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Can Sustained Deficit Irrigation Save Water and Meet the Quality Characteristics of Mango?

Leontina Lipan [1,*], Aarón A. Carbonell-Pedro [1], Belén Cárceles Rodríguez [2], Víctor Hugo Durán-Zuazo [2], Dionisio Franco Tarifa [3], Iván Francisco García-Tejero [4], Baltasar Gálvez Ruiz [2], Simón Cuadros Tavira [5], Raquel Muelas [6], Esther Sendra [1], Ángel A. Carbonell-Barrachina [1] and Francisca Hernández [7]

1 Research Group "Food Quality and Safety", Centro de Investigación e Innovación Agroalimentaria y Agroambiental (CIAGRO-UMH), Miguel Hernández University, Carretera de Beniel, km 3.2, Orihuela, 03312 Alicante, Spain; aaron.carbonell@goumh.umh.es (A.A.C.-P.); esther.sendra@umh.es (E.S.); angel.carbonell@umh.es (Á.A.C.-B.)
2 IFAPA Centro "Camino de Purchil", Camino de Purchil s/n, 18004 Granada, Spain; belen.carceles@juntadeandalucia.es (B.C.R.); victorh.duran@juntadeandalucia.es (V.H.D.-Z.); bagalves@gmail.com (B.G.R.)
3 Agriculture and Environment Area, Experimental Farm "El Zahori", Excmo. Ayto. de Almuñécar, Plaza de la Constitución 1, Almuñécar, 18690 Granada, Spain; dionifranco@yahoo.es
4 IFAPA Centro "Las Torres", Carretera Sevilla-Alcalá del Río km 12,2, Alcalá del Río, 41200 Sevilla, Spain; ivanf.garcia@juntadeandalucia.es
5 Department of Ingeniería Forestal, Campus de Rabanales, Universidad de Córdoba, E-14071 Córdoba, Spain; mc1cutas@uco.es
6 Centro de Investigación e Innovación Agroalimentaria y Agroambiental (CIAGRO-UMH), Miguel Hernández University, Carretera de Beniel, km 3.2, Orihuela, 03312 Alicante, Spain; raquel.muelas@umh.es
7 Research Group "Plant Production and Technology", Centro de Investigación e Innovación Agroalimentaria y Agroambiental (CIAGRO-UMH), Miguel Hernández University, Carretera de Beniel, km 3.2, Orihuela, 03312 Alicante, Spain; francisca.hernandez@umh.es
* Correspondence: leontina.lipan@goumh.umh.es; Tel.: +34-642-236-863

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Abstract: Mango is one of the most cultivated tropical fruits worldwide and one of few drought-tolerant plants. Thus, in this study the effect of a sustained deficit irrigation (SDI) strategy on mango yield and quality was assessed with the aim of reducing irrigation water in mango crop. A randomized block design with four treatments was developed: (i) full irrigation (FI), assuring the crop's water needs, and three levels of SDI receiving 75%, 50%, and 33% of irrigation water (SDI_{75}, SDI_{50}, and SDI_{33}). Yield, morphology, color, titratable acidity (TA), total soluble solids (TSS), organic acids (OA), sugars, minerals, fiber, antioxidant activity (AA), and total phenolic content (TPC) were analyzed. The yield was reduced in SDI conditions (8%, 11%, and 20% for SDI_{75}, SDI_{50}, and SDI_{33}, respectively), but the irrigation water productivity was higher in all SDI regimes. SDI significantly reduced the mango size, with SDI_{33} generating the smallest mangoes. Peel color significantly changed after 13 days of ripening, with SDI_{75} being the least ripe. The TA, AA, and citric acid were higher in SDI_{75}, while the TPC and fiber increased in all SDI levels. Consequently, SDI reduced the mango size but increased the functionality of samples, without a severe detrimental effect on the yield.

Keywords: *Mangifera indica* L.; drought stress; SDI; yield; fruit quality; color change; minerals; antioxidants; sugars; dietary fiber

1. Introduction

Food production demand has been continuously on the rise and is projected to increase by up to 50% by 2050 [1]. This has mainly happened due to global population growth, which despite slowing down in some regions continues to expand in others, with global population predictions of almost 10 billion by 2050 and 11.2 billion by 2100 [1]. This means that the natural resource base upon which agriculture depends will be increasingly stressed.

In this sense, the new challenge for the near future, according to the Food and Agriculture Organization of the United Nations (FAO, Rome, Italy), is to "produce more with less". For instance, using less irrigation water in agriculture could be one of the actions to meet the proposed challenge because the water crisis is one of the top five key global risks in terms of impact, and agriculture is the dominant user of water, consuming 70% of the world's available water. However, it is well-known that water abundance is the main factor in improving land productivity, agricultural performance, and even food security. Thus, it is crucial to optimize irrigation water by using strategies designed to preserve fruit quality and yield at the same time.

In this regard, there are many deficit irrigation (DI) strategies, among which sustained deficit irrigation (SDI), regulated deficit irrigation (RDI), and partial rootzone drying (PRD) have been successfully used in many crops to improve water use efficiency and fruit quality [2–6]. Sustained deficit irrigation (SDI) is a water optimizing technique which helps in reducing both the biomass production and irrigation water. SDI refers to a water restriction strategy in which the crop receives a lower and uniform volume of irrigation water. The water is applied below the crop evapotranspiration, creating a progressive stress in the plant throughout the season by not refilling the rootzone completely through irrigation [7].

Mango (*Mangifera indica* L.) is one of the most important tropical fruits worldwide and was the sixth most produced (56 million t year^{-1}) fruit in the world in 2019 after bananas (116 million t year^{-1}), watermelons (100 million t year^{-1}), apples (87 million t year^{-1}), oranges (79 million t year^{-1}), and grapes (77 million t year^{-1}) [8]. Its bright color, distinctive flavor, characteristic texture, and functional and nutritional value have raised its consumption and led to continued growth in the sales of mango fruit in retail stores and food service operations [9]. Mango is one of the most popular fruits, either consumed fresh, juiced, dried, or processed into jam, jellybeans, or desserts. This fruit is widely cultivated, with India being the biggest producer (25 million t year^{-1}), followed by Indonesia, China, Mexico, Pakistan, and Malawi (3.3, 2.4, 2.3, 2.2, and 2.0 million t year^{-1}, respectively) [8]. This crop grows well in tropical and subtropical conditions where the annual average temperature is above 20°C. For this reason, Spain is one of the few European countries that produces subtropical crops, including mangoes. In particular, Andalusia, which accounts for 87% of the total cultivated area (20,579 t year^{-1}), and the Canary Islands, with 13%, are the only places in which this fruit can be cultivated due to their Mediterranean climate conditions [6]. The Osteen cultivar is one of the most used scions in Spain, due to its high commercial acceptance and demand. This cultivar produces ovoid fruits with a reddish-purple peel color (often blotched with yellow and greenish dots) at the maturity stage. The pulp has an outstanding quality with a yellowish to orange color and is juicy and nonfibrous [6].

Although the mango tree is considered a crop resistant to drought, mango fruits of export quality can only be achieved using irrigation [10]. This water need is due to the fact that most of the fruit development occurs during the dry season; for instance, in Spain mangoes usually reach the maturity stage between September and November [5,6]. The quality grades of export mangoes are mainly defined by color, shape, size, and flavor. It has been reported that for premium quality grades, the farmers can obtain between 30% and 50% profits [11]. The strong influence of irrigation on the marketable yields forces farmers to increase irrigation levels in this crop. However, the water shortage and the excessive cost of energy required for pumping irrigation water to high altitudes, jeopardize fruit yields and their cultivation on terraces in the Mediterranean area of Spain [6]. For this reason, it is important to apply the right agricultural practices and agricultural water management systems to assure the highest grade of fruit quality and yields.

Altogether, mango can be considered a good target to contribute to managing water scarcity in agriculture. For this reason, the objective of this study was to reduce the irrigation water in mango farming and to evaluate the effect of SDI on the quality and yield of a mango crop (cv. Osteen) cultivated in Mediterranean conditions in Granada, Spain.

2. Materials and Methods

Plant Material and Experimental Design

The experiment was carried out in 2020, in Almuñécar (Granada, SE Spain, 36°48′00″ N, 3°38′0″ W). The average annual rainfall is 449 mm, and the climate can be classified as Mediterranean subtropical [12]. During the experimental irrigation period, climatic conditions were characteristic of the study area, with air temperature values that ranged between 10 and 31 ºC, and an average maximum relative humidity of 94.2%.

The soil can be classified as typical xerorthent, which is shallow, varied in depth, and formed from weathered slates, with 684, 235, and 81 g kg^{-1} of sand, silt, and clay, respectively, leading to good drainage.

The experimental mango plantation is located in typical terraces of the area, with a single row of 16-year-old mango trees (*Mangifera indica* L. *cv.* "Osteen" grafted onto "Gomera-1") in each bench, with trees spaced 3 m apart, and with a distance between terraces of 5 m (around 600 trees per ha). Taking into account the lack of literature about this strategy and the ease of implementation for farmers, three sustained deficit irrigation (SDI) regimes were applied, which corresponded to 33%, 50%, and 75% of crop evapotranspiration (ET_C). This strategy allows the crop to adapt to the stressful situation gradually as water becomes scarce and adapt the vegetative development of trees to water deficits. Additionally, a control treatment was established, in which trees were fully irrigated at 100% ET_C. The irrigation requirements were estimated using the reference evapotranspiration (ET_0) calculated according to the Penman–Monteith methodology, and local crop coefficients, K_C, previously defined in the studied area [13]. For this, a weather station located at the same experimental farm was used, obtaining the ET_0 and rainfall. Taking into consideration the crop's water requirements, total amounts of irrigation water of 562.1, 411.1, 290.8, and 247.5 mm were applied in the control, SDI_{75}, SDI_{50}, and SDI_{33} treatments, respectively.

The fruits were harvested manually at the pre-climacteric hard-green stage and the yield per tree was estimated. After harvest, 4 batches of 4 randomly selected fruits per treatment were stored for 13 days at 22 ± 1.9 °C and 47 ± 4% relative humidity for further analysis.

Morphological characterization included the size and weight of 16 fruits per treatment (4 whole fruits × 4 repetitions × treatment), which was done at the ripening stage (day 13). Moreover, the specific weight of the pulp, peel, pit (endocarp), and seed was also recorded. The size included the fruit length, width, and thickness measured with a digital caliper (Mitutoyo 500-197-20, Kawasaki, Japan), while a digital Gibertini scale (EU-C LCD series, Milan, Italy) was used for the weight.

Instrumental color and photography. The peel color of mango samples was measured using a Minolta CR-300 colorimeter (Minolta, Osaka, Japan). Three evenly distributed places along the green side of the fruit were selected and a mean value was used; the same procedure was done for the red side of the fruit. Peel color was measured every day during 13 days of ripening and was expressed using the CIE$L^*a^*b^*$ system. These coordinates determine color in a tridimensional space. Numeric values include the luminosity (L^* = 0 black: 100 white), red (a^*)—green ($-a^*$), and yellow (b^*)-blue ($-b^*$) coordinates. Additionally, photographs were also taken every day using a Nikon D3400 camera (Tokio, Japan) and a light box to uniform the lighting for all pictures.

Titratable acidity and total soluble solids. Both measurements were done in mango juice with an acid–base potentiometer (877 Titrino plus, Metrohm ion analyses CH9101; Herisau, Switzerland) for the titratable acidity (0.1 mol L^{-1} NaOH), and an Atago digital refractometer (model N-20; Atago, Bellevue, WA, USA) to determine the total soluble solids at 20 °C. The values were expressed as g citric acid L^{-1} and °Brix, respectively.

Organic acids and sugars were measured as previously described by Carbonell-Barrachina et al. [14] with some modifications. Briefly, 5 mL of mango juice was centrifuged at 10,000 rpm during 15 min. One milliliter aliquot of the supernatant was filtered through a 0.45 µm millipore membrane filter (Billerica, MA, USA) and injected into a high-performance liquid chromatograph (HPLC) Hewlett Packard HP 1100 (Wilmington, DE, USA) with a Supelcogel TM C-610H column (30 cm × 7.8 mm) with a precolumn (Supelguard 5 cm × 4.6 mm; 219 Supelco, Bellefonte, PA, USA). A refraction index detector (RID) and a diode-array detector (DAD) were used for sugar and organic acid measurements. Analyses were done in quadruplicate and the results were expressed as concentrations g L^{-1} of fresh weight (fw).

The mineral contents were determined as previously described by Cano-Lamadrid et al. [15] using a microwave digestion unit Ethos Easy, Milestone (Milestone, Sorisole, Italy) equipped with a rotor for ten TFM (chemically modified PTFE) vessels for sample mineralization and an inductively coupled plasma mass spectrometry (ICP-MS) instrument Agilent 7500× Octopole Reaction System (ORS) (Agilent Technologies, Tokyo, Japan) for mineral determination. The measurements were done in lyophilized samples and the results (mean of 4 replications) were expressed as mg kg^{-1} freeze dried mango.

Antioxidant activity and total phenolic content. To measure these parameters, the methodology previously reported in the literature [3,16] was used, with the slight modification that for the extraction step, 5 mL extractant ($MeOH/H_2O_2$ (80:20, *v*/*v*) + 1% HCl at 20 °C) for 0.5 g of lyophilized mango was used. All measurements were performed in an ultraviolet-visible (UV-vis) spectrophotometer (Helios Gamma model, UVG 1002E; Helios, Cambridge, UK).

Finally, *total dietary fiber* was determined following the AOAC Official Method 985.29 [17] using 1 g of lyophilized mango and the TDF-100 kit (Sigma-Aldrich, St. Louis, MO, USA). Together with mango samples, blank and reference samples were also analyzed simultaneously in triplicate for comparison.

Statistical Analysis. A randomized block design with 4 replications per treatment was used, monitoring the 5 central trees per replication. One-way analysis of variance (ANOVA) followed by Tukey's multiple range test was used to check the statistical differences among samples, and only those parameters significantly affected by the treatments were further considered for Pearson's correlation analysis. Statistical differences were considered significant when $p < 0.05$. To run the analyses, the XLSTAT Premium 2016 software was used, while Sigma Plot 11 software was used for figure preparation.

3. Results and Discussion

3.1. Yield and Morphology

The average yield for trees under SDI_{33}, SDI_{50} and SDI_{75} was 26.2, 28.8, and 32.3 kg per tree, respectively, compared to 35.8 kg per tree for the control treatment. As was expected, the effect of water stress induced by deficit irrigation treatments was evident by lowering the productivity with respect to non-stressed control trees (100% ET_C). Taking into account the irrigation water applied per tree in each treatment, an irrigation water productivity of 3.8, 4.7, 5.9, and 6.4 kg m^3 was reached for control, SDI_{75}, SDI_{50} and SDI_{33}, respectively.

Table 1 shows the morphological characteristics of mango *cv.* Osteen for each irrigation treatment. As observed, the control mangoes (FI) presented the highest weight and size compared to those fruits grown under DI conditions. For instance, FI mangoes reached a longitudinal diameter of 155 mm with a width and thickness of 98 and 82 mm, followed by SDI_{75} (146, 95, an1 mm, respectively) and SDI_{50} (143, 91 and 77 mm) with similar length between them, even though the SDI_{75} was more similar to the control in terms of width and thickness. The most affected treatment in terms of size was $SDI_{33,}$ the one which received the lowest amount of irrigation water. Similar results were also observed for the weight, where FI is the treatment with the highest weight (681 g), followed by SDI_{75} (586 g) and SDI_{50} (540 g), and the lowest value being that of SDI_{33} (455 g). However, in terms of relative values of each part of the fruit (Figure 1), it can be observed that an increase in the intensity of the DI treatment led to a greater pit fruit, with no differences being found for the weights of the peel or flesh. The main mango producing countries, such as Malaysia with 80,841 t $year^{-1}$ and more precisely the Perlis Department of Agriculture, have established grading standards which have been developed according to qualitative and quantitative criteria for mango *cv.* Harumanis. They established three grades: (i) A (weight >400 g), (ii) B (weight 351–399 g), and (iii) C (weight <350 g), requiring a standardize shape and size for all categories and no peel defects, except for the grade C. As observed, all the studied irrigation treatments (*cv.* Osteen) reached the top grade for mangoes (A) in terms of weight [18]. Additionally, according to international marketing standards (CODEX STAN 184-1993) for mango of *Codex Alimentarus*, the mangoes cultivated under FI and SDI_{75} fall under the C-size group (representing the highest weight ranging 551–800 g), while SDI_{50} and SDI_{33} belonged to the B-size group (351–550 g) [19]. It is important to highlight that this standard tolerates a minimum weight of mangoes of 200 g, which is the lowest group (A) with values between 200 and 350 g. Other authors working with *cv.* Osteen of 11-year old trees cultivated in Sicily (Italy) reported lower fruit weights (462 g) than those of FI, SDI_{75} and SDI_{50}, but similar to the most stressed treatment SDI_{33} [20]. Lower weight and size values were also reported by other authors for the same cultivar (400 g), but also for 27 other cultivars under study [21]. Among the scarce literature regarding the influence of DI on mango quality parameters, the morphological parameters of mango in RDI, PRD and non-irrigated conditions over 3 years have been reported by Spreer et al. [5]. They concluded that the weight was mainly affected in the second year of treatment and by RDI and non-irrigated strategies, while PRD samples remained similar to the control. These findings were reported on the Chok Anan cultivar and the mean values ranged from 223 g in the 1st season to 319 and 313 g in the 2nd and 3rd season, respectively. It has been clearly demonstrated that the effect of the irrigation strategies are cultivar- and season-dependent. However, not only drought conditions can affect the final production and quality; other climate variables such as air temperature or solar radiation are important factors that ultimately will determine the plant growth and development through the seasons. However, in our case, the climatic conditions registered during the monitoring period were very similar to those traditionally registered in the grown area of SE for this crop. This fact reinforces the obtained results in this work, evidencing how important is the irrigation water on the fruit development, and how severe water stress generated through the SDI strategy can significantly decrease both the size and weight, as well as increase the by-products of mangoes such as the pit.

3.2. Impact of Storage Time and Deficit Irrigation on the Appearance (Color) of Mango Fruits

Mango peel color represents one of the most important quality attributes with a key role in consumer acceptance, because it is the first trait perceived by consumers [20]. Figure 2 presents the mangoes from day 1 after harvest until day 13 of ripening storage. Mangoes are a climacteric tropical fruit in which the ripening process is associated with an increase in cellular respiration and ethylene production [22]. This means that the fruits were harvested when mature, but before ripening has started. In this figure, the changes in color with time can be easily observed for all treatments over 13 days of ripening, in both sides of the fruit. A color change from green to yellow was observed on the shaded side of the fruit (the green one) and from a red goji berry to a coral pantone on the sun-exposed side (the red one). The visual differences that could be observed among the treatments led to more yellow-coral fruits at the end of the ripening for FI and SDI_{33} samples, while more green-orange color was found for the SDI_{75} and SDI_{50} fruits. However, these differences can be attributed to the mango conditions at the beginning of ripening, because as seen, those from the FI and SDI_{33} already contained more reddish notes, while those from SDI_{75} and SDI_{50} contained more green notes. It is important to highlight that only one fruit per treatment was chosen to prepare the visual color changes represented in Figure 2; however, these fruits were selected to represent instrumental color coordinates presented in Figure 3, where values represented the mean of eight mangoes per treatment.

Table 1. Pomological aspects of mangoes affected by water stress.

	ANOVA [†]	FI	SDI_{75}	SDI_{50}	SDI_{33}
Size (mm)					
Length	***	155a [‡]	146b	143b	133c
Width	***	98.0a	94.7ab	91.0b	86.0c
Thickness	***	82.4a	81.1ab	77.2bc	74.7c
Weight (g)					
Whole	***	681a	586b	540b	455c
Peel	***	115a	103ab	87.2bc	76.3c
Flesh	***	535a	455b	424b	351c
Pit	NS	30.9	28.1	29.2	27.7
Seed	NS	10.7	9.44	11.0	9.35

[†] and *** significant at $p < 0.05$ and 0.001, respectively. [‡] Values (mean of 16 replication) followed by the same letter, within the same column and factor, were not significantly different ($p < 0.05$), according to Tukey's least significant difference test.

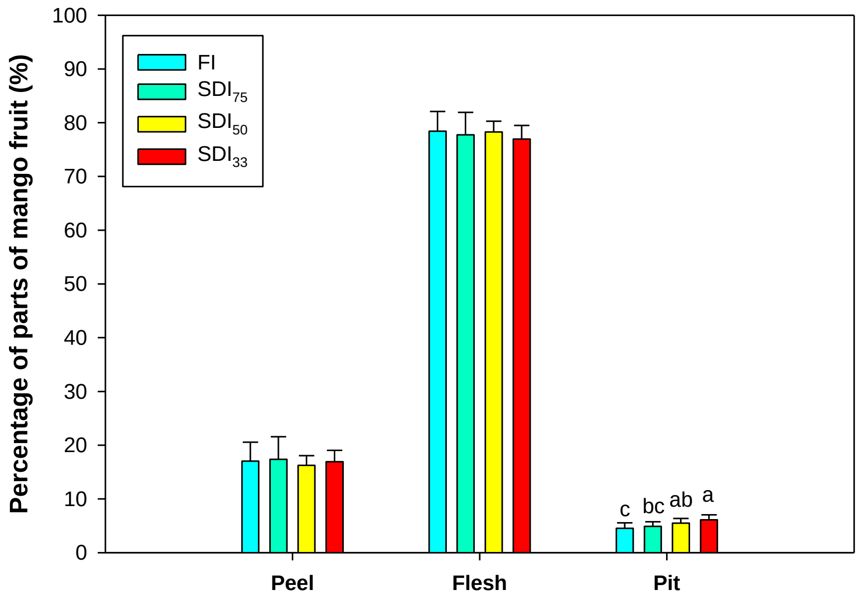


Figure 1. Percentage of parts of mango fruit as affected by deficit irrigation. Different letters mean significant differences ($p < 0.05$) among treatments, according to Tukey's least significant difference test.

The mean values of color change for each treatment during 13 days of storage are represented in Figure 3, using the CIE$L^*a^*b^*$ color coordinates. As observed in both figures, the examined mangoes presented a wide heterogeneity for the peel color, represented as high error bars in Figure 3. Regarding the shade side of the fruit (green side), it was observed a slight increase in L^* values from day 1 to 13 for all the treatments (FI: 53–57; SDI_{75}: 46–47; SDI_{50} = 48–53; and SDI_{33} = 52–54). This means that all treatments become lighter with storage time. Significant differences were also observed among the irrigation treatments: SDI_{75} and SDI_{50} were both darker at the beginning and at the end of storage, as can be seen in Figure 3. The a^* color coordinate significantly changed with the storage time, from green values at the beginning of storage to red notes at the end. No significant differences among irrigation treatments at the beginning of storage were observed, but at the end, SDI_{75} recorded the highest values of green notes, followed by SDI_{50}. Finally, the b^* color coordinate, which represents blue colors when the values are negative and yellow colors when the values are positive, also changed completely within the storage time registering mean values of all treatments between 24 (1st day) and 37 (13th day). The differences were also significant among treatments in SDI_{75}, where mangoes had the lowest values of b^* coordinates both at the beginning and end of storage, which means that this treatment has lower yellowish notes. These values also showed that each treatment ripens differently; for instance, SDI_{50} was the treatment with low values of *b** color coordinate at the beginning of storage and raised to values similar to SDI_{33} and FI at the end of storage. The same trend was observed for the *a** color coordinate, which at the beginning of storage was similar for all treatments, but at the end showed significant differences with SDI_{75} fruits being the less reddish ones.

Figure 2. Photographs of color change of mango from day one after harvest until day 13 of storage. For each treatment, the upper and lower rows of pictures represent the shade (green) and sun (red) sides of the fruit.

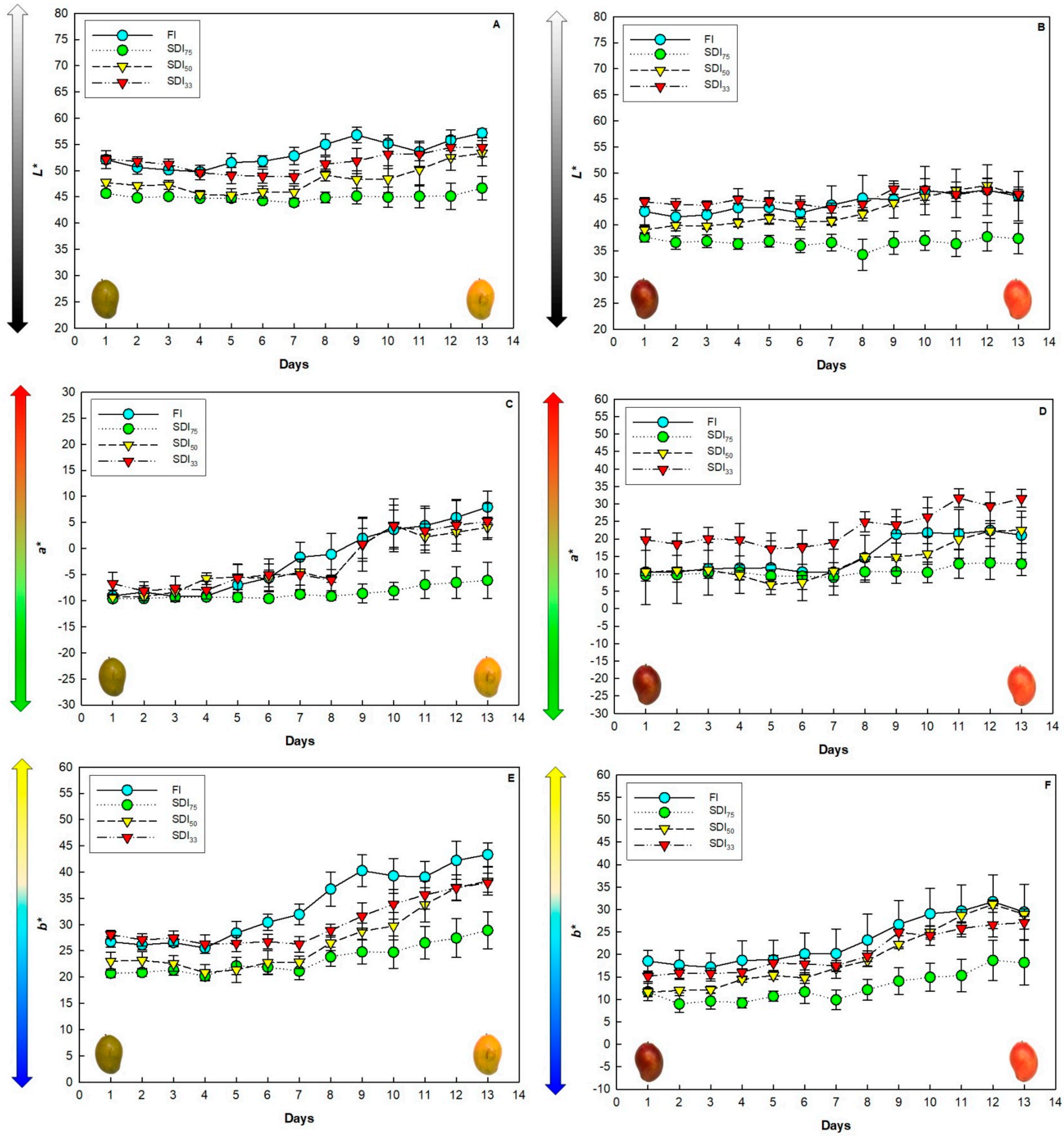


Figure 3. Color changes with time ($L^*a^*b^*$ color coordinates) during 13 days of storage. (**A**,**C**,**E**) figures represent data for the shade side of the fruits while (**B**,**D**,**F**) figures represent data for the sun side of the fruits.

Evaluating the sun side of the fruit (red side), an increase in all color coordinates was observed during storage from day 1 to 13 (mean values for all treatments L^* = 41–44; a^* = 13–22; and b^* = 14–26). As seen, the mangoes become sightly lighter with storage time, and with higher yellow-red notes. Regarding the irrigation treatments, significant differences were observed at the beginning of the ripening process, being SDI_{75} treatment that with the darkest fruits, while the control and SDI_{33} treatments led to the most yellowish fruits. However, at the end of ripening, the differences were not significant for any of the color coordinates.

Overall, the color change from green to yellow occurs during the ripening process when the transition of chlorophyll to carotenoids takes place, as well as other chemical reactions such as the biochemical conversion of starch into sugars, or the organic acids loss through oxidation [22]. The main phytochemicals responsible for pigmentation in mango peel are the carotenoids and anthocyanins, depending on the cultivar. The former imparts lighter and yellow to red colors, while the latter contributes to darker and pink-red to blue colors on the mango peel [23]. In this sense, the peel color can be used as an indicator of quality of the ripening stage, as the authors report a positive correlation between color and carotenoids or sugar content regardless storage temperature or harvest stage [22]. According to the shaded side of the fruit results, a soft deficit irrigation (SDI_{75}) led to more greenish fruits compared to the other treatments (yellow-orange fruits). This means that SDI_{75} can contribute to a higher shelf-life of mangoes, helping to extend the marketing period of this cultivar.

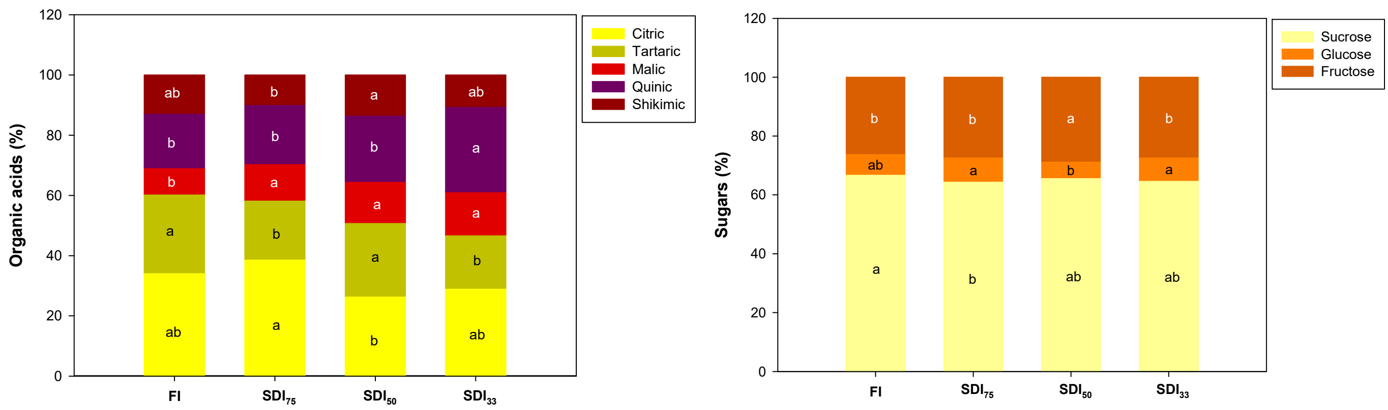
3.3. Impact of Water Stress on Total Soluble Solids, Titrabale Acidity, Organic Acids and Sugars

Titratable acidity, organic acids, total soluble solids and sugars were recorded at the end of ripening and the results are presented in Table 2. These parameters are essential as mango flavor is primarily generated by acids, sugars, and volatile compounds providing the desirable gustatory quality of mangoes. The TA results showed that SDI_{75} presented the most acid samples, while SDI_{50} the lowest ones. Regarding the total content of organic acids, ranging from 4.70 to 7.20 g L^{-1}, an increase was observed for all DI treatments, with SDI_{33} as the treatment with the highest content. On the other hand, regarding the TSS, only SDI_{75} treatment reached similar values to those of the control, because in most stressed conditions, TSS values were slightly decreased. The total amount of sugars ranged from 149 to 168 g L^{-1}, with all treatments being statistically equivalent except for SDI_{50} which registered the lowest values. Finally, Figure 4 represents the organic acid (a) and sugar (b) profiles for each irrigation strategy. As observed, the major organic acids were citric, representing 32% of total organic acids, followed by tartaric and quinic, with 22% each, and finally malic and shikimic acids representing 12% of the total acids. On the other hand, the main sugars found within this study were sucrose (66%), fructose (27%) and glucose (7%). These results agreed with those previously reported by other authors in mango fruits of different cultivars, such as Gleen, Mamme, Saigon, etc. [24,25]. It was observed that the SDI_{75} strategy increased the citric acid content, which leads to a stronger sour taste in the fruit, while more severe DI treatments lead to more bitter and astringent fruits due to the increase in quinic and shikimic acids. On the other hand, sucrose was lower in SDI_{75}, with respect to the other treatments, and a reduction of glucose and an increase of fructose was observed for SDI_{50} treatment. During the ripening process, organic acid levels are often inversely related to sugar levels; this means that sugars are accumulated mainly due to the starch hydrolyzation from unripe mango to more simple sugars such as glucose [25,26]. On the other hand, organic acids that are usually accumulated in unripe fruits strongly decrease during fruit ripening. For instance, a reduction in mango acidity it reported after 15 days of storage, which was attributed to the enhanced activity of citric acid glyoxylase implicated in citric acid degradation, as well as to their conversion into sugars and additional consumption in the metabolic process of fruit [22,27]. Consequently, these might explain how the SDI_{75} strategy led to mangoes less ripe after 13 days of storage, which might help to increase the mangoes shelf life on the fresh market. Other authors also reported similar values of TA and TSS, which were correlated with the ripening period obtaining the highest values of TSS (17° Brix) and lowest acidity (0.2%) after 120 h of ripening [28]. The effect of DI on fruit quality was studied on different fruits such as almonds, olives, pistachios, tomatoes, grapes, etc., and authors reported a greater quality in hydro sustainable (hydroSOStainable) fruits [2,29–33]. However, little information regarding the DI influence on mango quality exists, and almost none on *cv.* Osteen. Authors working with Chok Anan, studied the effect of different DI strategies (FI, RDI, PRD and non-irrigated) on the fruit quality both pre- and post-harvest and concluded that all DI produced fruits with desirable traits for the fresh market [34]. Additionally, they reported that those fruits cultivated under RDI conditions significantly increased the TSS sugars after 6 days of ripening. The same happened with mangoes *cv.* Guifei grown under RDI at the maturity, which helped to raise the TSS and also the TA in mangoes in two consecutive seasons [4]. In this sense, the authors highly recommended the use of RDI during maturity stage because it was able to significantly increase the water use efficiency and quality parameters such as soluble solids, organic acids, and carotenoids in fruit. This phenomenon might occur because the maturity stage demands low water volume, and the RDI strategy might reduce the water potential of fruit cells, increasing the ability of cells to absorb nutrients enhancing in this way the soluble solids content, sugars, organic acids and other compounds [4]. As seen, there are pros and cons of the RDI strategy, because it can either negatively affect the weight or positively affect the fruit quality. In this case, the stress level of RDI must be optimized to assure both parameters as previously observed in other crops [3].

Table 2. Titratable acidity, total organic acids, soluble solids, and sugars of mangoes as affected by the irrigation treatment.

Treatments	Titratable Acidity	Organic Acids	Total Soluble Solids	Sugars
	g L^{-1}	g L^{-1}	°Brix	g L^{-1}
	ANOVA Test †			
	*	***	***	***
	Tukey Multiple Range Test ‡			
FI	0.87ab	4.67c	17.5a	168a
SDI$_{75}$	1.52a	6.33ab	16.1ab	161a
SDI$_{50}$	0.75b	5.12bc	14.8b	149b
SDI$_{33}$	0.99ab	7.16a	15.3b	161a

† * and *** significant at $p < 0.05$ and 0.001, respectively. ‡ Values (mean of 4 replication) followed by the same letter, within the same column and factor, were not significantly different ($p < 0.05$), according to Tukey's least significant difference test.



(**a**) (**b**)

Figure 4. (**a**) Organic acids profile; and (**b**) sugars profile of mangoes affected by irrigation treatments. Different letters mean significant differences ($p < 0.05$) among treatments, according to Tukey's least significant difference test.

3.4. Impact of Water Stress on the Minerals Content of Mango

Table 3 shows the effect of SDI on both plant micro-(Fe, Cu, Mn and Zn) and macro-(K, P, Mg and Na) nutrients. Potassium represented almost 80% of the cations found in mangoes cv. Osteen, followed by P (8.1%), Mg (7.6%), Ca (5.8%), and Na (0.22%) within macroelements. On the other hand, the highest microelement was Fe (0.09%), followed by Zn (0.06%), Cu (0.05%), and Mn (0.04%). The present values agree with other authors and the United States Department of Agriculture (USDA, Washington, DC, USA) [25,35] database considering a dry weight of mango ~16% as calculated in the present study or reported by other authors [36]. As observed, K (7188 mg kg^{-1}) was the predominant element in these mangoes and together with P, Mg and Ca (750, 696, and 533 mg kg^{-1}) make these fruit a good source of these macroelements [20]. Moreover, authors working with different mango cultivars stated that cv. Osteen was the one with the highest K content (2420 mg kg^{-1} fw) [20]. Deficits in irrigation affected each element in a different way depending on stress level; for instance, elements such as Na, Mg, K, Ca, Mn and Zn were increased with water stress, while P, Fe, and Cu were decreased in the most severe treatments. In general, SDI_{50} was the most effective level for almost all elements except Mg, which only increased in the most severe conditions of SDI_{33}. It is well known that water scarcity reduces the transports of mineral nutrients from root to shoot, due to the early closure of stomata and so a decrease in transpiration rate [37]. However, there are plants able to obtain and preserve more water, creating a greater resistance to water stress due to a better water use efficiency, and minerals plays a key role. In the present study, it might be said that the plant coped with the water stress because most of the elements were maintained or increased in those mangoes' growth with a lower amount of irrigation water. The effect of DI on the mineral composition of fruit and vegetables has been studied by several researchers, however it is contradictory and elusive. For instance, there are authors concluding that an increase in irrigation water helps to increase the mineral content in fruit due to the release of a greater amount of ions in the solution with the irrigation water, also increasing the rate of absorption by the plant roots [38]. On the other hand, other authors reported no differences between FI and DI fruit minerals or even higher content in those grown under DI strategies, on different crops such as olives, tomatoes, grapes, apples, almonds and pistachios [39–42].

Table 3. Effect of irrigation dose on mineral content (mg kg^{-1}) on lyophilized mango pulp as affected by the irrigation treatment.

Treatments	Na	Mg	P	K	Ca	Mn	Fe	Cu	Zn
	mg kg^{-1}								
	ANOVA Test †								
	***	***	**	**	***	***	***	***	***
	Tukey Multiple Range Test ‡								
FI	17.3c	621b	772a	7053ab	301c	2.60c	8.78a	6.09a	5.32b
SDI_{75}	20.9b	678b	791a	6549b	513b	3.49b	7.33b	5.50a	4.88b
SDI_{50}	24.2a	692b	788a	7441a	661a	4.15a	8.90a	5.59a	7.17a
SDI_{33}	17.6c	792a	646b	7709a	655a	3.08bc	7.68b	2.76b	3.79b

† ** and *** significant at $p < 0.01$ and 0.001, respectively. ‡ Values (mean of 4 replication) followed by the same letter, within the same column and factor, were not significantly different ($p < 0.05$), according to Tukey's least significant difference test.

3.5. Impact of Water Stress on the Antioxidant Activity (AA) and Total Phenolic Content (TPC)

The AA and TPC were also evaluated, and the results were embodied in Table 4. These parameters are important from a functional point of view because oxidative stress is reported to be the key factor for many diseases such as cardiovascular, hypertension, atherosclerosis, neurodegenerative or cancer, mainly caused by an imbalance between reactive oxygen species (ROS) and the antioxidative defense system [43,44]. The AA was measured using three spectrophotometric assays, $ABTS^{\bullet+}$, $DPPH^{\bullet}$ and FRAP, as each antioxidant compound has different mechanism of action, either by way of single-electron or hydrogen atom transfer [45]. Moreover, the main aspect that influenced these methods' potential are the concentration and structure of phenolic compounds in the specific plant material or extract under study. As seen, significant differences were observed among DI levels for both functional parameters. In the case of AA, this was reduced in DI mangoes by $ABTS^{\bullet+}$ and $DPPH^{\bullet}$ methods, while an increase within the FRAP method was shown. The observed discrepancies occurred because the reagents used in these methods react in a different way with a wide range of phenolic compounds present in the samples due to differences in their structures and concentrations [45]. In this sense, a greater value of TPC was observed for those mangoes cultivated under DI conditions (2.8 g GAE kg^{-1}) compared to the full irrigation ones (2.2 g GAE kg^{-1}). These results agreed with those reported by other authors (2.6 g GAE kg^{-1}) in their study about lipophilic and hydrophilic antioxidant capacity of common foods, including mangoes, in the United States [46]. As seen, SDI_{75} and SDI_{50} boosted the TPC, while more severe conditions started to decrease it. Here, it is important to investigate irrigation strategies with different stress levels to optimize the stress in plants and avoid loss of important bioactive compounds. It is known that drought is conducive an excessive production of very reactive ROS ($^1O_2$, O_2^- and H_2O_2) which damage the plant cells, and the risk of irreparable cell damage is higher under water stress conditions [47]. Nevertheless, plants have the ability to readjust and grow under drought conditions due to their adaptation mechanisms such as the antioxidant defense system (phenolic compounds, enzymes, vitamins, etc.) and osmotic adjustments (sugars, sugar alcohols and amino acids, etc.). As observed in the present study, the plant defense system was still able to produce and accumulate phenolic compounds up to a 50% reduction of the irrigation water, but a 70% water reduction started the reduction of these compounds.

Table 4. Effect of irrigation dose on the antioxidant activity (mmol Trolox kg^{-1}) and total phenolic content (g GAE kg^{-1}) on lyophilized mango pulp as affected by the irrigation treatment.

Treatments	$ABTS^{\bullet+}$	DPPH	FRAP	TPC
	mmol Trolox kg^{-1}			g GAE kg^{-1}
	ANOVA †			
	**	*	***	*
	Tukey Multiple Range Test ‡			
FI	145a	192a	5.97c	2.28b
SDI_{75}	145a	183ab	6.37bc	2.83a
SDI_{50}	141b	181ab	7.43ab	2.81a
SDI_{33}	142b	170b	8.44a	2.75ab

† *, ** and *** significant at $p < 0.05$, 0.01and 0.001, respectively. ‡ Values (mean of 4 replication) followed by the same letter, within the same column and factor, were not significantly different ($p < 0.05$), according to Tukey's least significant difference test.

3.6. Impact of Water Stress on the Fiber Content of Mango

According to the *Codex Alimentarus*, dietary fiber is the indigestible cell wall component of the plant and plays a key role in the human diet and health because it contains mainly polysaccharides that cannot be completely broken down by the human gastrointestinal tract and are not absorbed in the human body. This means dietary fiber helps to maintain the gut balance by increasing the beneficial bacteria (*Lactobacillus*, *Bifidobacterium*) and reducing pathogen microorganisms (*Clostridium*, *E. coli*) preventing constipation and colon cancer [48]. In this sense, the dietary fiber of mango was analyzed within this study and the results are showed in Figure 5. The total dietary mango in *cv.* Osteen ranged between 12 and 21%, and an increase in mango fiber was observed within the water stress fruits; in this sense, FI registered the lowest amount 12% and SDI_{75} and SDI_{33} the highest one (19 and 21%, respectively). Similar values for dietary fiber were also shown by other authors in the pulp of unripe mango (*cv.* Ataulfo) [49]. Regarding the effect of water deficit, authors stated that water deficit can affect the fiber content in tomato fruits, for instance, a strong negative correlation (R^2 = 0.908) between the fiber content of the tomato fruits and the volume of water used was previously reported [38]. Additionally, drought has also been reported to affect the dietary fiber of wheat, because under natural conditions, drought usually occurs in combination with heat and these two stresses have been reported to act synergistically to increase the dietary fiber content of wheat [50].

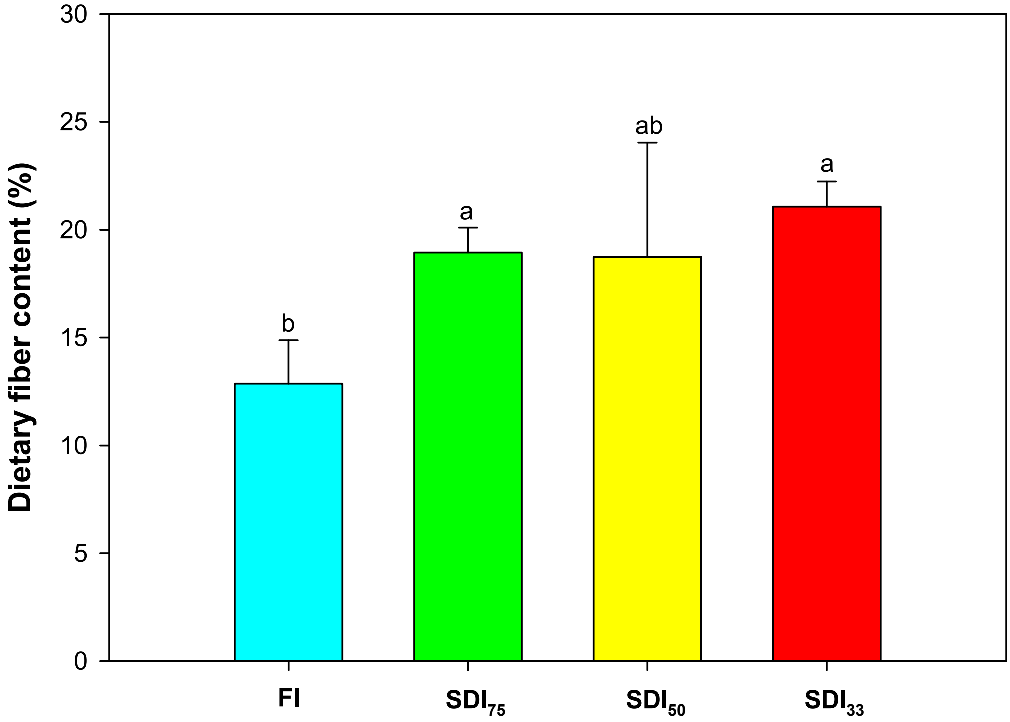


Figure 5. Mango dietary fiber as affected by the irrigation treatment. Different letters mean significant differences ($p < 0.05$) among treatments, according to Tukey's least significant difference test.

Finally, Pearson's correlations were run among the stress integral and all the quality variables with significant differences among treatments. In this sense, a positive relationship among the stress integral with sucrose and total sugars ($R = 0.98$; $p < 0.02$; and $R = 0.97$; $p < 0.02$, respectively) was shown, implying that deficit irrigation can contribute to sweeter mangoes as previously reported in other crops such as tomatoes, thyme, nectarines or almonds [3,51–53], due to an osmotic adjustment, activated by accumulation of solutes rich in hydroxyl groups (sugars, proline, etc.) in the cytoplasm [54]. Moreover, the irrigation water use productivity obtained using SDI strategy led to 4.7, 5.9, and 6.4 kg m^3 for SDI_{75}, for SDI_{50}, and SDI_{33}, respectively compared to 3.8 kg m^3 of the control. Thus, different deficit irrigation regimes together with the fruit quality characteristics are important factors to be evaluated in order to reach an efficient use of water in agriculture, assuring at the same time optimal fruit traits. Because decision making in on-farm irrigation improves through the use of biophysical and economic water productivity indicators, thus helping to increase the fruit quality and save water as shown in the present study and as concluded by other authors working on the sustainability of water resources in cultivars such as peach and olives [55,56].

4. Conclusions

Finally, this study contributes to an efficient and sustainable management of water resources in mango farming, producing fruits with higher quality and functionality when a sustained deficit irrigation strategy is used. It was demonstrated that controlled deficit irrigation can increase the fruit quality and functionality leading to a higher content of sugars, minerals, fiber or total phenolics. Moreover, it was shown that SDI_{75} and SDI_{50} can lead to minimal losses on fruit yield and can increase the irrigation water productivity.

Thus, these results might be used by the farmers and industry when the water availability is below the mango irrigation requirements, producing fruits with a greater quality and minimal yield loses. However, building on the present results which provide baseline information of SDI regimes on mango yield and quality, further research during several seasons of water stress is required to confirm the present findings, as well as transferring the most positive SDI strategy to other mango cultivars in order to establish the behavior of other cultivars.

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References

1. Food and Agriculture Organization of the United Nations (FAO). The Future of Food and Agriculture—Trends and Challenges. Available online: http://www.fao.org/3/i6583e/i6583e.pdf (accessed on 8 March 2021).
2. Lipan, L.; Garcia-Tejero, I.F.; Gutierrez-Gordillo, S.; Demirbas, N.; Sendra, E.; Hernandez, F.; Duran-Zuazo, V.H.; Carbonell-Barrachina, A.A. Enhancing Nut Quality Parameters and Sensory Profiles in Three Almond Cultivars by Different Irrigation Regimes. *J. Agric. Food Chem.* **2020**, *68*, 2316–2328. [CrossRef] [PubMed]
3. Lipan, L.; Cano-Lamadrid, M.; Hernández, F.; Sendra, E.; Corell, M.; Vázquez-Araújo, L.; Moriana, A.; Carbonell-Barrachina, Á.A. Long-Term Correlation between Water Deficit and Quality Markers in HydroSOStainable Almonds. *Agronomy* **2020**, *10*, 1470. [CrossRef]
4. Liu, X.; Peng, Y.; Yang, Q.; Wang, X.; Cui, N. Determining optimal deficit irrigation and fertilization to increase mango yield, quality, and WUE in a dry hot environment based on TOPSIS. *Agric. Water Manag.* **2021**, *245*, 106650. [CrossRef]
5. Spreer, W.; Ongprasert, S.; Hegele, M.; Wünsche, J.N.; Müller, J. Yield and fruit development in mango (*Mangifera indica* L. cv. Chok Anan) under different irrigation regimes. *Agric. Water Manag.* **2009**, *96*, 574–584. [CrossRef]
6. Rodríguez Pleguezuelo, C.R.; Cárceles Rodríguez, B.; García Tejero, I.F.; Gálvez Ruíz, B.; Franco Tarifa, D.; Francia Martínez, J.R.; Durán Zuazo, V.H. Chapter 13—Irrigation Strategies for Mango (*Mangifera indica L.*) Under Water-Scarcity Scenario in the Mediterranean Subtropical Environment. In *Water Scarcity and Sustainable Agriculture in Semiarid Environment*; García Tejero, I.F., Durán Zuazo, V.H., Eds.; Academic Press: Cambridge, MA, USA, 2018; pp. 299–316.
7. Durán Zuazo, V.H.; Pleguezuelo, C.R.R.; Tarifa, D.F. Impact of sustained-deficit irrigation on tree growth, mineral nutrition, fruit yield and quality of mango in Spain. *Fruits* **2011**, *66*, 257–268. [CrossRef]
8. Food and Agriculture Organization of the United Nations (FAOSTAT). Worldwide Fruit Production. Available online: http://www.fao.org/faostat/en/#data/QC (accessed on 8 March 2021).
9. Ngamchuachit, P.; Sivertsen, H.K.; Mitcham, E.J.; Barrett, D.M. Influence of cultivar and ripeness stage at the time of fresh-cut processing on instrumental and sensory qualities of fresh-cut mangos. *Postharvest Biol. Technol.* **2015**, *106*, 11–20. [CrossRef]
10. Fukuda, S.; Spreer, W.; Yasunaga, E.; Yuge, K.; Sardsud, V.; Müller, J. Random Forests modelling for the estimation of mango (*Mangifera indica L.* cv. Chok Anan) fruit yields under different irrigation regimes. *Agric. Water Manag.* **2013**, *116*, 142–150. [CrossRef]
11. Chomchalow, N.; Songkhla, P.N. Thai Mango Export: A Slow-but-Sustainable Development. *AU J. Technol.* **2008**, *12*, 1–8.

12. Elias, F.; Ruiz, L. Agroclimatología de España. *Cuaderno I.N.I.A.* **2008**, *12*, 1–8.
13. Rodríguez Pleguezuelo, C.R.; Durán Zuazo, V.H.; Francia Martínez, J.R.; Muriel Fernández, J.L.; Tarifa, D.F. Monitoring the pollution risk and water use in orchard terraces with mango and cherimoya trees by drainage lysimeters. *Irrig. Drain. Syst.* **2011**, *25*, 61–79. [CrossRef]
14. Carbonell-Barrachina, A.; Calín-Sánchez, Á.; Bagatar, B.; Hernandez, F.; Legua, P.; Martínez, R.; Melgarejo, P. Potential of Spanish sour–sweet pomegranates (cultivar C25) for the juice industry. *Food Sci. Technol. Int.* **2012**, *18*, 129–138. [CrossRef] [PubMed]
15. Cano-Lamadrid, M.; Girona, D.; García-García, E.; Dominguis-Rovira, V.; Domingo, C.; Sendra, E.; López-Lluch, D.; Carbonell-Barrachina, Á.A. Distribution of essential and non-essential elements in rice located in a Protected Natural Reserve "Marjal de Pego-Oliva". *J. Food Compos. Anal.* **2020**, *94*, 103654. [CrossRef]
16. Brand-Williams, W.; Cuvelier, M.E.; Berset, C. Use of a free radical method to evaluate antioxidant activity. *LWT Food Sci. Technol.* **1995**, *28*, 25–30. [CrossRef]
17. AOAC. *Official Methods (985.29) of Analysis of AOAC International*, 16th ed.; Association of Official Analytical Chemists: Washington, DC, USA, 1997; Volume 2.
18. Sa'ad, F.S.A.; Ibrahim, M.F.; Shakaff, A.Y.M.; Zakaria, A.; Abdullah, M.Z. Shape and weight grading of mangoes using visible imaging. *Comput. Electron. Agric.* **2015**, *115*, 51–56. [CrossRef]
19. Food and Agriculture Organization of the United Nations; WHO. *Codex Alimentarius, 1993—Codex Standard for Mangoes (Codex Stan 184-2003, Amended 2005)*; FAO: Rome, Italy, 2018.
20. Farina, V.; Gentile, C.; Sortino, G.; Gianguzzi, G.; Palazzolo, E.; Mazzaglia, A. Tree-Ripe Mango Fruit: Physicochemical Characterization, Antioxidant Properties and Sensory Profile of Six Mediterranean-Grown Cultivars. *Agronomy* **2020**, *10*, 884. [CrossRef]
21. Abdelsalam, N.R.; Ali, H.M.; Salem, M.Z.M.; Ibrahem, E.G.; Elshikh, M.S. Genetic and Morphological Characterization of *Mangifera indica* L. Growing in Egypt. *HortScience* **2018**, *53*, 1266–1270. [CrossRef]
22. Baloch, M.K.; Bibi, F. Effect of harvesting and storage conditions on the post harvest quality and shelf life of mango (*Mangifera indica* L.) fruit. *S. Afr. J. Bot.* **2012**, *83*, 109–116. [CrossRef]
23. Karanjalker, G.R.; Ravishankar, K.V.; Shivashankara, K.S.; Dinesh, M.R.; Roy, T.K.; Sudhakar Rao, D.V. A Study on the Expression of Genes Involved in Carotenoids and Anthocyanins During Ripening in Fruit Peel of Green, Yellow, and Red Colored Mango Cultivars. *Appl. Biochem. Biotechnol.* **2018**, *184*, 140–154. [CrossRef] [PubMed]
24. Sung, J.; Suh, J.H.; Chambers, A.H.; Crane, J.; Wang, Y. Relationship between Sensory Attributes and Chemical Composition of Different Mango Cultivars. *J. Agric. Food Chem.* **2019**, *67*, 5177–5188. [CrossRef] [PubMed]
25. Maldonado-Celis, M.E.; Yahia, E.M.; Bedoya, R.; Landázuri, P.; Loango, N.; Aguillón, J.; Restrepo, B.; Guerrero Ospina, J.C. Chemical Composition of Mango (*Mangifera indica L.*) Fruit: Nutritional and Phytochemical Compounds. *Front. Plant Sci.* **2019**, *10*, 1073. [CrossRef]
26. Batista-Silva, W.; Nascimento, V.L.; Medeiros, D.B.; Nunes-Nesi, A.; Ribeiro, D.M.; Zsögön, A.; Araújo, W.L. Modifications in Organic Acid Profiles During Fruit Development and Ripening: Correlation or Causation? *Front. Plant Sci.* **2018**, *9*, 1689. [CrossRef] [PubMed]
27. Rathore, H.; Tariq, M.; Sammi, S.; Soomro, A.H. Effect of Storage on Physico-Chemical Composition and Sensory Properties of Mango (*Mangifera indica* L.) Variety Dosehari. *Pak. J. Nutr.* **2007**, *6*, 143–148.
28. Kour, R.; Singh, M.; Gill, P.P.S.; Jawandha, S.K. Ripening quality of Dusehri mango in relation to harvest time. *J. Food Sci. Technol.* **2018**, *55*, 2395–2400. [CrossRef] [PubMed]
29. Zhu, Y.; Taylor, C.; Sommer, K.; Wilkinson, K.; Wirthensohn, M. Influence of deficit irrigation strategies on fatty acid and tocopherol concentration of almond (*Prunus dulcis*). *Food Chem.* **2015**, *173*, 821–826. [CrossRef]
30. Noguera-Artiaga, L.; Lipan, L.; Vázquez-Araújo, L.; Barber, X.; Pérez-López, D.; Carbonell-Barrachina, Á. Opinion of Spanish Consumers on Hydrosustainable Pistachios. *J. Food Sci.* **2016**, *81*, S2559–S2565. [CrossRef] [PubMed]
31. Sánchez-Rodríguez, L.; Lipan, L.; Andreu, L.; Martín-Palomo, M.J.; Carbonell-Barrachina, Á.A.; Hernández, F.; Sendra, E. Effect of regulated deficit irrigation on the quality of raw and table olives. *Agric. Water Manag.* **2019**, *221*, 415–421. [CrossRef]
32. Mohammed, H.N.; Mahmud, T.M.M.; Puteri, E.M.W. Deficit irrigation for improving the postharvest quality of lowland tomato fruits. *Pertanika J. Trop. Agric. Sci.* **2018**, *41*, 741–758.
33. Faci, J.M.; Blanco, O.; Medina, E.T.; Martínez-Cob, A. Effect of post veraison regulated deficit irrigation in production and berry quality of Autumn Royal and Crimson table grape cultivars. *Agric. Water Manag.* **2014**, *134*, 73–83. [CrossRef]
34. Spreer, W.; Nagle, M.; Neidhart, S.; Carle, R.; Ongprasert, S.; Müller, J. Effect of regulated deficit irrigation and partial rootzone drying on the quality of mango fruits (*Mangifera indica L.*, cv. 'Chok Anan'). *Agric. Water Manag.* **2007**, *88*, 173–180. [CrossRef]
35. United States Department of Agriculture (USDA). Food Data Central. Available online: https://fdc.nal.usda.gov/fdc-app.html#/food-details/170567/nutrients (accessed on 8 March 2021).
36. Anderson, N.T.; Subedi, P.P.; Walsh, K.B. Manipulation of mango fruit dry matter content to improve eating quality. *Sci. Hortic.* **2017**, *226*, 316–321. [CrossRef]
37. Ahanger, M.A.; Morad-Talab, N.; Abd-Allah, E.F.; Ahmad, P.; Hajiboland, R. Plant growth under drought stress: Significance of mineral nutrients. In *Water Stress and Crop Plants: A Sustainable Approach*; Wiley: Hoboken, NJ, USA, 2016; Volume 2, pp. 649–668.
38. Agbemafle, R.; Owusu-Sekyere, J.; Plange, A. Effect of deficit irrigation and storage on the nutritional composition of tomato (*Lycopersicon esculentum* Mill. cv. Pectomech). *Croat. J. Food Technol. Biotechnol. Nutr.* **2015**, *10*, 59–65.

39. Alimohammadi, R.M.A.; Tatari, M.; Fattahi, A. Effects of deficit irrigation during different phenological stages of fruit growth and development on mineral elements and almond yield. *Iran. J. Water Res. Agric.* **2012**, *26*, 143–159.
40. Alikhani-Koupaei, M.; Fatahi, R.; Zamani, Z.; Salimi, S. Effects of deficit irrigation on some physiological traits, production and fruit quality of 'Mazafati' date palm and the fruit wilting and dropping disorder. *Agric. Water Manag.* **2018**, *209*, 219–227. [CrossRef]
41. Carbonell-Barrachina, A.A.; Memmi, H.; Noguera-Artiaga, L.; Gijon-Lopez, M.D.; Ciapa, R.; Perez-Lopez, D. Quality attributes of pistachio nuts as affected by rootstock and deficit irrigation. *J. Sci. Food Agric.* **2015**, *95*, 2866–2873. [CrossRef] [PubMed]
42. Nakajima, H.; Behboudian, M.H.; Greven, M.; Zegbe-Domínguez, J.A. Mineral contents of grape, olive, apple, and tomato under reduced irrigation. *J. Plant Nutr. Soil Sci.* **2004**, *167*, 91–92. [CrossRef]
43. Tayarani-Najaran, Z.; Rashidi, R.; Rashedinia, M.; Khoshbakht, S.; Javadi, B. The protective effect of Lavandula officinalis extract on 6-hydroxydopamine-induced reactive oxygen species and apoptosis in PC12 cells. *Eur. J. Integr. Med.* **2021**, *41*, 101233. [CrossRef]
44. Shrivastava, A.; Mishra, S.P.; Pradhan, S.; Choudhary, S.; Singla, S.; Zahra, K.; Aggarwal, L.M. An Assessment of Serum Oxidative Stress and Antioxidant Parameters in Patients Undergoing Treatment for Cervical Cancer. *Free Radic. Biol. Med.* **2021**, *167*, 29–35. [CrossRef]
45. Alam, M.Z.; Alhebsi, M.S.R.; Ghnimi, S.; Kamal-Eldin, A. Inability of total antioxidant activity assays to accurately assess the phenolic compounds of date palm fruit (*Phoenix dactylifera* L.). *NFS J.* **2021**, *22*, 32–40. [CrossRef]
46. Wu, X.; Beecher, G.R.; Holden, J.M.; Haytowitz, D.B.; Gebhardt, S.E.; Prior, R.L. Lipophilic and hydrophilic antioxidant capacities of common foods in the United States. *J. Agric. Food Chem.* **2004**, *52*, 4026–4037. [CrossRef] [PubMed]
47. Khaleghi, A.; Naderi, R.; Brunetti, C.; Maserti, B.E.; Salami, S.A.; Babalar, M. Morphological, physiochemical and antioxidant responses of *Maclura pomifera* to drought stress. *Sci. Rep.* **2019**, *9*, 19250. [CrossRef]
48. Yang, H.; Sun, Y.; Cai, R.; Chen, Y.; Gu, B. The impact of dietary fiber and probiotics in infectious diseases. *Microbe Pathog.* **2020**, *140*, 103931. [CrossRef] [PubMed]
49. Patiño-Rodríguez, O.; Bello-Pérez, L.A.; Agama-Acevedo, E.; Pacheco-Vargas, G. Pulp and peel of unripe stenospermocarpic mango (*Mangifera indica L.* cv Ataulfo) as an alternative source of starch, polyphenols and dietary fibre. *Food Res. Int.* **2020**, *138*, 109719. [CrossRef]
50. Gebruers, K.; Dornez, E.; Bedõ, Z.; Rakszegi, M.; Frás, A.; Boros, D.; Courtin, C.M.; Delcour, J.A. Environment and Genotype Effects on the Content of Dietary Fiber and Its Components in Wheat in the HEALTHGRAIN Diversity Screen. *J. Agric. Food Chem.* **2010**, *58*, 9353–9361. [CrossRef] [PubMed]
51. Du, T.; Kang, S.; Zhang, J.; Davies, W.J. Deficit irrigation and sustainable water-resource strategies in agriculture for China's food security. *J. Exp. Bot.* **2015**, *66*, 2253–2269. [CrossRef] [PubMed]
52. Ashrafi, M.; Azimi-Moqadam, M.R.; Moradi, P.; MohseniFard, E.; Shekari, F.; Kompany-Zareh, M. Effect of drought stress on metabolite adjustments in drought tolerant and sensitive thyme. *Plant Physiol. Biochem.* **2018**, *132*, 391–399. [CrossRef]
53. Thakur, A.; Singh, Z. Responses of 'Spring Bright' and 'Summer Bright' nectarines to deficit irrigation: Fruit growth and concentration of sugars and organic acids. *Sci. Hortic.* **2012**, *135*, 112–119. [CrossRef]
54. Nahar, K.; Gretzmacher, R. Effect of water stress on nutrient uptake, yield and quality of tomato (*Lycopersicon esculentum* Mill.) under subtropical conditions. *Die Bodenkultur* **2002**, *53*, 45–51.
55. Campi, P.; Gaeta, L.; Mastrorilli, M.; Losciale, L. Innovative soil management and micro-climate modulation for saving water in peach orchards. *Front. Plant Sci.* **2020**, *11*, 1052. [CrossRef] [PubMed]
56. Fernàndez, J.E.; Alcon, F.; Diaz-Espejo, A.; Hernandez-Santana, V.; Cuevas, M.V. Water use indicators and economic analysis for on-farm irrigation decision: A case study of a super high density olive trees orchard. *Agric. Water Manag.* **2020**, *233*, 106074. [CrossRef]