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Optimization of the deficit irrigation management for strawberry production in the Loukkos region

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Abstract. The Moroccan red fruit sector has undergone remarkable development over the last decade, driven by the increase in demand from international markets and promoted by the national agricultural strategy. However, this development calls for the sustainability of water resources, especially in the current context of climate change which makes the future availability of water uncertain. In this sense, deficit irrigation (DI) is one of the promising techniques to improve the efficiency of crop water use. Strawberry is one of the most sensitive red fruits to water deficit. Sufficient and correct irrigation is critical to successful production. Therefore, growers often bring in quantities that exceed the needs of the crop, especially in areas where the cost of water is relatively negligible. In this paper, we studied the response of the two strawberry varieties (Sabrina, Victory) to four water treatments ranging from 50% to 125% of crop evapotranspiration (ETc). The two varieties differed significantly in yield and water consumption, with significant reductions in yield under DI treatments (50%ETc) for Sabrina. However, the fully irrigated treatment (100% ETc), and the DI treatments (75% and 50% ETc) did not show significant differences in yield for Victory.
Keywords : Deficit irrigation ; irrigation management ; strawberry ; berries

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1 Introduction

Morocco has known a significant evolution in berries production during the last decade. The total area cultivated reached 9650 hectares in 2020/21 divided between strawberry (3400 ha), raspberry (4100 ha) and blueberry (3000 ha) [1]. Strawberry production is concentrated in the irrigated areas of Gharb-Loukkos. The Loukkos perimeter is characterized by significant rainfall given its geographical location, which allows the recharge of the water table and the supply of wells and boreholes. However, the increased pressure on the water and the current context of climate change makes the future availability of water uncertain [2]. This situation calls for the the question of the sustainability of water resources, which is both the most determining and the most critical.
Thus, it is essential to adopt more efficient strategies for the management of crop irrigation to adequately meet the needs of the plant while reducing the pressure of the agricultural sector on water. In this sense, deficit irrigation is one of the promising techniques to improve the efficiency of crop water use. Strawberry is one of the crops sensitive to water deficit [3]. Successful production depends primarily on sufficient and correct irrigation. And given the high water requirement of strawberry [4], growers often bring in quantities that far exceed the needs of the crop, especially in areas where the cost of water is relatively negligible.

In this study we compared two strawberry cultivars, Sabrina and victory, in terms of their response to different irrigation levels. Our aim was to determine the feasibility of reducing water supply without compromising crop productivity.

2 Materiels & Methods

2.1 Plant material and growing conditions

The field experiment was conducted during the cropping season 2022/2023 at a berry farm located in Laaouamra, Larache (Morocco). The region has a Mediterranean-type climate, with dry and warm summers and relatively cold winters (Figure of temperature and humidity). The soil is a sandy soil with 9.07% clay, 3.04% silt, and 87.89% sand, 0.99% organic matter, 0.07 mS/cm EC 1/5 à 25°C, <1% active CaCO3, and a pH of 7.02 (saturated soil extract in 1:2.5 soil:H2O).
The short-day cultivars 'Sabrina' and 'Victory' of strawberry frigo plants were cultivated under polyethylene covered tunnel structures. 'Sabrina' strawberry produced abundant, large, red and conical firm fruits. 'Victory' is an early variety that produced fruits regularly throughout the whole season. Its fruit is heart-shaped with deep red color and firm skin.
Planting was done in mid-October in raised beds covered with plastic (40 cm high and 60 cm wide) spaced at 0.6m. On each line, plants were planted in double rows spaced at 25 x 25 cm (~70,000 plants/ha). Irrigation was done using a double T-tape line with a discharge rate of 5 L h-1 m-1 (1 L water per hour on a single dripper). Plants were cultivated following conventional cropping management of strawberry.

2.2 Irrigation treatment and experimental design

The irrigation treatments were determined based on the daily crop evapotranspiration (ETc). The ETc values were calculated using the FAO56 method [5] by multiplying the reference evapotranspiration values (ET0) collected continuously from a local weather station by the strawberry crop coefficients (Kc). The Kc values are mentioned in (Table 1).
The equation used for calculating ETc is as follows:

$$ETc = Kc \times ET0 \quad (1)$$

Table 1. Proposed Kc model for strawberry growing under plastique greenhouses in FAO56 [5,6].

Stage	Kc
Vegetative growth	0.3-0.4
Flowering	0.5-0.7
Harvest	0.8-1.0

The experiment was conducted using a split-plot randomized complete block design with four replications. The main plots were arranged based on the irrigation levels, and the sub-plots were arranged based on the variety. A total of 32 experimental plots were arranged, considering four different irrigation levels (125%, 100%, 75%, and 50% ETc) combined with two strawberry varieties (Sabrina and Victory). Each elementary plot consisted of 30 strawberry plants.
After planting, all treatments were irrigated to reach the upper limit of field capacity. Four weeks after planting, irrigation was adjusted to maintain different soil moisture levels.

2.3 Measured parameters

2.3.1 Stomatal conductance

Stomatal conductance was measured between 11:00 PM and 2:00 PM under clear skies the day before irrigation. A leaf porometer (DECAGON SC-1) with a portable desiccant was used. Calibration was performed before each measurement using standard calibration paper. Four measurements were done during the cropping season. Each one was performed on five plants per plot.

2.3.2 Chlorophyll content

Chlorophyll content were measured twice a month using a leafclip meter (Dualex sensor) which gives an instant non-destructive measurement.

2.3.3 Plant growth, Fruit production

Plants were assessed for the number of leaves and flowers (including fruits) twice a month, based on five plants per plot. Crown diameter was measured using a slide gauge, and canopy diameter was determined as the longest leaf-covered distance in two perpendicular directions. Mature strawberry fruits (at least 75% red colour) were harvested twice weekly to determine marketable yield. Fruits that were free of rot and had a regular shape (conical or flattened wedge) were considered marketable fruits.

2.3.4 Irrigation water use efficiency

Irrigation water use efficiency (IWUE) was calculated using the approach presented in [7]. IWUE (kg m^{-3}) is the ratio of the total marketable fruit yield (kg $ha^{-1} \times 0.10$) to the applied seasonal irrigation amount (mm).

2.4 Data analysis

Statistical analysis methods were used to analyse the data obtained from the experiment to determine the effect of water stress and strawberry variety on yield and growth components. The analysis tools used were Analysis of Variance (ANOVA) and the student-Newman-Keuls (SNK) multiple comparison test, which were performed using SPSS software (version 20). Treatment effects were considered significant at $P < 0.05$.

3 Results & Discussion

3.1 Strawberry Water Requirements and Irrigation Water Supply

This cropping season has experienced a few periods of high temperatures, especially after the planting and during the period of plant establishment (from October to December) (Figure1.a). However, there was a decrease in temperature in January, with temperatures dropping below 5°C. These temperature variations resulted in periods of extremely high and low reference evapotranspiration inside the tunnel (ET0) (Figure 1.b). The calculated irrigation quantities for each treatment are shown in Figure 1.c.

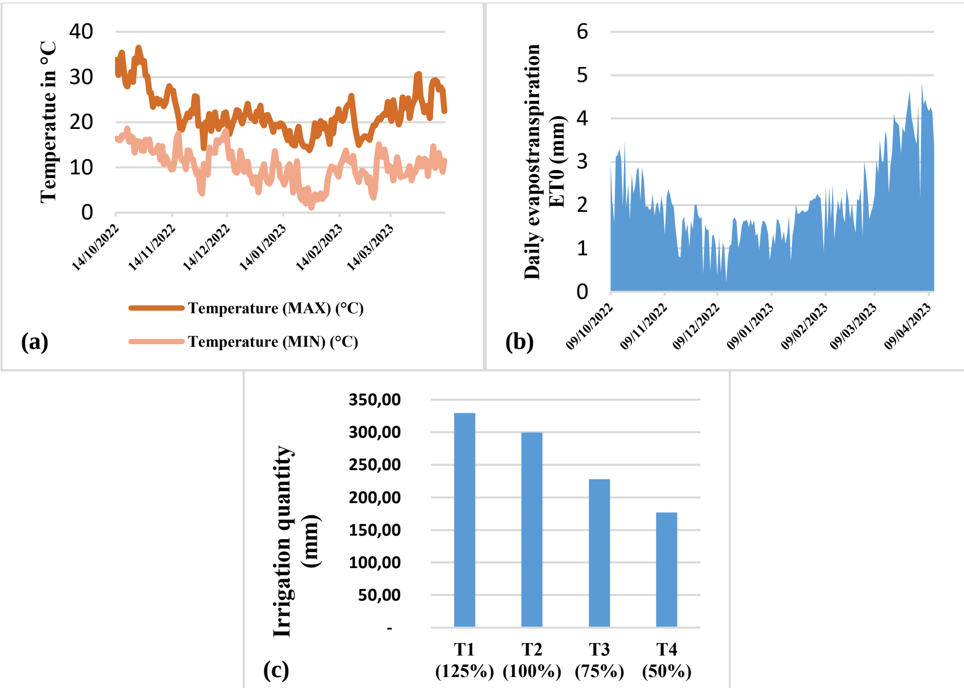

Fig. 1. Daily Average temperature (°C) (a) reference evapotranspiration (ET0) (b) and irrigation water quantities (mm) (c) during the growing period.

3.2 Physiological Response to Water Treatments

3.2.1 Chlorophyll content

The chlorophyll content was not significantly affected by the irrigation doses (Figure 2.a). The fully irrigated treatment had a content of 41.96 ug/cm^2, while the deficit treatment had a content of 42.78 ug/cm^2. Other studies have also reported no significant effect of deficit irrigation on chlorophyll content in strawberry plants [8]. However, the results of this study are not consistent with similar studies who reported a significant decrease in chlorophyll content in the leaves due to deficit irrigation [9,10].

3.2.2 Stomatal conductance

Deficit irrigation resulted in a decrease in stomatal conductance in strawberry plants (Figure 2.b), as the plants attempt to conserve water in response to stress conditions. The 125% treatment had the highest value of stomatal conductance for both cultivars, while the 50% treatment had the lowest value. This decrease in stomatal conductance with deficit irrigation has been reported by [8,9,11].

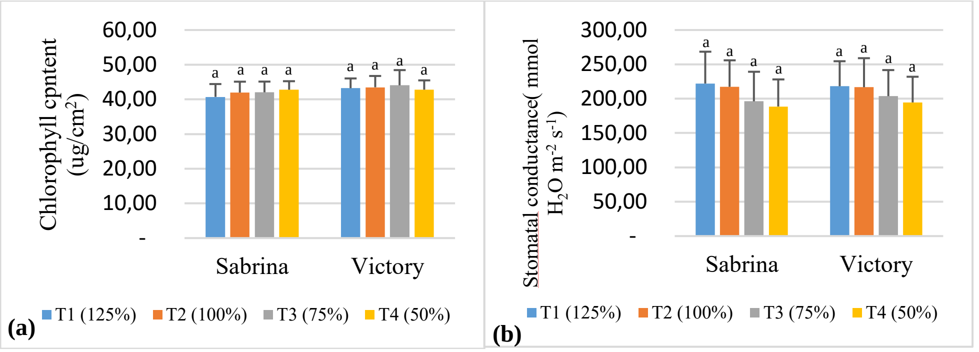

Fig. 2. Mean values of the chlorophyll content (a) and the stomatal conductance (b) of strawberry leaves under water treatments. The lines represent the standard deviation. The different letters indicate significant differences according to the SNK test at P ≤ 0.05.

3.3 Plant Growth and Fruit yield

3.3.1 Plant growth

Late in the season, canopy size was significantly lower in the deficit-irrigated treatment (T50%) than in the well-watered treatments in both cultivars. This finding is consistent with other studies that have reported a significant decrease in canopy size under deficit irrigation [9, 12]. Regarding the number of leaves, there was no significant difference between water treatments in both cultivars, the 125% treatment of the Sabrina cultivar, which had the highest number of leaves. However, other studies reported that strawberry plants under deficit irrigation had a lower number of leaves and smaller plant size than those under full irrigation [13, 14].

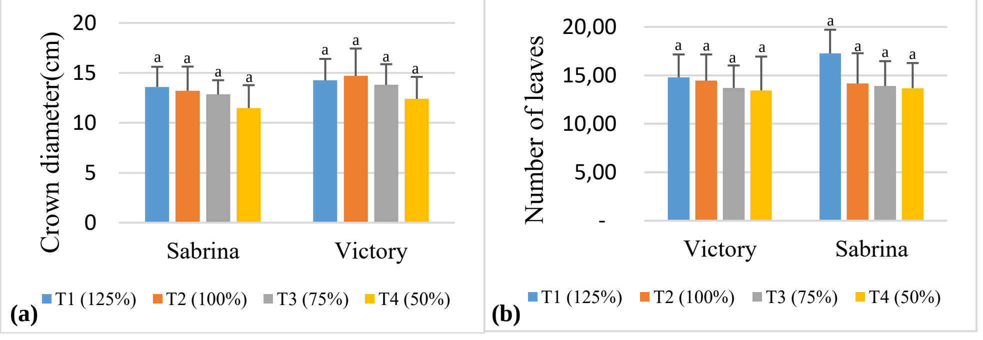

Fig. 3. Mean values of the crown diameter (a) and the number of leaves (b) of the study cultivars under water treatments. The lines represent the standard deviation. The different letters indicate significant differences according to the SNK test at P ≤ 0.05.

3.3.2 Yield

The two varieties differed substantially in yield and water consumption. Sabrina cultivar showed no significant differences between the well-watered treatments (T125, T100), which is consistent with the findings of similar studies [9]. However, the 50% treatment resulted in a significantly lower yield compared to the 100% irrigated treatment, with a 35% loss. For Victory, it showed the highest yield of 199g/plant with the 125% treatment, suggesting a higher water requirement for this cultivar. The 100% treatment and the two deficit irrigation treatments did not show significant differences in yield.

It is worth noting that both cultivars exhibited lower marketable fruit yield, which may be due to the agroclimate conditions early in the season. The high temperatures during the planting period may have affected the flowering process [15, 16].

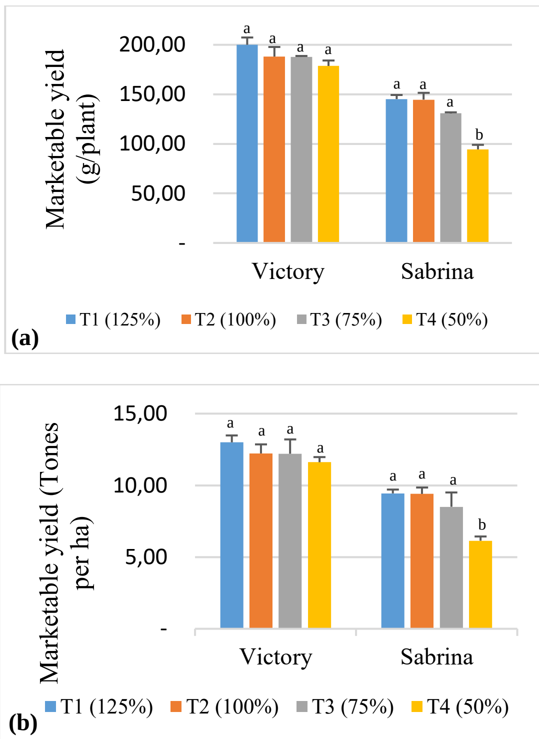

Fig. 4. Mean values of the marketable yield in g/plant (a) and Tons/ha (b) of the study cultivars under water treatments. The lines represent the standard deviation. The different letters indicate significant differences between water treatment among each cultivar according to the SNK test at $P \leq 0.05$.

3.3.3 Water productivity

Victory had the highest WP value for deficit irrigation treatments (Figure 5), with values of 7.07 kg/m^3 and 5.77 kg/m^3 for 50% and 75% irrigation treatments, respectively. The 125% and 100% water treatments did not show a significant difference. Sabrina had a less significant effect of deficit irrigation on WP than Victory, with the 75% treatment recording the highest value of 4.02 kg/m^3.

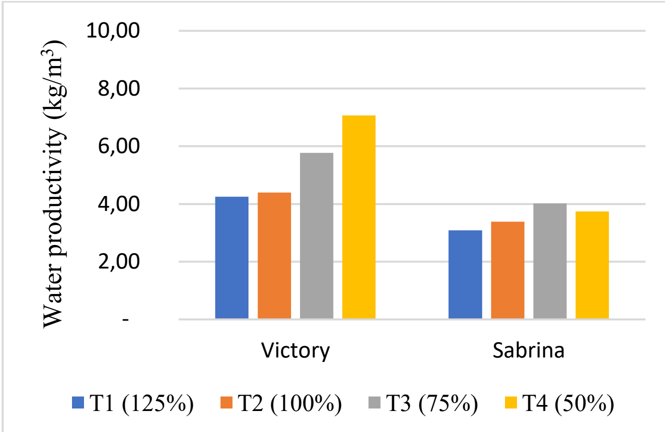

Fig.5. Mean values of the water productivity of the study cultivars under water treatments.

4 Conclusion

In conclusion, the present study showed that Victory was more tolerant to deficit irrigation than Sabrina. Therefore, the choice of cultivar could lead to significant water savings. Yield efficiency and water productivity of both cultivars remained high even under conditions of higher water shortage. Consequently, the use of deficit irrigation in strawberry cultivation by reducing 25% of the irrigation is a possible practice in low water availability scenarios, providing a balance between water sustainability and economic benefit. However, further research is required to better understand the underlying mechanisms determining water productivity in strawberries.

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