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EVAPOTRANSPIRATION AND INTERACTIVE EFFECTS OF IRRIGATION AND FERTIGATION ON WHITE STRAWBERRY FRUITS

Elena GRANCHAROVA[1], Blagoj ELENOV[1], Petya IVANOVA[2], Emilija ELENOVA[1], Georgi KOSTADINOV[1]

[1]Institute of Soil Science, Agrotechnologies and Plant Protection "Nikola Poushkarov", 7 Shosse Bankya Str., Sofia, Bulgaria
[2]Institute of Food Preservation and Quality, 154 Vasil Aprilov Blvd, Plovdiv, Bulgaria

Corresponding author email: eveha@abv.bg

Abstract

This research presents the crop evapotranspiration and investigates the effects of drip irrigation and fertigation on white strawberry fruits (diameter and number of fruits per plant). A two-factor experiment was conducted during 2023 and 2024 in an unheated greenhouse in the Chelopechene experimental field, Sofia, Bulgaria with drip irrigated and fertigated strawberry cultivar (Fragaria × ananassa 'Snow White'). The irrigation and the fertilization factors were applied in two rates: I1 - 75% (ETc) I2 - 50% (ETc), F1: optimal fertilization $N_{8.09}P_{12.76}K_{15.62}$; F2 – suboptimal fertilization - 75% (F1). Total strawberry evapotranspiration was 380.99 mm for 2023 season and 416.34 mm for 2024 season. The results showed that the highest mean fruit diameter (d) was obtained from I1F2 treatment (22.23 mm) in 2023 and 21.55 mm in 2024 from I1F1. There was a significant reduction (12%) in fruit diameter (d) in the second growing year (2024) in the most unfavourable growing treatment (I2F2). The fruit weight reduction from I2F2 treatment was 31% in 2024. The highest mean number of fruits per plant was obtained from I1F1 treatment – 60.97 pcs in 2023 - 2024. As opposed to fruit sizes and fruit weight the fruits number per plant increased. The fruits number per plant increasing from I1F1 treatment was 84% in 2024.

Key words: *white strawberry, irrigation, fertigation, fruit diameter, fruit weight.*

INTRODUCTION

The evapotranspiration, using current climatic data, estimate the crop water requirements and might serve to achieve better irrigation water productivity. The evapotranspiration estimation plays an important role in strawberry water requirements determination as a drought sensitive plant (Celiktopuz, 2023). The dynamics of change in current climate data due to climate changes draws researcher`s attention on strawberry evapotranspiration observations (Janssens et al., 2024; Jo et al., 2021; Menzel, 2021; Santosh, 2021).

It is essential to find the balance between irrigation and fertigation to achieve high yield and good quality while at the same time reducing the risk of soil nitrate nitrogen leaching (Bhagwat et al., 2023; Kulikov et al., 2020; Li et al., 2024; Richa & Sanjeev, 2022; Webler et al., 2023)

Strawberries with white fruits have long history of cultivation no shorter then red varieties. White strawberry has cultivated for hundreds of years in Chile and has grown in two botanical forms - wild *Fragaria chiloensis* ssp. *chiloensis* f. *patagonica* and cultivated *Fragaria chiloensis* ssp. *chiloensis* f. *chiloensis* (Grez et al., 2020). It was brought to Europe in the 18th century. 'Snow White' cultivar has been selected in 2010 out from *Fragaria x ananassa* 'Weisse Ananas' and *Fragaria chiloensis* f. *chiloensis* (Olbricht et al., 2013). White strawberries are distinguished by their white or pale pink flesh and unique pineapple-like flavor.

This research presents the crop evapotranspiration and investigates the effects of drip irrigation and fertigation on white strawberry fruits (diameter and number of fruits per plant).

MATERIALS AND METHODS

A two years two-factor experiment was conducted on drip irrigated strawberry plants in a tunnel greenhouse in 2023 and 2024 in the Chelopechene experimental field (latitude 42°44′22.8″N, longitude 23°28′3.7″E and altitude 550 m above sea level) of the Institute of Soil Science, Agrotechnologies and Plant

Protection "Nikola Poushkarov" in Sofia, Bulgaria. Sofia field falls into temperate continental climate subzone. The greenhouse was unheated with area 420 m^2 (7.9 m x 53 m) covered with a five-layer UV+EVA+IR+AD+dif -150 µm polyethylene film. The soil could be defined as moderate to strong water-permeable with an average filtration capacity. The soil was *Chromic Luvisol* with bulk density 1.47 g cm^{-3}, field capacity 22% and wilting point 10% for 0-50 cm layer. Pre-planting physico-chemical characteristics of the soil (0-20 cm) at the experimental plot were pH 6.5, organic carbon 2.87% and available nitrogen (N) 19.30 mg kg^{-1}, phosphorus (P_2O_5) - 4.35 mg kg^{-1} and potassium (K_2O) - 2.79 mg kg^{-1}. To further reduce water losses, mulching with silver-black UV polyethylene mulch with a thickness of 30 µm was applied.

The object of the study was white strawberry cultivar (*Fragaria* × *ananassa* 'Snow White'). The experimental treatments were arranged according to the method of long plots with three replications. Each plot has 23.2 m^2 area and consisted of twin rows of strawberries. Healthy bare-root frigo plants were planted in scheme of 90 + 30/30 cm on 22 March 2023. According to the white strawberries cultivation technology in each of the experimental plots were provided the appropriate amount of red fruit plants (4: 1 ratio) to ensure better pollination. The irrigation factor was applied in two rates: I1 - deficit irrigation - 75% (ETc); I2 - deficit irrigation - 50% (ETc). The fertilization factor was applied in two rates: F1: optimal fertilization $N_{8.09}P_{12.76}K_{15.62}$; F2 - suboptimal fertilization - 75% (F1) - $N_{6.07}P_{9.57}K_{11.94}$. Optimal fertilization was developed according to Haifa nutrition recommendations (Haifa Group, 2021) as follows: Haifa MAP- 25-45 kg ha^{-1} , Multi K – 80 kg ha^{-1} , Haifa MKP - 25 kg ha^{-1} , Haifa Cal - 30 kg ha^{-1} , Maguisal - 10 kg ha^{-1} , Poly-feed - 25-40 kg ha^{-1}. Five treatments were tested: control treatment I0F0: 100% (ETc) - full irrigation and without fertigation; I1F1; I1F2; I2F1; I2F2. Irrigation was applied trough drip system include NMC Junior controller for precise irrigation rate application, FertiKit Nutrigation system for precise fertigation rate application, pressure-compensated pipelines UniRam AS with 14.6 mm inside diameter, 1.2 mm wall thickness, built-in trough 20 cm drippers and flow rate 1.6 l h^{-1}.

The microclimate data (air temperature, relative humidity, solar radiation, sunshine duration and wind speed) in the greenhouse was measured at every 30 min using an automatic meteorological station located in the centre of experimental area and recorded in data logger (HOBO USB Micro Data Logger, USA). FAO Penman-Monteith Equation (Allen et al., 2006a) was used for determining daily reference evapotranspiration and irrigation scheduling. Crop coefficient was 0.30, 0.80 and 0.70 respectively in initial, middle and end growing stage (Allen et al., 2006b). Fruit mass was determined through weighing with a electronic precision balance Vedia FR-H (±0.01 g). Fruit width and length was measured with a digital calliper (±0.01 mm). All the observations were carried out of 5 consecutive plants in three replications.

The obtained data were statistically analyzed using STATISTICA 8.0. Duncan's Multiple Range tests at a significance level ($p<0.05$) to measure specific differences between pairs of means was used.

RESULTS AND DISCUSSIONS

Figure 1 shows the minimum and maximum daily temperature inside the greenhouse through the 2023 and 2024 growing season. The average minimum daily temperature inside the greenhouse through the 2023 season was 10.16°C and 10.28°C through the 2024 season. The average maximum daily temperature inside the greenhouse through the 2023 season was 31.77°C and 37.86°C through the 2024 season.

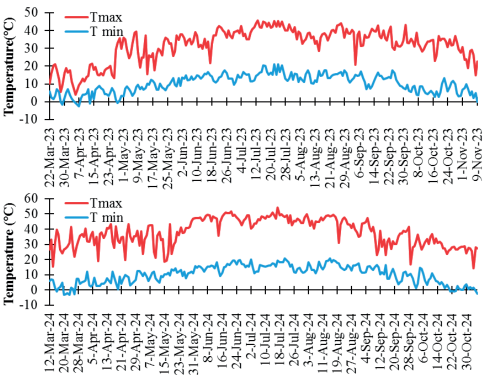

Figure 1. Minimum and maximum daily temperature throughout the 2023 and 2024 growing season

Figure 2 shows the minimum and maximum daily humidity inside the greenhouse through the 2023 and 2024 growing season. The average minimum daily humidity inside the greenhouse through the 2023 season was 37.53% and 29.08% through the 2024 season. The average maximum daily humidity inside the greenhouse through the 2023 season was 87.98% and 83.55% through the 2024 season.

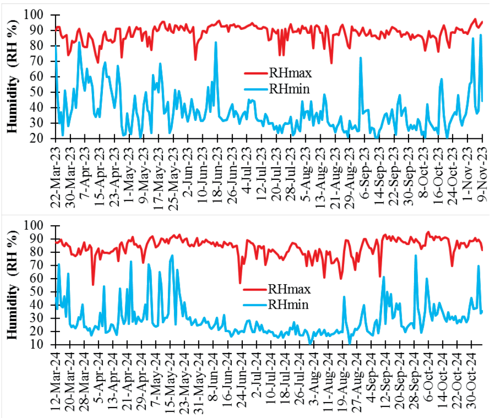

Figure 2. Minimum and maximum daily humidity throughout the 2023 and 2024 growing season

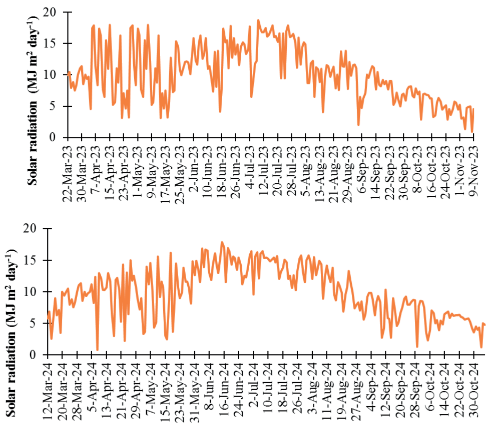

Figure 3. Daily solar radiation throughout the 2023 and 2024 growing season

Figure 3 shows the daily solar radiation inside the greenhouse through the 2023 and 2024 growing season. The average daily solar radiation inside the greenhouse through the 2023 season was 10.19 MJ m^{2} day^{-1} and 9.98 MJ m^{2} day^{-1} through the 2024 season.

Figure 4 shows the daily reference evapotranspiration through the 2023 and 2024 growing season. The average daily reference evapotranspiration through the 2023 growing season was 2.26 mm and 2.36 mm through the 2024 growing season.

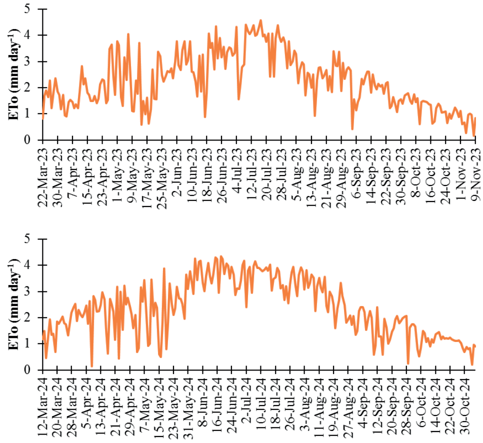

Figure 4. Daily reference evapotranspiration throughout the 2023 and 2024 growing season

The data was used to calculate daily reference evapotranspiration. Mean daily crop evapotranspiration (ETc) throughout the 2023 growing season was 1.64 mm day^{-1} and it was ranged from 0.11 mm day^{-1} (8 November 2023) to 3.66 mm day^{-1} (17 July 2023). Mean daily crop evapotranspiration throughout the 2024 growing season was 1.74 mm day^{-1} and it was ranged from 0.11 mm day^{-1} (8 April 2024) to 3.48 mm day^{-1} (18 June 2024). The ETc increased synchronized with the intensity of vegetative development of strawberries and with temperature increasing. Average ETc throughout the flowering stage (25 April 2023 - 24 May 2023) was 1.71 mm day^{-1} and 1.38 mm day^{-1} (27 March 2024 - 02 May 2024). Average ETc throughout the fruiting stage was 2.46 mm day^{-1} (25 May 2023 – 14 July 2023) and 2.08 mm day^{-1} (17 April 2024 - 17 June 2024). Lower daily average ETc throughout the 2024 season was due to earlier crop vegetative development compared to 2023 season. Total strawberry evapotranspiration for 2023 growing season was 380.99 mm and 416.34 mm for 2024 season.

The fruit size data are presented in Figure 5. The results showed that the highest mean transversal

(x) fruit size was obtained from I1F1 treatment (23.71 mm in 2023 and 22.35 mm in 2024). The lowest mean transversal (x) fruit size was obtained from I2F1 treatment (22.66 mm) in 2023 and 19.04 mm in 2024 from I2F2. There was a significant reduction (16%) in transversal (x) fruit size in the second growing year (2024) from the most unfavourable growing treatment (I2F2). While, the reduction was in the order of 5-7% from the other treatments.

The results showed that the highest mean longitudinal (y) fruit size was obtained from I1F2 treatment (20.77 mm) in 2023 and 20.75 mm in 2024 from I1F1. The lowest mean longitudinal (y) fruit size was obtained from I2F1 treatment (19.61 mm) in 2023 and 18.01 mm in 2024 from I2F2. There was a reduction (8%) in longitudinal (y) fruit size in the second growing year (2024) from the most unfavourable growing treatment (I2F2). While, from I1F1, I0F0 and I2F1 an increase was observed.

The results showed that the highest mean fruit diameter (d) was obtained from I1F2 treatment (22.23 mm) in 2023 and 21.55 mm in 2024 from I1F1. The lowest mean fruit diameter (d) was obtained from I2F1 treatment (21.14 mm) in 2023 and 18.53 mm in 2024 from I2F2. There was a significant reduction (12%) in fruit diameter (d) in the second growing year (2024) from the most unfavourable growing treatment (I2F2). While, the reduction was in the order of 2-4% from the other treatments.

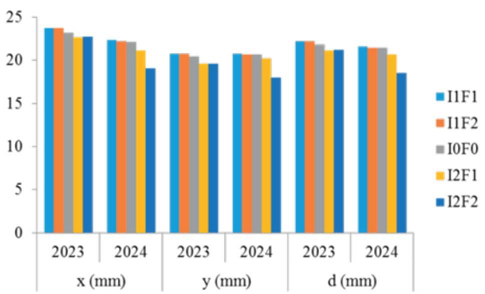

Figure 5. Fruits size by treatments throughout the 2023 and 2024 growing season

The reduction fruit sizes in the second growing year (2024) from the most unfavourable growing treatment (I2F2) probably due to depletion of plant potential and reserves. Similar results have been reported by Bibi et al. (2016) for red variety.

The fruit weight (g) and fruits number per plant data are presented in Figure 6. Fruit weight reduction was 6-9% from I0F0, I1F1 and I1F2 treatments in 2023 and 2024 growing season. The fruit weight reduction from I2F1 treatment was 16% in 2024. The fruit weight reduction from I2F2 treatment was 31% in 2024. As opposed to fruit sizes and fruit weight the fruits number per plant increased. The fruits number per plant increasing from I1F1 treatment was 84% in 2024. The fruits number per plant increasing from control I0F0 treatment was 81% in 2024. The lowest increasing was obtained from I2F1 treatment – 75% in 2024 growing season.

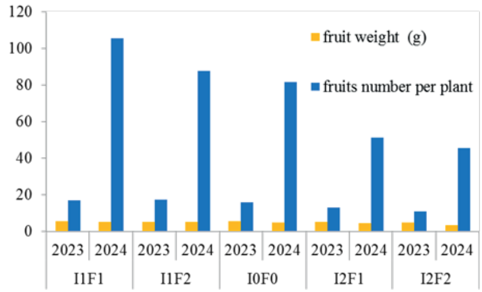

Figure 6. Fruits number per plant and fruit weight by treatments throughout the 2023 and 2024 growing season

The results (Table 1) showed that the highest mean fruit numbers was obtained from I1F2 treatment 17.27 pcs in 2023. Reduction of the fruit numbers between the highest (I1F2) and the lowest (I2F2) values was 37%. Results of Duncan's Multiple Range test show that there was significant difference between the means of I2F2 and I1F1, I1F2 and I0F0. The treatments were divided into two homogeneous groups.

Table 1. Average number of fruits per plant by treatments

Treatment	Fruits/plant (pcs)		
	2023	2024	2023-2024
I1F1	16.60a	105.33a	60.97a
I1F2	17.27a	87.67a	52.47ab
I0F0	15.60a	81.33	48.47b
I2F1	12.80ab	51.07b	31.93c
I2F2	10.93b	45.53b	28.23c
F	3.227	17.337	14.62
p	0.0188	0.000	0.000

Values with same lowercase letter for the same parameter were not statistically different.

The results (Table 1) showed that the highest mean fruit numbers was obtained from I1F1 treatment 105.33 pcs in 2024. Reduction of the fruit numbers between the highest (I1F1) and the lowest (I2F2) values was 57%. Results of Duncan's Multiple Range test show that there was significant difference between the means of control treatment I0F0 and all other treatments. The treatments were divided into three homogeneous groups.

For the two years period 2023-2024, the highest average number of fruits per plant was observed in I1F1 treatment 60.97 pcs. Reduction of the fruit numbers between the highest (I1F1) and the control treatment (I0F0) was 21%. Reduction of the fruit numbers between the highest (I1F1) and lowest (I2F2) was 54% more than the most unfavourably grown variant I2F2 (Table 1). The results from Duncan's multiple range test indicated that there was a significant difference between means of I0F0 and all other treatments excluding I1F2 at p=0.05. The treatments were divided into three homogeneous groups.

With the decrease of irrigation rate and fertigation rate, the mean fruit weight and fruits number per plant also decreases. Similar results have been reported by Kang et al. (2018), Kachwaya et al. (2015) for red variety.

CONCLUSIONS

Water and nutrient regimes are the main factors, which affect white strawberry fruit sizes, fruit weight and number of fruits per plant.

These results show that optimal irrigation and fertilization conditions lead to significantly greater fruit mass as well as number of fruits per plant. However, there is no significant difference in their mass and number between certain combinations of irrigation and fertilizer rates, such as I1F1 and I1F2, and between I1F2 and I0F0, which indicates that some combinations are interchangeable in the context of achieving greater fruit mass and number.

The significant differences between the other pairs of treatments highlight the importance of proper irrigation and fertigation management to optimize yield. As irrigation and fertigation rates decrease, the average fruit weight and number also decrease.

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