Growth, Productivity and Quality Performance of Costata Persimmon in Relation to Canopy Position and Rootstock

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ABSTRACT

According to their position within a tree canopy, fruits will be exposed to varied climatic conditions especially light and temperature, which would reflect variation in their growth and maturation. In the present study, the differences occurring in vegetative growth, fruit yield and quality of Costata persimmon in accordance with rootstock type and fruit position in the canopy were investigated. Periphery especially, both southern and western directions besides the upper part and the outer canopy side indicated the highest values of fruit retention, average fruit number per shoot, fruit yield, spring shoot length, leaf area, total leaf area per fruit and leaf chlorophyll content. While the percentage of sunburned fruits was lower at both northern and eastern directions, as well as at the lower and inner part than the other directions of tree canopy. The best fruit physiochemical characteristics were found in both western and southern directions, as well as the upper part and outer part of the tree canopy. Trees grown on seedy rootstock gave the highest values of fruit yield, shoot length, leaf area and total leaf area per fruit. Along with lower sunburned fruits, longer, wider, heavier and firmer fruits were also found on Seedy rootstock.

Keywords: Canopy directions, *Diospyros kaki*, Fruit position, Seedy rootstock, Tarabouls, yield and fruit quality.

INTRODUCTION

As the Egyptian consumer became aware of the persimmon fruit's nutritional value and health advantages, persimmon farming in Egypt has become more significant in the recent years. The increase of both production and acreage increased the number of fruits supplied to the local market. The Costata persimmon is the primary cultivar grown and distributed in the Egyptian market (Gerges *et al.*, 2010), and is regarded nowadays as the variety with the highest potential for commercial success. It is an astringent cultivar that requires artificial postharvest ripening treatment before marketing (Abd El-Aziz, 2021).

According to Anthony and Minas (2021), improving pre-harvest elements such as orchard design and training systems is the only way to increase tree productivity and fruit quality. In addition to nutrition and irrigation, cultural practices like planting distance, pruning, and rootstock type have a significant impact on the growth of tree canopy in any fruit orchard. The key factor that determines fruit trees cropping in a certain region is the structure and distribution of the canopy. The arrangement of branches along the tree trunk and their capacity to absorb various resources for growth, particularly light, are determined by the angles at which they grow (Wani *et al.*, 2021). For appropriate fruit productivity and quality, light is a crucial resource (Bastías and Corelli-Grappadelli, 2012). The position of the fruit within the canopy and the type of rootstock are important variables affecting the physicochemical characteristics of the fruit. Fruit quality will be impacted by the amount of light that each fruit receives depending on its position on the tree canopy and the tree location in the orchard (Sakhidin *et al.*, 2018). The effect of light distribution inside tree canopy on fruit quality characteristics is reported (Wagenmakers & Callesen, 1995 and Wünsche *et al.*, 1996). Exposure to light influences the growing and ripening processes in the fruit such as pigments biosynthesis, carbohydrate, amino acid, and organic acid metabolism (Rudell *et al.*, 2008).

Variability in vegetative growth, tree productivity, and internal and exterior fruit quality occur with time and with the aging of trees in the majority of fruit orchards. This might be the result of branches competing with one another for light, since they may grow more upwards or outwards depending on the lighting conditions surrounding the tree canopy. Meanwhile, branch growth and position in the canopy have an impact on light interception, which in turn has an impact on photosynthesis, the crucial physiological activity that affects flowering and the number of fruits at the various tree sites. The number and size of a fruit tree's leaves, as well as its stem, branches, and shoots,

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all determine the canopy's density. To make the most of solar radiation, a canopy's foliage should be robust and highly photosynthetic, and there should be ample room inside the canopy for air circulation (Zhang *et al.*, 2019). Higher light interception is typically found in higher tree densities which provide large leaf area and more even light distribution (Palmer, 1989; Wunsche *et al.*, 1996 and Palmer & Warrington, 2000). Nevertheless, rootstocks provide a useful horticultural tool for regulating scion vigor, yield, and yield efficiency as well as facilitating canopy design configurations that might enhance fruit quality (Reighard and Loreti, 2008). Persimmons are known to have dense tree canopies with large leaves; however, the problem of fruits shading appears especially for those positioned in the lower parts of the canopy and leads to poor coloration (Ullio, 2003). Additionally, a vigorous or dwarfing rootstock would affect flowering efficiency and the amount of light that reaches the leaves, as well as flower initiation and consequent floral differentiation.

In several studies on apples, the impact of canopy location and orchard practices on tree production and fruit quality was examined (Racskó *et al.*, 2005; Hamadziripi *et al.*, 2013 and Laužik *et al.*, 2020), and the same issue was studied on citrus (Sakhidini *et al.*, 2018 and Alam *et al.*, 2022), while less on persimmon. To find out the optimal strategies for crop development and quality improvement, studies examining persimmon phenological growth features and agricultural practices used in an orchard need to be expanded.

Our present study was conducted in a region where oranges are mainly planted. However, several growers tend to use the quincunx planting strategy to cultivate Costata persimmon inside orange orchards to boost their income. To identify the best method for canopy management for optimal light utilization and the best canopy position that produces the highest yield with better fruit quality at harvest time or thereafter, the current study is conducted to investigate the growth and productivity of the Costata trees under such conditions by examining the effect of canopy positions and rootstocks.

MATERIAL AND METHODS

Plant material and experimental design

The present study was conducted during the two successive seasons 2021 and 2022. Twenty years old "Costata" persimmon trees (*Diospyros kaki*) budded on Seedy or Tarabouls (*Diospyros lotus*) rootstocks and trained to standard modified central leader system were used. The quincunx planting system was used to plant Costata cultivar in a private orange orchard in the El-Tarh region, El-Behera governorate near Alexandria, Egypt. The orange trees were spaced 5×5m apart and grown in a clay soil with a water table depth of 100 -110 cm and a pH range of 7.8 – 8.3 with rows direction from south to north. The trees were surface irrigated every two weeks and fertilized in February of both seasons with 20 m3 organic manure and 200 kg calcium super phosphate (15.5% P_2O_5) /feddan. Also, 250g potassium sulphate (48% K_2O) and 400g actual nitrogen as ammonium nitrate (33.5% N) was added per persimmon tree in two equal doses in mid-April and July of each season.

To determine their principal influences on Costata persimmon tree development, fruit yield component, and quality, a factorial experiment involving four factors: canopy direction (south, north, east, and west), canopy part (upper and lower), canopy side (outer and inner), and rootstock was designed. Ninety-six trees (48 grafted on Tarabouls and 48 grafted on Seedy rootstocks) were selected as uniformly as possible and distributed as randomized complete block design (RCBD). Sixteen position combinations were studied on each rootstock (4 directions × 2 parts × 2 sides = 16). Each position underwent three replications with a single tree per replicate (each position combination on a separate tree). Height and width of trees on Seedy rootstocks were 5-6m and 3.5- 4 m, while Tarabouls were 3-3.5 m and 2.5-3.15 m, respectively.

Measured parameters

In the middle of March in 2021 and 2022 growing seasons, (3-4) one-year-old branches per position combinations (16 position per rootstock) were chosen and labeled and the following data were collected from the labeled branches:

Vegetative growth

At each position combination, the total number of new shoots and their total leaves number were counted, as well as their length (cm) on the same labeled branches were measured during August. The average shoot length and the average leaves number per position were estimated. In addition, during August of each season a randomly chosen sample of fifteen fully expanded leaves from each position combination was also taken to estimate leaf area (cm^2) and chlorophyll a and b concentration (mg/100g FW). Leaf area was calculated by measuring the maximum length and width of the leaf according to Chou (1966) and Fakhry *et al.* (2020) as follows:

Leaf area = 2/3 × leaf length x leaf width.

Leaf chlorophyll a and b concentration in acetone extraction was measured spectrophotometrically (VersaMax™ microplate reader) at the wavelengths of 648 nm and 664 nm and calculated for Chlorophyll a and b contents, as described by Miazek and Ledakowicz (2013).

Fruit retention percent

The total number of fruitlets on each position combination was counted in mid-June, and the total number of harvested fruits (mid-October) was also counted, and the percentage of fruit retention was estimated as follows:

Fruit retention (%) = (Total number of harvested fruits / Total fruitlets number) ×100

Fruit yield

At the time of commercial harvest (mid-October), total number and weight of fruits of each position combination were recorded, then sunburned fruits were removed, and their number was recorded, the percentage of sunburned fruits was estimated as follows:

Sunburned fruits (%) = (Number of sunburned fruits/ Total number of fruits) × 100.

Fruit physico-chemical quality

A random sample of six fruits from each position combination (i.e., 6 fruits X 16 positions× 3 replicates = 288 fruits per each rootstock) was taken and transferred directly to the postharvest laboratory at the Pomology Department, Faculty of Agriculture, Alexandria University. The fruit samples were properly cleaned with tap water, drained, and dried using a soft cloth before the fruit's physico-chemical characteristics were measured. A vernier caliper was used to measure the fruit length and diameter (cm) and shape index (L/D ratio) was calculated as well as the fruit weight (g) was measured. Fruit firmness (kg/cm^2) was measured on two peeled sides of each fruit with a fruit Texture Analyzer (Guss, Strand, Western Cape, South Africa). This texture tester measured the force needed to puncture a 7.9-mm-deep hole on each of the two peeled sides, using an 11-mm tip. Also, fruit dry matter content was determined gravimetrically by drying fruit samples to a constant weight at 100°C.

Total fruit water content (%) = [(fresh fruit weight-fruit dry weight) / fresh fruit weight] ×100 Fruit dry matter content (%) = 100 - Total fruit water content.

Moreover, a representative sample of fruit flesh from each replicate was homogenized in the fruit blender. The resulted juice was used to measure the malic acid content (mg/100 ml juice) and was determined as an indicator of total acidity using titration with 0.1 N standardized hydroxide sodium solution according to AOAC (2012). Fruit soluble solids content, SSC (°Brix) was measured by a digital refractometer PR-32. In addition, the sugar extraction was carried out by using ten grams of well mixed fruit fresh tissues, using ethyl alcohol 80% according to AOAC (2012). Reducing and total reducing sugars were then determined by reduction with Fehling solution and total sugars by hydrolysis with hydrochloric acid according to AOAC (2012) and non-reducing sugars computed by the difference between the two. Additionally, fruit carotenoid content was determined according to Britton *et al.* (2004), about, 1 g fresh fruit was homogenized with 7 ml acetone 95% and mixed in shaker machine and then carotenoids were determined at 460 nm using spectrophotometer (Model: 20, Milton Roy Company, USA). The fresh fruit pulp total tannins percent was evaluated as follows: Extraction of fruit tannins: 2 g of fruit samples were extracted in 30 ml of 80% acetone and stirred for 15 minutes in accordance to the method described by Kassegn (2018).

Statistical analysis

Using the statistical analysis system, SAS (Statistical Analysis System) version 8.1, a combined analysis of variance (4-way ANOVA) spanning both seasons. In 2001, the SAS Institute. Snedecor and Cochran (1989) used the least significant difference test (LSD) at a 0.05 level of significance to compare the means of the studied treatments and their interactions for each measured parameter.

RESULTS

Vegetative growth

Obtained data of the vegetative growth are presented in Table (1). The lengths of the spring shoots that were measured in the south and west directions of the canopy were similar and much greater than those measured in the north and east directions. However, the spring shoot length was longer in the east of the canopy than in the north. Compared to the lower part and inner side, the upper part and outer side reported longer spring shoots. Spring shoots were significantly longer in trees budded on Seedy than on Tarabouls, indicating the rootstock effect. Additionally, measured data revealed that the average leaf area and total leaf area share per fruit were equivalent in value and much greater in the south and west directions than in the north and east. The leaf area and total leaf area per fruit were both much higher in the upper section of the canopy than the lower part. Additionally, compared to the inner side of the tree canopy, the outside side exhibited higher values. Moreover, trees that budded on Seedy rootstock predominantly greatly outgrew the ones that budded on Tarabouls in terms of average leaf area and total leaf area per fruit. Nevertheless, as shown in Table (1), the southern and western canopy directions indicated higher leaf chlorophyll a (Chl.a) content than the eastern and northern. The west direction indicated the highest value of chlorophyll b (Chl.b) content followed by the south then the east and, the lowest was found in the north direction. In the meanwhile, leaf chlorophyll a and b contents were higher at the upper part of the canopy than the lower one and, in leaves of the outer side than the inner one. However, no evident differences were found in the values of chlorophyll a and b content between both rootstocks.

Fruit retention

The fruit retention percentage in the south and west positions of the canopy were comparable and much higher than those in the north and east positions, with no discernible variations occurring between the final two. Additionally, the upper part and the outer side of the canopy retained more fruits than the lower part and the inner side, respectively. However, neither rootstock had any significant impact on fruit retention (Table 1).

Average fruits number per shoot

Similar numbers of fruits were produced on each shoot in the south and west positions of the canopy, and these numbers were much higher than those in the north and east, with no significant differences between these last two. Additionally, the upper part of the canopy had more average fruits per shoot than the lower part. In contrast to the inner canopy side, a high quantity of fruits per shoot was recorded on the outer side. Trees budded on Tarabouls rootstock had an average of more fruits per shoot than those budded on Seedy (Table 1).

Fruit yield

The fruit yield as weight and number per position was evenly distributed at the west and south canopy directions and was significantly higher than that at the north and east sides. The canopy's upper part had a significantly higher fruit load than the lower one. Also, fruit yield was highest on the outer side compared to the canopy inner side. Regardless of canopy position, trees budded on Seedy rootstock had significantly higher yield than those budded on Tarabouls (Table 1).

The percentage of sunburned fruits

Similar percentages of sunburned fruits were observed from both the north and east directions and both were lower than those observed on the south and west directions. A significant high percentage of sunburned fruits was found at the upper canopy part compared to the lower part. The canopy outer side recorded a higher percentage of sunburned fruit than the inner side. Nevertheless, compared to trees budded on Seedy rootstock, considerably more fruits from trees budded on Tarabouls were sunburned (Table 1).

Fruit quality

The combined analysis data of both growing seasons presented in Table (2) showed a general impact of canopy position and rootstock on the external appearance of the fruit and its chemical quality. In comparison to the other three directions, the west direction dramatically cleared the highest fruit weight, length, and diameter. Fruit length and diameter were higher in the south and east of the canopy than in the north. The upper part of the canopy had fruits with more weight, length, and diameter than the lower part. Additionally, the outer side of the tree canopy had larger fruits in terms of weight, length, and diameter than the inner side. Fruit shape index did not differ among canopy directions, except for those fruits positioned on the east of the canopy, which had an increased shape index than those in the north. The outer side and upper part of the canopy showed a larger shape index than the inner side and lower part. As a regard to the rootstock effect, fruits on Seedy had a greater weight and shape index and were longer and wider than those on Tarabouls rootstock. Nevertheless, the lowest fruit firmness values were measured in fruits at the northern direction compared to the other three directions. Additionally, firmer fruits were found on the upper part and on the outer side of the tree canopy than the lower part and the inner side. Moreover, compared to Tarabouls, the fruits of trees budded on Seedy rootstock were obviously firmer.

As for the internal quality of the fruit and regarding the main effect of canopy directions, presented data in Table (2) showed that in general, fruit tannins content was lowest in fruits of the north direction compared to the other three directions. Additionally, fruits positioned on the lower part as well as in the inner side of the canopy had less tannin content than fruits located on the upper part and the outer side. Fruits found in trees budded on Seedy rootstock contained less tannin than those on Tarabouls. High carotenoids and dry matter content were found in fruits positioned in the south and west directions. Fruits located on the upper part as well as in the canopy outer side had significantly high carotenoids and dry matter content than those on the lower part and in the inner side of the canopy. Fruit carotenoids and dry matter content were higher in Tarabouls than in Seedy rootstock. Moreover, fruits facing the south and west directions were found to have the highest fruit acidity values, followed by those facing north, and then the east. However, the canopy upper and lower parts, canopy sides and rootstock did not significantly influence fruit acidity. Fruits facing the south and west directions had the highest levels of reducing sugars and SSC content, while non-reducing sugar content was not affected by canopy directions.

Table 1. The main effect of canopy position and rootstocks on fruit yield (kg and No.) and retention (%), spring shoots length (cm), and average fruit No./shoot, sunburned fruits (%), average leaf area (cm^2), total leaf area/fruit (cm^2/fruit), and leaf chlorophyll content (mg/100g FW) of "Costata" persimmon trees over 2021and 2022 seasons (a combined analysis).

Canopy Direction	Fruit retention	Average fruit No./ shoot	Fruit yield		Sunburned fruits	Spring shoot length	Average leaf area	Total leaf area	Leaf chlorophyll	
			Kg	No.					a	b
South	58.5[a]	3.0[a]	6.6[a]	37.5[a]	5.1[a]	69.7[a]	161.3[a]	127.5[a]	114[a]	41[b]
North	45.7[b]	1.8[b]	3.7[b]	22.8[b]	1.4[b]	40.9[c]	128.5[b]	103.0[b]	92[b]	27[d]
West	55.3[a]	3.4[a]	6.8[a]	36.3[a]	4.0[a]	64.4[a]	163.7[a]	128.1[a]	111[a]	45[a]
East	46.8[b]	2.0[b]	4.3[b]	24.9[b]	2.3[b]	52.4[b]	120.2[b]	98.4[b]	97[b]	33[c]
Part										
Upper	55.4[a]	3.4[a]	6.5[a]	36.5[a]	4.0[a]	64.3[a]	156.4[a]	122.8[a]	113[a]	42[a]
Lower	47.5[b]	1.7[b]	4.2[b]	24.3[b]	2.2[b]	49.7[b]	130.5[b]	105.6[b]	94[b]	31[b]
Side										
Outer	56.9[a]	3.6[a]	6.9[a]	39.2[a]	3.4[a]	60.2[a]	157.5[a]	4.02[b]	120[a]	46[a]
Inner	46.8[b]	1.6[b]	3.7[b]	21.6[b]	2.7[b]	51.5[b]	129.3[b]	5.99[a]	86[b]	27[b]
Rootstocks										
Seedy	52.7[a]	2.2[b]	6.5[a]	36.8[a]	2.6[b]	63.8[a]	154.6[a]	126.2[a]	106[a]	36.9[a]
Tarabouls	51.2[a]	2.9[a]	4.2[b]	24.0[b]	3.4[a]	50.2[b]	132.2[b]	102.4[b]	101[a]	36.7[a]

Mean separation within columns in each group of treatments by least significant difference at 5% level.

Table 2. The main effect of canopy positions and rootstocks on fruit weight (g), length, and diameter (cm), shape index, soluble solids content (SSC %), total tannins (%), total carotenoids (mg/ 100g), dry matter (%), acidity (mg/100 ml juice) and sugars (%) and firmness (kg/cm^{2}) of "Costata" persimmon trees over 2021 and 2022 seasons (a combined analysis).

Canopy Directions	Weight	Length	Diameter	Shape index	Firmness	Total tannins	Total carotenoids	Dry matter	Acidity	Sugars		SSC
										Reducing	Non-Reducing	
South	177.4^{b}	6.4^{b}	6.3^{b}	1.02^{ab}	20.2^{a}	2.21^{a}	2.80^{a}	15.7^{a}	0.46^{a}	15.67^{a}	3.24^{a}	23.9^{a}
North	176.9^{b}	5.8^{c}	5.8^{d}	1.00^{b}	17.3^{b}	1.92^{c}	1.96^{b}	12.7^{b}	0.38^{b}	12.68^{c}	2.98^{a}	20.9^{b}
West	179.7^{a}	6.7^{a}	6.5^{a}	1.03^{ab}	21.0^{a}	2.02^{b}	2.60^{a}	16.2^{a}	0.46^{a}	15.89^{a}	3.12^{a}	23.5^{a}
East	175.9^{b}	6.3^{b}	6.0^{c}	1.05^{a}	20.0^{a}	2.03^{b}	2.20^{b}	14.7^{ab}	0.25^{c}	13.65^{b}	3.01^{a}	20.9^{b}
Part												
Upper	178.2^{a}	6.6^{a}	6.4^{a}	1.03^{a}	20.6^{a}	2.18^{a}	2.48^{a}	15.6^{a}	0.41^{a}	15.50^{a}	3.76^{a}	23.2^{a}
lower	176.7^{b}	5.^{9b}	6.0^{b}	0.98^{b}	18.4^{b}	1.92^{b}	2.10^{b}	13.9^{b}	0.38^{a}	13.40^{b}	2.46^{b}	21.8^{b}
Side												
Outer	179.6^{a}	6.6^{a}	6.3^{a}	1.05^{a}	21.0^{a}	2.20^{a}	2.7^{a}	15.9^{a}	0.40^{a}	16.10^{a}	3.80^{a}	23.3^{a}
Inner	175.4^{b}	6.1^{b}	6.0b	1.02^{b}	18.6^{b}	1.92^{a}	2.0^{b}	13.8b	0.39^{a}	12.80^{b}	2.48^{b}	21.5^{b}
Rootstock												
Seedy	179.5^{a}	6.6^{a}	6.3^{a}	1.05^{a}	21.0^{a}	1.90^{b}	2.0^{b}	14.1^{b}	0.40^{a}	14.20^{b}	3.0^{b}	21.4^{b}
Tarabouls	175.2^{b}	6.1^{b}	6.0^{b}	1.02^{b}	19.2^{b}	2.19^{a}	2.5^{a}	15.5^{a}	0.38^{a}	14.80^{a}	3.2^{a}	23.5^{a}

Mean separation within columns in each group of treatments by least significant difference at 5% level.

In addition, fruits located at the upper part and those on the outer side as well as those grown on the Tarabouls rootstock had significantly high levels of sugars and SSC content (Table 2).

DISCUSSION

Position within the tree canopy

At various positions of the canopy, the variability of climatic factors, particularly light and temperature, may be taken into consideration. It is suggested that a tree canopy with a wide leaf area will have a high light interception and give more consistent lighting (Anthony *et al.*, 2021). Fruit yield is said to be affected by the dispersion of light within tree canopies (Wünsche and Lakso, 2000). The light and temperature conditions for fruits growing inside the canopy, however, are less favorable than those growing outside (Arshad *et al.*, 2014). In a study on wax apple trees, Khandaker *et al.* (2017) found that stomatal aperture was highest in leaves of the outer canopy, stating that more open stomata allow greater conductance, and consequently indicating potentially higher photosynthesis and transpiration rates. Additionally, similar to our findings, they also reported variant leaf chlorophyll content among the different canopy positions. Chlorophyll distribution within a canopy can vary considerably as a function of time and space as mentioned by Coops et al. (2003). However, Anthony and Minas (2021) found that optimizing light interception and light dispersion could lead to a balanced maximum yield with maximum fruit quality. Moreover, in earlier study, George *et al.* (1997) indicated that fruits drop occurs when roots and branches of a persimmon tree reach their lowest levels of their carbohydrate reserves and simultaneously compete with fruits. Accordingly, it might be concluded that more light interception and better airflow might have been provided at the canopy's south and west directions, and the upper part and outer side of the Costata trees in the present study. Such conditions might have encouraged vegetative growth which is evident in the longer spring shoots and larger leaf area measured, and higher leaf chlorophyll content determined in those mentioned positions. Thus, photosynthesis might have been enhanced and enough assimilates were accumulated for better fruit setting and growth. The results of our study correspond with those of Khandaker *et al.* (2017), who found that the outer canopy position retained more fruits of higher quality.

In our study, Costata fruits harvested from the different canopy positions exhibited varied physicochemical properties. These findings agree with those reviewed by Pandy *et al.* (2013). They reported that a fruit position on a tree is found to influence its maturity, size, skin and flesh color, mineral composition, TSS and acidity content. Similar to our findings, Hamadziripi (2012) working on apples recorded high carbohydrates accumulation, high soluble solids and dry matter concentration of fruits from the outer canopy. Also, Feng *et al.* (2014) indicated higher fresh weight, soluble solids and soluble sugars content in fruits at the outer canopy than the inner-canopy part of three apple cultivars. Also, Khandaker *et al.* (2017) working on wax apples, mentioned that fruit size, fruit weight, and total soluble solids were higher in fruits of the outer canopy with improved peel color. In the meantime, Karl and Peck (2022) reported that apple fruits harvested from the top of the tree canopy had greater polyphenol and soluble solids concentrations than those from the interior of the canopy. In the present study carotenoids content was low in fruits positioned in the canopy's inner side. As carotenoid synthesis is regulated by light, Smrke *et al.* (2019) recorded increase of carotenoids in persimmon fruits positioned at the canopy's lower part when using reflective light foil. However, Sakhidin *et al.* (2018) working on citrus found no influence of fruit position in the canopy on its physical and chemical characteristics.

Nonetheless, sunburn injury is common on fruits due to high solar radiation levels and air temperatures, low relative humidity, and high elevations as reviewed by Lal and Sahu (2017). Three types of sunburn induced by heat and/or light stress in apples were reported and characterized by Schrader *et al.* (2008). Intense exposure of persimmon fruit to sunlight causes sunburn damage appearing as large black spots on the fruit skin, which render the fruit marketability and cause high losses in yield (Abo Ogiela, 2020). In our study, the lowest percentage of fruit sunburn was recorded at the canopy inner side, and at the lower part as well as at the north and east directions. This could be because fruits were exposed to less sunlight at these positions. A canopy should support adequate shade to protect the fruits from sunburn (Pandey *et al.*, 2013). The persimmon canopy is very dense with large leaves that lessen light penetration through the canopy resulting in protecting fruits from direct sunlight exposure, especially those positioned in lower part and the canopy inner side.

Rootstock

A persimmon tree takes 8-10 years to reach a full bearing stage, and tree vigor can be controlled by choice of rootstock. The Seedy persimmon (*D. kaki*) is the most common rootstock globally, and trees on it tend to be tall reaching 4 to 8 m in height as it is considered vigorous rootstock, while the Tarabouls (*D. lotus*) is a semi-dwarfing rootstock known for its tolerance to saline soils (Yakushiji *et al.*, 2008 and Gil-Munoz *et al.*, 2020). Regarding the results of our study, tree canopy on Seedy rootstock (*D. kaki*) resulted in a higher yield than on Tarabouls. This increase might be because of the vigorous canopy of trees on the Seedy rootstock observed by the higher shoot length and larger leaf area, compared to canopy vigor on Tarabouls which might have been too weak to produce similar yield. Also, both rootstocks showed some variation in their influence on the fruit physicochemical properties. The variant effects of rootstocks on scion growth and productivity are evident in previous studies on persimmon (Yakushiji *et al.,* 2021 and Tetsumura *et al.,* 2015, 2022). In similar conditions to the present study, Khalil and Kassem (2020) stated that Costata trees grafted on *D. kaki* had more shoot growth, better fruit set, yield, and fruit weight compared to trees grafted on *D. lotus*

Moreover, in any chain production of a fruit crop, homogeneity in both crop harvesting and quality appearance are important aspects that are asked for. Thus, orchard management strategies aiming at increasing production and decreasing variation in maturity and appearance among fruits, decreasing the number of harvests in the same orchard is of major commercial importance. As mentioned by Palmer and Warrington (2000) working on apples, the success of any system depends upon the correct management practices including manipulation of the vegetative and reproductive development of the tree canopy by using size controlling rootstocks and tree training and pruning in order to achieve high light interception and maintain good light penetration into the canopy at all times and to have efficient fruit harvesting. Such investigations about the effect of fruit location on a tree canopy would help growers to decide the best production system to follow in accordance with the crop postharvest use either fresh or processed, shipped or local consumed, and to minimize pre and postharvest losses.

From the above discussed, variability observed in the physicochemical characters of Costata fruits in our study according to its position are reflecting differences in fruit maturity and ripening on the same tree and accordingly obtained findings may aid growers under similar conditions of the present study to decide with which part of the canopy to start harvesting and which to end with for best crop homogeneity and less losses and costs.

CONCLUSION

The information provided will help persimmon growers understand how microclimatic variation within the tree canopy causes differences in crop yield and quality. This information would help them to decide the best training and pruning practices as well as harvesting date of the different canopy parts in accordance to fruit-consuming purposes. Additionally, based on the data obtained, it is concluded that both west and south directions, as well as the upper and outer parts of the Costata persimmon trees growing in comparable conditions, could produce more fruits with improved physicochemical features. It is also concluded that the Costata scion interacted better with the Tarabouls rootstock resulting in higher yield efficiency (i.e., average fruit number/ shoot).

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الملخص العربي

نمو وإنتاجية وجودة الكاكي كوستاتا وعلاقته بموضع مظلة والأصل

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تتعرض الثمار لظروف مناخية متنوعة وخاصة الضوء ودرجة الحرارة وفقًا لموقعها داخل مظلة الشجرة، مما يعكس التباين في نموها ونضجها. هذه الدراسة تدرس الاختلافات التي تحدث في النمو الخضري وإنتاجية الثمار وجودة ثمار الكاكي صنف كوستاتا وفقًا لتاثير نوع الأصل وموقع الثمرة في المظلة بشكل عام، تشير الاتجاهات الجنوبية والغربية إلى جانب الجزء العلوي وجانب المظلة الخارجية إلى أعلى قيم لبقاء الثمار وكذلك عدد ثمار في الفرع الواحد ووطول الفرع في الربيع ومساحة الورقة وإجمالي مساحة الورقة لكل ثمرة ومحتوى الورقة من الكلوروفيل. وكانت نسبة الثمار مصابة بالسعة الشمس أقل في شمال وشرق المظلة وكذلك في الجزء السفلي والجانب الداخلي. تم العثور على خصائص فيزيائية وكيميائية أفضل للثمار في كلا الاتجاهين الغربي والجنوبي، بالإضافة إلى الجزء العلوي والجانب الخارجي لمظلة الشجرة. كان للأشجار الموجودة على الأصل البذري أعلى قيم إنتاجية الثمار وطول الساق ومساحة الورقة وإجمالي مساحة الورقة لكل ثمرة. بالإضافة إلى اقل نسبة ثمار مصابة بلسعة الشمس، تم العثور أيضًا على ثمار اكبر حجما وأكثر صلابة على الاصل البذري.