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INFLUENCE OF IRRIGATION AND FERTIGATION ON SENSORY CHARACTERISTICS OF FRUITS OF WHITE STRAWBERRY (*FRAGARIA X ANANNASSA* "SNOW WHITE") GROWN IN BULGARIA

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Abstract

The aim of this paper is to present the effects of the applied regimes of fertilization and irrigation on the sensory characteristics of white strawberry variety. A two factors experiment was conducted during 2023 in unheated greenhouse in the Chelopechene experimental field, Sofia, Bulgaria with drip irrigated and fertigated strawberry variety (Fragaria x Anannassa "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). Five treatments was tested: control: I0F0:100% (ETc) without fertigation; I1F1; I1F2; I2F1; I2F2. Sensory analyzes were carried out during the first growing season of the fruits according to indicators: appearance, color, consistency, taste, aroma and general sensory evaluation on a 5-point rating scale, given by 10 experts. It was established that the applied agricultural techniques have an impact on the indicators of appearance, color and aroma of the investigated fruit variants. The total sensory evaluation was statistically distinguishable only in the fruits of the control and the variant with 50% irrigation and 75% fertilization ($p<0.05$).

Key words*: strawberry, irrigation, fertigation, sensory characteristics, Bulgaria.*

INTRODUCTION

Strawberries are widely cultivated for their tasty flavor, soft texture, pleasant aroma and nutrient content. In 2022 world production of strawberries was 9.57 million tons produced in 81 countries (FAOSTAT, 2024). At the same time strawberry is one of the most drought sensitive plants due to shallow roots. Water deficit affects yield, vegetative growth and development (Taparauskienė & Miseckaitė, 2014). Soil types and fertilization also have an influence on strawberry quality and sensory characteristics (Taghavi et al., 2019). *Fragaria x Anannassa* berries are an important source of vitamins, minerals and fibre, as are other fruits and vegetables. The diversity of bioactive compounds, such as phenols in berry species, is reflected in a wide range of their biological activities, which have a beneficial effect on human health and disease prevention (Moyer et al., 2002). 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 grow in two botanical forms (Grez et al., 2020) - wild (*Fragaria chiloensis* ssp. *chiloensis* f. *patagonica*) and cultivated (*Fragaria chiloensis* ssp. *chiloensis* f. *chiloensis*). It was brought to Europe in the 18th century. "Snow White" variety has been selected in 2010 out from *Fragaria* ×*ananassa* "Weisse Ananas" and *Fragaria chiloensis* f. *chiloensis* (Olbricht et al., 2013).

Investigations of sensory characteristics (appearance, color, texture, flavour, odour) of strawberries are conducted mainly for red varieties (Kampuss et al., 2021; Darbellay et al., 2002; Testoni & Nuzzi, 2006; Carlen et al. 2007; Bianchi et al., 2017). White varieties are studied mainly in regard to physiological process (Grez et al., 2021), floral differentiation (Grez et al., 2017), taste and health relating compounds (Sarıdaş et al., 2021), pomological characteristics (Antonova & Petrova-Branicheva, 2023).

The aim of this paper is to present the effects of the applied regimes of fertilization and

irrigation on the sensory characteristics of white strawberry variety *Fragaria x Anannassa* "Snow White" based on the harvest date.

MATERIALS AND METHODS

A first year two-factor experiment was conducted on drip irrigated strawberry plants in an unheated polyethylene tunnel greenhouse in 2023 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, agro technologies and plant protection "Nikola Pushkarov" in Sofia, Bulgaria (Figure 1). Mulching was applied to further reduce water evaporation and inhibits weeds. The object of the study was white strawberry variety (*Fragaria x Anannassa* "Snow White").

Figure 1. View from unheated polyethylene tunnel greenhouse in the Chelopechene, Bulgaria

The experimental treatments were arranged according to the method of long plots. Each treatment was replicated three times. 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). Five treatments were tested: control treatment I0F0: 100% (ETc) - full irrigation and without fertigation; I1F1; I1F2; I2F1; I2F2. The microclimate of greenhouse: 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 and recorded in data logger (HOBO USB Micro Data Logger, USA). FAO Penman-Monteith Equation (Allen et al., 2006) was used for determining reference evapotranspiration and irrigation scheduling. 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 fruits during the first vegetation period in three harvests (6 June, 22 June and 4 July) have been provided and analysed in the Food Testing Laboratory at the Institute of Food Preservation and Quality in Plovdiv, using an adapted methodology developed at the same institute.

On the day of harvesting, the fruits were transported in coolers, and the evaluation was conducted 24 hours after the harvest was brought to the Sensory Laboratory at a temperature of 20 ± 5°C. Ten trained experts were provided with coded samples of strawberry fruits from the four cultivation variants and the control for assessment. During the sensory analysis, the tasters neutralized their taste buds between sample variants with water and crackers.

To assess the sensory attributes of the fruits for the three harvests, the tasters provided their quantitative ratings on a five-point hedonistic scale for the following indicators: external appearance (uniformity and size of the fruits), color (white with red seeds), consistency (juiciness, presence of seeds), taste (sweetness, taste intensity), and aroma (fruitiness, aroma intensity). The overall sensory evaluation is calculated based on the sum of the average ratings given by the tasters, multiplied by the weighting coefficient for each category: external appearance - 0.25; color - 0.20; consistency - 0.15; taste - 0.25; and aroma - 0.15.

Mathematical and statistical analysis

The presented results are the arithmetic mean values from at least three parallel determinations, with variation coefficients less than 5%. The statistical data processing was conducted using ANOVA software, as well as Microsoft Excel and SPSS Statistics.

RESULTS AND DISCUSSIONS

Three series of tests were conducted on the investigated variants of white strawberries depending on the harvests. The data is presented in Figure 2. The fruits from the first harvest of the control group (I0F0) are uniform, with average dimensions 29.6/25.2 mm and average weight 8.55 g (Figure 3), white in color with red seeds, juicy, sweet, and aromatic. The white strawberries from the second harvest had average dimensions 21.9/19.5 mm and average weight 4.42 g, white in color with pink hues in some areas, with red seeds. They are juicy but lack sufficient sweetness and have a weak aroma.

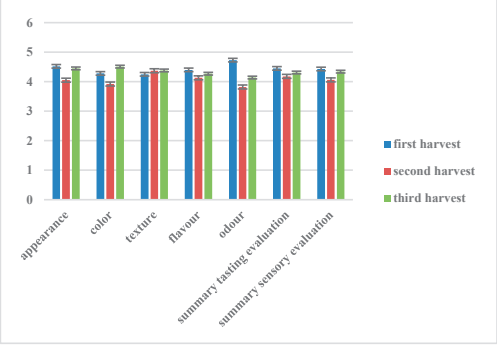

Figure 2. Sensory characteristics of white strawberry fruits in the control group (I0F0) depending on the harvests

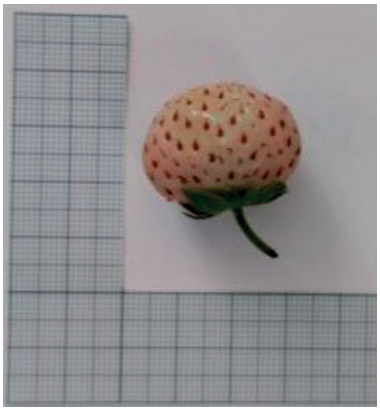

Figure 3. White strawberry fruits from the control group (I0F0)

During the third harvest, the fruits had average dimensions 21.9/19.2 mm and average weight 4.52 g, white in color with pink hues and red seeds. They are juicy, with sweetness and aroma intensity close to those of the fruits from the first harvest. For the control variant of white strawberries, the external appearance of the fruits received very good ratings for the first and third harvests, while for the second harvest, the tasters provided good ratings. Similar results were obtained for the evaluations of color, overall taste, and overall sensory assessment. The factor of harvest time influences the values of these indicators ($p < 0.05$).

For the consistency indicator of the investigated fruits, it was found that the harvest factor does not have an influence, and the ratings (above 4.2) are statistically indistinguishable ($p > 0.05$). The tasters rated the taste of the fruits with good scores, with fruits from the first harvest leading, followed by fruits from the third harvest. Fruits from the second harvest received the lowest scores for taste (4.13), indicating that the harvest time influences the taste of the fruits ($p < 0.05$).

With maximum and minimum ratings for all examined fruits and indicators, the evaluators gave the aroma indicator for white strawberry fruits as follows: for the first harvest (4.73) and for the second harvest (3.82). After the statistical processing of the data, it was confirmed that the harvest time factor influences the aroma of the fruits ($p < 0.05$). The overall taste assessment and the formed overall sensory evaluation of the white strawberry fruits from the control group showed that there were no statistically significant differences between the first and third harvests (values above 4.3) ($p > 0.05$), while the harvest factor influences the ratings of the fruits from the second harvest ($p < 0.05$).

The data from the conducted sensory characteristics of the white strawberry fruits, variant I2F1, are presented in Figure 4. The fruits from the first harvest had average dimensions 29.2/24.7 mm and average weight 8.23 g (Figure 5), white with red seeds. Fruits from the second harvest had average dimensions 21.9/18.4 mm and average weight 4.04 g and third harvest had average dimensions 2.02/18.6 mm and average weight 3.68 g, a pink hue, better consistency, and juiciness.

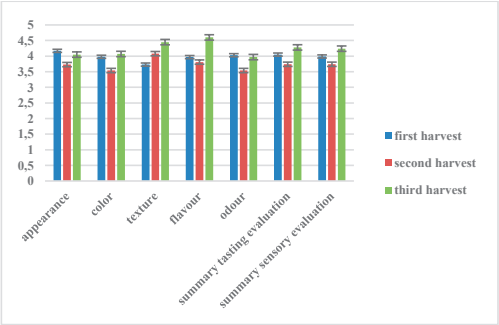

Figure 4. Sensory characteristics of white strawberry fruits, variant I2F1, depending on the harvests

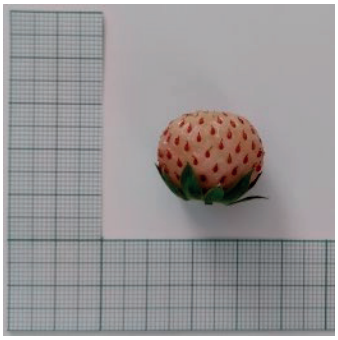

Figure 5. White strawberry fruits from variant I2F1

For all examined fruits, the ratings for the indicators of external appearance, color, and aroma are statistically indistinguishable between the first and third harvests. The harvest time factor does not influence these indicators of the fruits, and they are around and slightly above 4 ($p > 0.05$). With maximum ratings (4.5), the tasters evaluated the fruits from the third harvest for consistency and taste indicators, while with minimum ratings (3.5) they evaluated the fruits from the second harvest for indicators such as external appearance, color, aroma, taste, overall taste assessment, and overall sensory evaluation. The harvest time factor influences the examined indicators of the fruits from the second harvest ($p < 0.05$), while the fruits from the third harvest have maximum or similar values to those from the first harvest. White strawberry fruits grown with 75% irrigation and 100% fertilization (I1F1) from the first harvest had average dimensions 30.4/26.2 mm and average weight 8.99 g (Figure 6), white with red seeds, juicy, moderately sweet, and aromatic. From the second harvest, the fruits are smaller, average dimensions 22.5/20.2 mm and average weight 4.54 g, white with pink hues, red seeds, juicy, with insufficient sweetness and aroma. The white strawberries from the third harvest had average dimensions 23.7/20.1 mm and average weight 5.22 g, uniform, white with pink hues, red seeds, juicy, sweet, and aromatic.

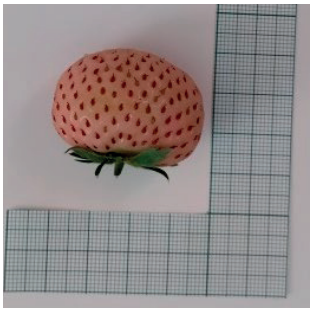

Figure 6. White strawberry fruits from variant I1F1.

The fruits from the first and third harvests have the highest average ratings for the examined indicators and the summarized taste and sensory evaluations (Figure 7). Once again, the fruits from the second harvest have the lowest average ratings, and the harvest time factor influences their sensory indicators ($p < 0.05$).

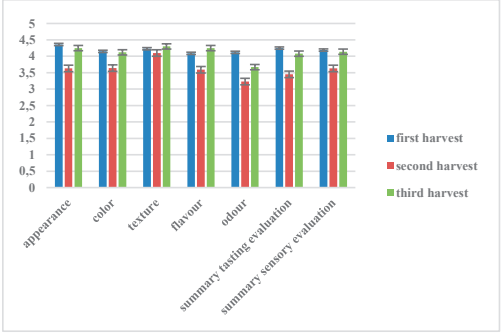

Figure 7. Sensory characteristics of white strawberry fruits, variant I1F1, depending on the harvests

Figure 8 shows the average ratings for the examined sensory indicators of fruits grown with 75% irrigation and 75% fertilization (I1F2). The fruits from the first harvest had average dimensions 30.4/26.2 mm and average weight 8.59 g (Figure 9), white with red seeds. Fruits from the second harvest had average dimensions 22.5/19.8mm and average weight 4.47 g, white with a pink hue, red seeds, juicy,

but with insufficient sweetness and aroma. Third harvest had average dimensions 23.5/19.4 mm and average weight 5.02 g, a pink hue, better consistency, and juiciness.

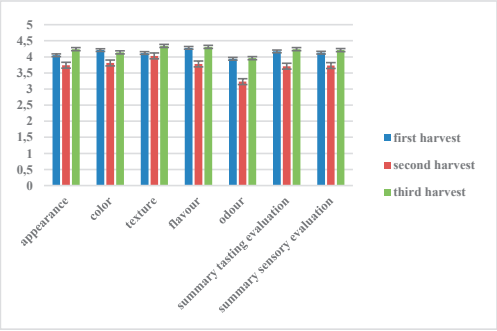

Figure 8. Sensory characteristics of white strawberry fruits, variant I1F2, depending on the harvests

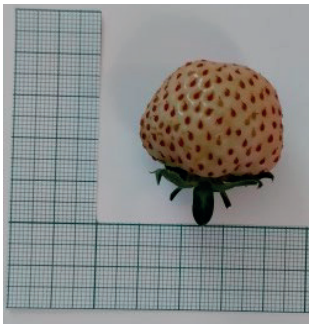

Figure 9. White strawberry fruits from variant I1F2

The tasters gave good ratings for the fruits from the first and third harvests, while they rated the fruits from the second harvest with slightly lower scores. Comparative analysis showed that for all indicators of the fruits from all harvests, the aroma was rated lower than (3.2). White strawberries from the first harvest, grown with 50% irrigation and 75% fertilization (I2F2), are small-sized, average dimensions 27.9/24.1 mm and average weight 7.16 g, white with red seeds, softer in texture, sweet, and aromatic. The fruits from the second harvests are white with a pink hue, red seeds, juicy, sweet, and slightly aromatic had average dimensions 21.6/18.4 mm and average weight 4.04 g (Figure 10). The fruits from the third harvest had average dimensions 19.5/17.2 mm and average weight 3.39 g.

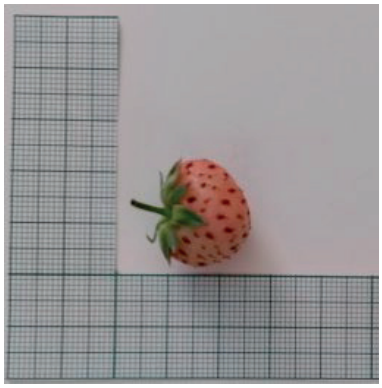

Figure 10. White strawberry fruits from variant I2F2

The fruits grown under this variant were rated with average scores across the three harvests for the indicators of external appearance, color, aroma, overall sensory assessment, and taste assessment (Figure 11).

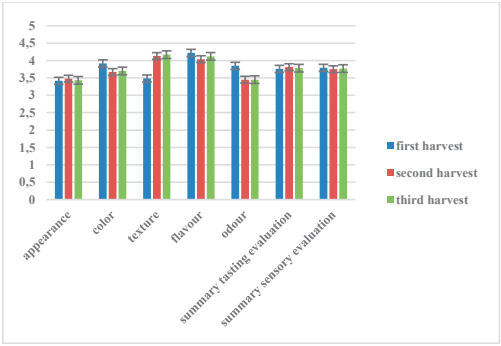

Figure 11. Sensory characteristics of white strawberry fruits, variant I2F2, depending on the harvests

Only for the indicators of taste and consistency did the tasters rate the fruits with good scores for all three harvests. The strawberry fruits from the first harvest received good ratings for color, taste, and aroma, with a minimum rating for consistency. The fruits from the remaining harvests had statistically indistinguishable values among themselves, and the harvest factor did not influence the mentioned indicators. After statistical data processing, it was found that for the indicators of external appearance, overall taste assessment, and overall sensory evaluation, the fruits from the three harvests showed no statistically significant differences, and the harvest factor did not influence these indicators ($p > 0.05$).

The comparative analysis for all variants, depending on the applied irrigation and fertilization treatments of white strawberry fruits, showed that after applying statistical methods such as Principal Component Analysis (PCA), ANOVA, and Pearson Correlation, significant differences were found in the examined sensory characteristics and overall sensory evaluation. The fruits from the control group I0F0, and the fruits from I2F2 showed these differences. Negative linear correlation dependencies were identified for all cultivation variants of white strawberries, with a moderate coefficient of determination (R^2 = 0.549), between sensory color evaluations and color saturation calculated from instrumental measurements of the fruits, as well as between sensory color evaluation and calculated color index (R^2 = 0.624). The influence of the cultivation method on the taste for all examined fruit variants was established through a negative linear correlation with a high coefficient of determination (R^2 = 0.806) between soluble solids content and sensory taste evaluations.

CONCLUSIONS

A sensory evaluation was conducted on white strawberry fruits grown under different irrigation and fertilization regimes (I1 - 75% (ETc), I2 - 50% (ETc), F1: optimal fertilization $N_{8.09}P_{12.76}K_{15.62}$; F2 - suboptimal fertilization - 75% (F1), with five treatments tested: control: I0F0: 100% (ETc) without fertilization; I1F1; I1F2; I2F1; I2F2) at three harvest maturities (6 June, 22 June and 4 July). It was found that the applied agronomic techniques influence the indicators for external appearance, color, and aroma of the studied cultivation variants' fruits. The overall sensory evaluation is statistically different only for the fruits from the control group I0F0 and the variant I2F2 ($p<0.05$). The harvest factor influences the sensory characteristics of the fruits for all cultivation variants. The fruits with maximum sensory scores for the examined indicators are those from the first harvest of the control group (I0F0), I1F1, I1F2, and I2F2, followed by the white strawberries from the third harvest. The fruits from the second harvest have the lowest taste ratings depending on the harvests for all examined agronomic technique variants.

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