido Y. & Kumakura H. (1996), Tindall et al. (1990) mention that temperatures of 25°C at the root level, determine a larger leaf area but at temperatures of about 15ºC the leaf mass decreased.

Temperatures below the optimal level, for tomatoes, determine a longer duration of vegetation but also a difficult ripening of fruits. The lycopene content is higher at higher ripening fruit temperatures of 43.5 milligrams/g at 17.8ºC and 64.77 milligrams/g at 25.6ºC (Koskitalo & Ormrod, 1972).

Studies performed on cherry tomatoes regarding the storage of the fruits at temperatures of 5ºC showed a very low percentage of fruits affected by fungi, but also a very small weight loss compared to those stored at temperatures of 10ºC. The firmness and the content in vitamin C of the fruits had also good values (Mohammad, 2012).

Tomato fruits that have reached physiological maturity have a dry matter content of about 3.0-8.88% (Ando, 2016; Dobrin et al., 2019; Kurina et al., 2021), and their content depends on genotype, growing conditions and fruit development stage (Ina et al., 2022) Mohammad et al. (2012) suggest that consumers prefer tomatoes of first quality, both in terms of appearance, nutritional quality and long shelf life. The authors also mentioned that in the 'Unicorn' cultivar at 25ºC/11ºC the carbohydrate content decreased after 28 days of storage compared to storage at 5ºC/11ºC.

Sensory characteristics of tomato fruits are a very important component of their quality and decide on a high degree of consumer's acceptance of the fruit. Azodanlou et al. (2003) mention the importance of the sensory characteristics of tomato fruits, an aspect highlighted also by other researchers (Getinet et al., 2008; Cliff et al., 2009).

MATERIALS AND METHODS

The present study was carried out at the research greenhouses, from USAMV of Bucharest, Faculty of Horticulture, this belongs to the Research Centre for Quality Control of Horticultural Products. The greenhouses have a height of 7 m and are equipped with air conditioning systems. In the experiment, we used Cheramy F_1 cultivar as biological material. Sowing for seedling production was carried out on September 12, 2021. Planting was carried out on October 30, 2021, in controlled conditions and the seedling was 40 days old at planting. At planting, the seedling already had the first inflorescence formed.

The culture space was prepared by disinfecting it and distributing the coconut hydroponic growing media on the culture gutters.

After placing the coconut substrate, they were moistened with a nutrient solution that had a pH of 5.5 and an EC of 3 mSiemens. Three plants were planted on a 1 m coconut substrate at a distance of 30 cm between plants. The distance between the rows was 1.5 m. Observations for some quality parameters on the nitrate and carbohydrate content of tomato fruits were made directly in culture, as the fruits reached physiological maturity, for each inflorescence. The dry matter content was performed in laboratory conditions using the oven, at a temperature of 105ºC (Dobrin et al., 2019).

The values of temperature, light, atmospheric humidity and CO_2 were recorded from the planting of the seedling until the end of the determinations for 5 months.

We determined the number of inflorescences as well as the number of fruits in the inflorescence.

Determinations for chlorophyll content were performed directly on the plant, with Chlorophyll Content Meter Opti-Sciences, Model CCM-200 Plus GPS, expressed in CCI = %. Measured Parameters: Optical Transmittance at 653 nm, and at 931 nm.

The Greentest ECO, a portable tester, was used to determine the nitrate content.

The sugars were determined directly in the greenhouse for the fruits from inflorescences 1-6 using the Portable Refractometer with Brix scale (Figure 1).

Figure 1 Greentest ECO and Refractometer
All data obtained were statistically processed with Microsoft Excel.

RESULTS AND DISCUSSIONS

Temperatures were taken from the computer database, and recorded for 24 hours, day and at night by the culture compartment sensor, throughout the culture period. The atmospheric humidity in the tomato culture compartment was registered for the period of growth and fruiting. The recorded data showed that the atmospheric humidity values were between 50% and 60%.

Calculating the average daily temperatures, from flower formation to fruit harvest, for each inflorescence (fruiting stage) it was found that from the formation of the first inflorescence to fruit ripening, average temperatures of 19.658°C were recorded during 30.11.2021-10.01.2022 and 19.964°C, during the formation of the second inflorescence until the fruits ripen.

It was found that from the formation of flowers in the third inflorescence to fruit ripening the average temperature was 20.139°C and until the formation of the fourth inflorescence an average of 20.574°C.

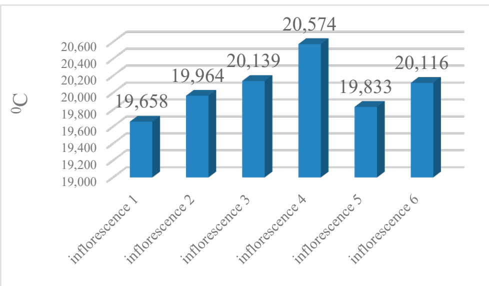

Figure 2. Average temperatures recorded from flower binding to physiological fruit maturity, on inflorescences

During the appearance of inflorescences 5 and 6 and until the ripening of the fruits, the average recorded temperatures were 19.833°C and 20.116°C, respectively. All this information was correlated with the time until the physiological ripening of the fruits (Figure 2)

Atmospheric humidity in the crop compartment was recorded during all periods of vegetation. Figure 3 shows the average atmospheric humidity data from the binding of the flowers to the physiological maturation of the fruits. The lowest value of atmospheric humidity was noticed at 53.691%, during the formation of the first inflorescence.

In the case of the following inflorescences, the values were higher from 55.28% at inflorescence 2 and up to 57.236% during the formation and physiological maturation of the fruits from the sixth inflorescence. Some authors recommend that the humidity values be about 70% during the vegetative growth and 60% during the fruiting period. It also states that the minimum values during the period of vegetative growth should not be less than 30% and during the period of flowering and fruiting less than 40% (Shamshiri et al., 2018).

Liu et al. (2006), mention as favorable the values of 55-90% for atmospheric humidity, these do not influence the photosynthetic activity. Decreasing atmospheric humidity below the threshold of 30-40% influences pollination and fruiting (Huang et al., 2011). In the case of our experiment the humidity values, correlated with the temperature values were corresponding.

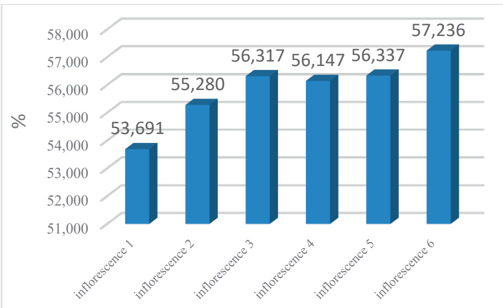

Figure 3. Atmospheric humidity recorded during fruiting stages

The lowest CO_2 values were recorded during the ripening of fruits in the first inflorescence being 435.332 ppm and the highest concentration of 551.383 ppm was recorded during the formation of the third inflorescence. In the case of the other inflorescences, values of 465.137 ppm were registered during the formation of the second inflorescence. Values of 468.827 ppm were recorded during the fruit grown in the fourth inflorescence of 476.237 ppm for the fifth inflorescence and 537.234 ppm for the period of fruit formation in the 6th inflorescence (Figure 4).

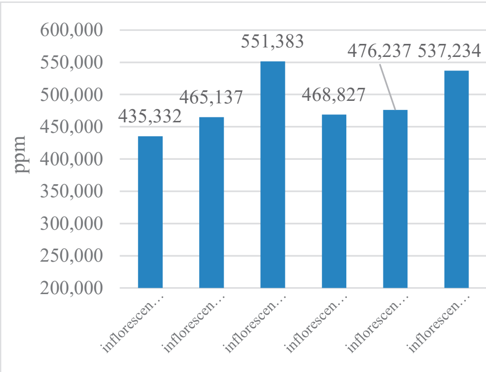

Figure 4. The average CO_2 concentration recorded for each period of fruit grown in the inflorescences

The light radiation recorded outside the greenhouse, throughout the culture period showed higher values from planting to the first harvest on 9.01.2022. The average daily values useful to plants, calculated for the period from fruit binding to physiological fruit maturity, were the lowest during the fruit growth period of inflorescence 1 (429.54 W/m^2). For the rest of the period, the average daily values recorded reached 601.05 W/m^2 in February (Figure 5).

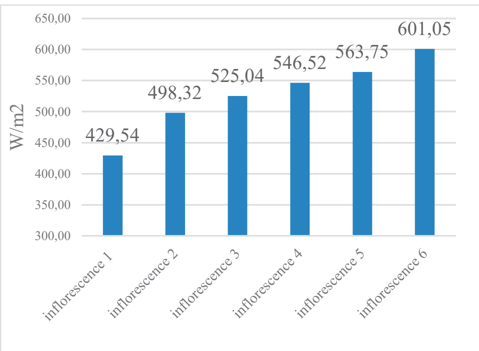

Figure 5. The average of the light radiation recorded for each period of fruit grown in the inflorescences

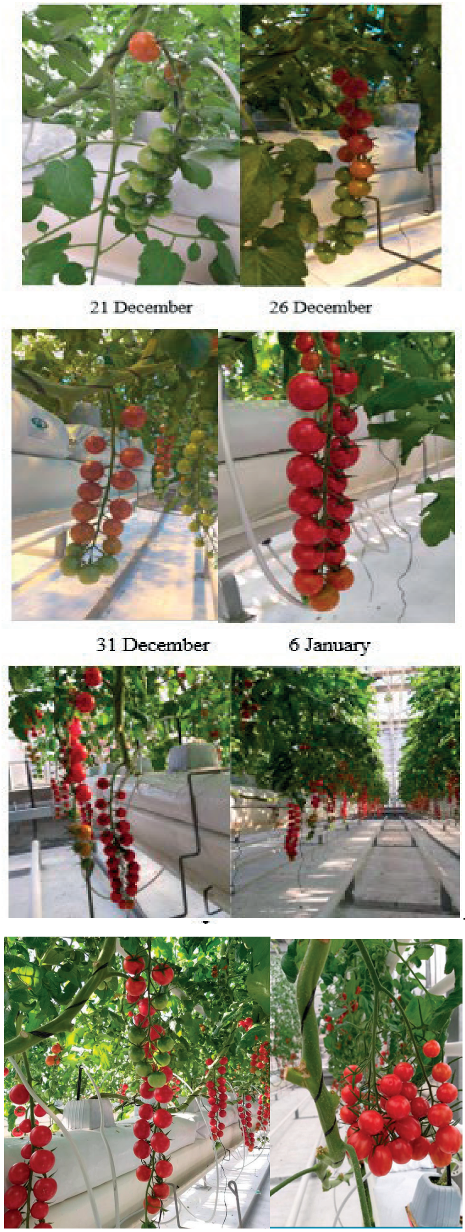

Figure 6. Aspects from culture

Figure 6 shows some aspects of tomato culture, the Cheramy variety.

In January, an average amount of 617 g of fruit per plant was harvested, and in February 1028 g/plant. The total production obtained per plant during January-February was 1645 g/plant (Figure 7).

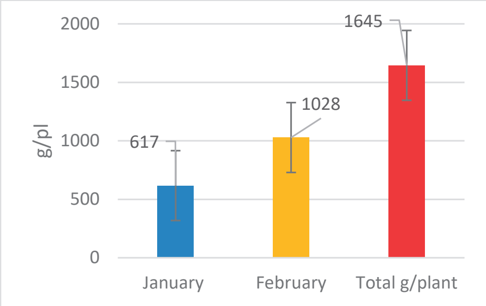

Figure 7. The average mass of fruit per inflorescence - fruits harvested in January and February and total average per plant in January-February

The firmness of the tomato fruits was performed for each fruit that reached physiological maturity, on each inflorescence, and varied between 1.54 kg/cm^2 for inflorescence 5 and 2.13 kg/cm^2 for the first inflorescence. The dry matter varied between 3.57% for inflorescence 1 and 4.30% for inflorescence 4, the values being very closed to each other (Table 1.).

Table 1. Determinations of fruit firmness and dry matter content in tomato fruit (average data on inflorescence)

Inflorescence	Firmness (kg/cm^2)	Dry matter (%)
1	2.13±0.042	3.57± 0.153
2	2.06±0.051	4.18±0.166
3	1.81±0.081	4.13±0.153
4	1.54±0.061	4.30±0.265
5	1.76±0.040	4.23±0.252
6	1.86±0.065	4.23±0.208

The average chlorophyll content in the tomato leaves was determined in the mature leaves at three points on each leaflet, at the top of the leaflet, in the middle and at the base.

It was also determined in young leaves following the same method as for mature leaves (Figures 8 and 9).

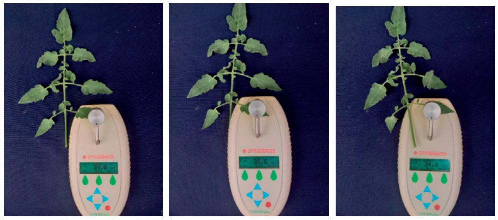

Figure 8. Determination of chlorophyll directly in tomato culture

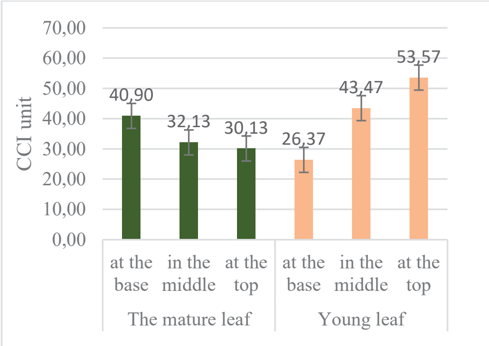

Figure 9. The average chlorophyll content in tomato leaves

The Table 2 shows the data on nitrate content in the fruits of inflorescences 1-6. The lowest nitrate content was determined in the green fruits from inflorescence no 3 (67.33 mg/kg) and the highest content in the fruits from inflorescence 6 (101.33 mg/kg). We found an increase in the level of nitrates in tomato fruits with their physiological maturity. Thus, in the case of immature fruits, the lowest content was registered for the fruits from inflorescence 1 (72.0 mg/kg) and the highest for the fruits from inflorescence 5 (132.0 mg/kg). The fruits reached physiological maturity and accumulated between 109.67 mg/kg for the fruits from inflorescence 2 and 153.0 mg/kg for the fruits from inflorescence 6.

Tabel 2. Nitrate content - mg/kg

Inflores - cence	Green fruit	Immature fruit	Fruit at physiological maturity
1	70.33±2.082	72.00±1.155	131.67±2.0817
2	72.67±1.528	78.33±2.517	109.67±1.5275
3	67.33±2.082	76.67±1.155	133.00±3.6056
4	76.33±1.528	83.67±2.082	128.67±2.3094
5	70.00±1.155	132.00±5.292	139.33±3.0551
6	101.33±2.517	91.33±3.606	153.00±4.3589
Standard norm 300 mg/kg			

Relationship between greenhouse temperature and nitrate content (mg/kg) accumulated in tomato fruits showed an insignificant influence. We can say that the temperature doesn't influence the nitrate concentration for the immature (green) fruit (R^2 = 0.0608) (Figure10).

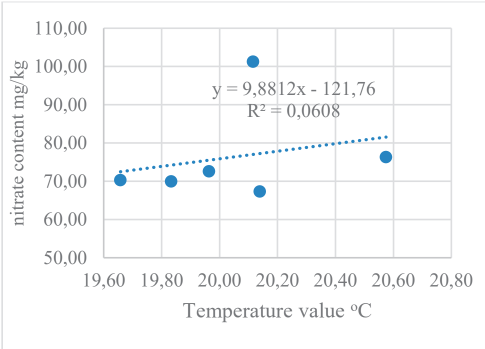

Figure 10. The influence of temperatures on the nitrate content accumulated in green fruit

In the fruits at physiological maturity, in the case of analyzing the relation between *temperature* x *content in nitrates*, (immature fruit) an insignificant influence was registered (R^2 = 0.0249), Figure 11.

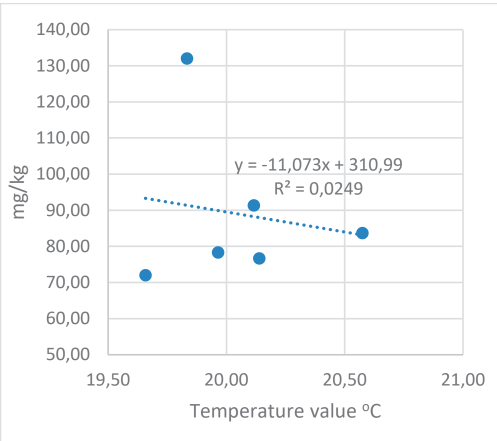

Figure 11. The influence of temperatures on the nitrate content, around physiological maturity accumulated

Determinations of total sugar content made directly in the culture showed differences depending on the stage of fruiting but also the degree of maturity of the fruit. Low sugar content was recorded for green fruit, which was between 4.40% for green fruit in the 5th inflorescence and 7.37% for fruit in the 2nd inflorescence. The fruits had a total sugar content of 5.83% for the fruits from the 6th inflorescence and 7.10% for the fruits from the 4th inflorescence. In the fruits at physiological maturity, the lowest total sugar content was registered for the fruits from the 6th inflorescence at 6.27% and the highest for the fruits from the 2nd inflorescence with 7.27% (Table 3).

Table 3. Total sugar content of tomato fruits

Inflores -cence	Green fruit (%)	Immature fruit (%)	Fruit at physiologic al maturity (%)
1	6.10±0.153	7.03±0.153	7.03±0.153
2	7.37±0.379	6.93±0.379	7.27±0.208
3	6.83±0.252	7.00±0.200	6.93±0.231
4	6.87±0.153	7.10±0.100	7.00±0.100
5	4.40±0.529	6.37±0.513	6.77±0.252
6	5.27±0.252	5.83±0.153	6.27±0.643

The relationships between *temperature x total sugar* content determined in green fruits indicated a low influence R^2 = 0.1499 (Figure 12).

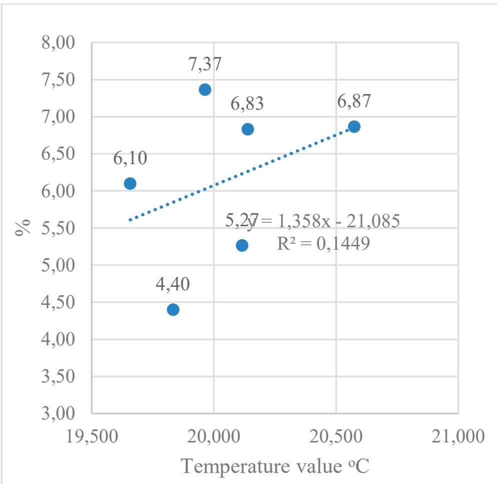

Figure 12. The influence of temperatures on the accumulation of carbohydrates in green fruit

In the case of fruits in the ripening phenophase I found that the accumulation of sugars in the fruits was not influenced by the average temperature values recorded R^2 = 0.0161 (Figure 13).

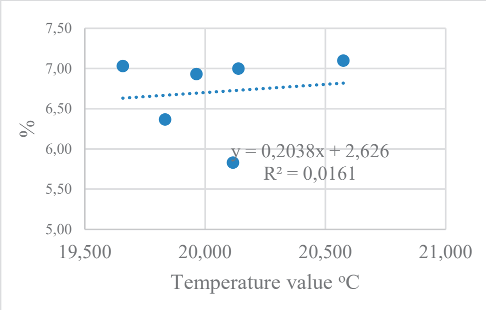

Figure 13. The influence of temperatures on the accumulation of carbohydrates in the fruit and the ripening phenophase

Analyzing the data obtained on the influence of average temperature values for each inflorescence, on the fruiting stage, on the accumulation of total sugar in the fruit, in the phenophase of physiological maturity we noticed insignificant influences $R^2 = 0.006$, which means that relatively constant temperature values led to obtaining fruits with relatively constant values in sugars (Figure 14).

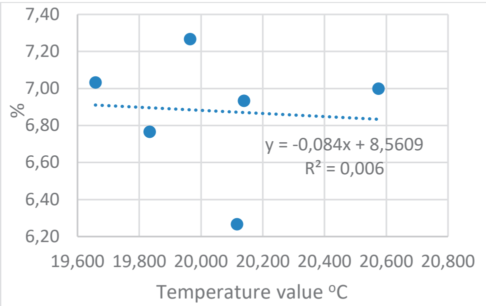

Figure 14. The influence of temperatures on the accumulation of total sugar in the fruit in the phase of physiological maturity

The correlations made to see how the light intensity influenced the accumulation of nitrates in tomato fruits, on inflorescences, showed that the light intensity influenced the accumulation of nitrates to a lesser extent, both in green fruits and immature fruits as well as in physiological maturity, the relations being $R^2 = 0.3877$, $R^2 = 0.3092$, respectively $R^2 = 0.3351$ (Figures 15-17).

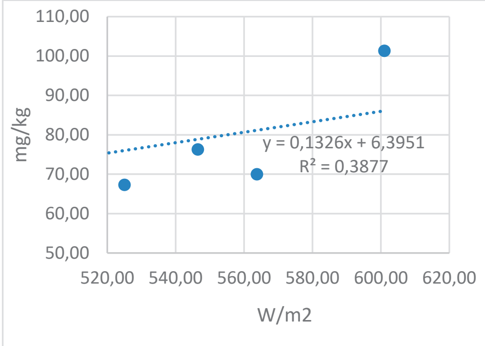

Figure 15. The influence of light intensity on the accumulation of nitrates in green fruit

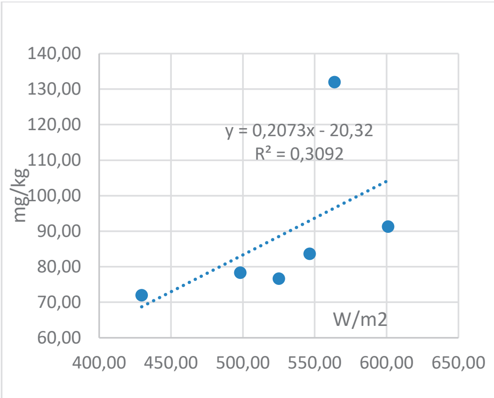

Figure 16. The influence of light intensity on the accumulation of nitrates in the fruit around physiological maturity

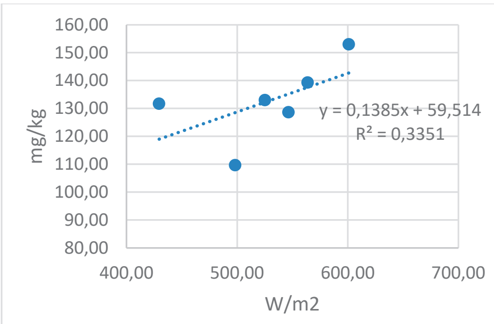

Figure 17. The influence of light intensity on the accumulation of nitrates in the fruit at physiological maturity

The light intensity did not influence the accumulation of sugars in immature (green) fruits, the relationship being insignificant $R^2 = 0.1956$, however, it showed a significant influence on fruits around physiological maturity (R^2 = 0.5299) and those that have reached physiological maturity. (R^2 = 0.5247), Figure 18.

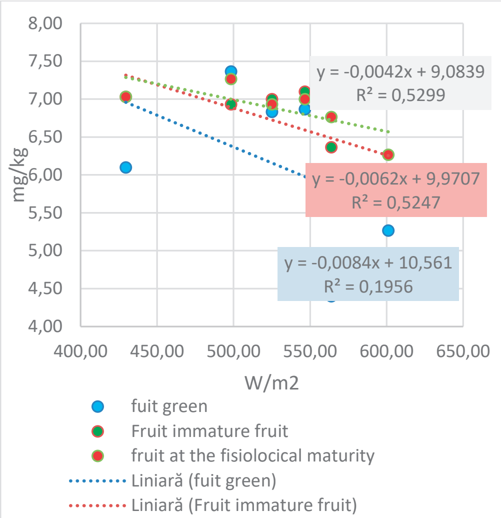

Figure 18. The influence of light intensity on the accumulation of sugars in the fruit

CONCLUSIONS

The study was carried out and, based on the analyzes performed and it was possible to highlight the influence of growth parameters, temperature, light, atmospheric humidity, CO_2 content, on the total fruit production per plant but also on the influence of dry matter content, fruit firmness, nitrate and carbohydrate content. The comparison was made taking as a constant parameter the nutrient solution for each period of growth and fruiting.

It was found that there were no significant variations between the analyzed parameters, which means that in the greenhouse the environmental factors that can be controlled, are temperature, atmospheric humidity, and CO2 content.

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