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Research Article
Effects of Rootstock Type and Potassium Fertilization Rate on Growth, Yield, Leaf Mineral Content and Fruit Quality of 'Costata' Persimmon Trees

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Abstract
Background and Objective: Cultivation of 'Costata' persimmon has been increasing in Egypt due to the increasing consumption of the fruit having a distinctive taste. The main problem is June drop and pre-harvest fruit drop, especially because that 'Costata' persimmon is a parthenocarpic cultivar, subsequently, the fruit yield and quality is not economical. Therefore, improving yield and fruit quality is a major goal and could be achieved by using fertilization and rootstocks. **Materials and Methods:** This investigation conducted during two consecutive seasons 2018/2019 on 'Costata' (*Diospyros kaki*) persimmons, grafted onto *D. kaki* and *D. lotus* seedlings, grown in a private orchard at El-Tarh region. A split-plot design had performed. ANOVA test were used to compare the samples of different treatments. **Results:** 'Costata' persimmon trees grafted onto *D. kaki* had higher shoot length, fruit set, fruit retention, yield and leaf nitrogen in the first season and calcium content as compared with the trees grafted onto *D. lotus*. Potassium fertilization increased shoot length, fruit set, fruit retention, yield, fruit weight, Total Soluble Solids (TSS) (%), total sugars, carotenoids. It also increased leaf potassium, magnesium, zinc, manganese, iron and phosphorus content in the second season, whereas tannins, acidity and calcium content decreased. **Conclusion:** It is concluded that potassium fertilization at 1000 g/tree was more effective application for the persimmon trees grafted on *D. kaki* which is a better choice for more shoot growth, fruit set and retention (%), yield and fruit weight compared with the trees grafted on *D. lotus*. However, the trees grafted on *D. lotus* have fruits with more quality.

Key words: *Diospyros kaki*, *D. lotus*, carotenoids, fruit retention, tannins

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The production, marketing and consumption of persimmon crop are contentiously increasing in Egypt. The cultivation of persimmon in Egypt is centered on the cultivar ‘Costata’, mainly due to its high appearance and excellent quality[1]. The potent effects of rootstocks on the growth, yield, nutritional status and fruit quality of the trees are already widely recognized[2]. Rootstocks play a critical role in determining orchard performance in fruit crops. Combining the desirable features of two different plants by grafting can produce contrasting growth effects. The effect of rootstock on fruit quality in terms of physical parameters and chemical compositions is well illustrated in temperate fruit crops in comparison with tropical and subtropical fruit crops. This difference can establish by comparing the relative significance of rootstocks for precocity, growth, yield and trees size control and through differences in crop load, phenological cycles, fruit behaviour and canopy management techniques[3]. This could might be to the role of rootstock and its significant impact on fruit crop production by affecting canopy structure, nutritional uptake, flowering and yield and fruit quality[3]. Besides, it can also encounter biotic and abiotic stress as salinity, nutritional stress, soil pathogens and thermal stress[4]. Guava trees on *Psidium cattleianum* rootstock were the tallest and gave the maximum yield. *Psidium pumilum* rootstock had dwarfing effect but fruits had highest TSS, total sugars and the maximum number of seeds. Whereas, trees on *Psidium cujavillis* produced the largest fruit with rough-skinned and the highest ascorbic acid content[5]. Apple trees grafted on MM106 rootstock had significantly higher fruit set, yield and yield efficiency than those on M7[6]. Almond rootstocks were subjected to soil salinity stress showed that osmotic and leaf water potentials were affected by salinity in GF677 almond, but less so in GN15[7] suggesting a higher selectivity for potassium and calcium ions against sodium ion in this latter rootstock. Peach seedlings commonly show susceptibility to nematode attack but ‘Nemaguard’ and ‘Okinawa’ showed tolerance to nematode[8].

Fertilization of horticultural crops is one of the most promising tools to improve fruit crop production. Mineral nutrition is considerable tools to maximize yield and fruit quality[9]. Potassium is an important mineral nutrient for protein synthesis that provides plant growth processes in all stages[10]. Potassium manages activities of several enzymes in plants, by the timbre of photosynthesis rate, increase in the translocation rates from leaves through the phloem to roots, leading to enhance the fruit yield and quality[11]. It assists to regulate the CO_2 supply to plant by regulating stomata opening and closing. It enhances the water use efficiency in the plants and sugars use for maintenance growth functions. Potassium fertilization is important for several physiological functions such as normal cell division and growth, synthesis of proteins, the formation of sugars and starch and neutralization of organic acids. Potassium is important in fruit formation and enhances fruit size, flavor and color. This nutrient also important to reduce the affect of adverse weather conditions[12]. Thus, we purposed in this study to evaluate the effect of different potassium fertilization rates and rootstock type and their interactions on trees growth, flowering, yield, fruit quality and nutrient status of ‘Costata’ (*Diospyros kaki*) persimmon trees, grafted on *D. kaki* and *D. lotus* seedlings.

MATERIALS AND METHODS

The present study was carried out during 2018 and 2019 seasons in a private orchard at El-Tarh region, near Behira Governorate, Egypt. Thirty six trees, twenty years old, of ‘Costata’ (*Diospyros kaki*) persimmons, grafted onto *D. kaki* and *D. lotus* seedlings were selected for the present study. The trees were grown in clay well drained soil with water table depth of 100-120 cm and pH of 7.8-7.9. Soil texture, Electric Conductivity (EC), total calcium carbonate and available macro and micro nutrients are presented in Table 1. Trees were planted and spaced 5 m between trees and 5 m between rows. The trees were irrigated every 15 days with river Nile water and received the same horticulture practices in the orchard (25 m^3 organic manure/feddan in November every year and calcium superphosphate was added at a rate of 150 kg/feddan in mid-February in both seasons). Potassium fertilizer which was in granular form of potassium sulphate (48% K_2O) was applied twice to the soil (at early of May and August in each season).

Table 1: Physical and chemical analysis of the clay soil of the experimental orchard at different soil depths before starting the treatments

	Soil depth (cm)		
Characteristics	0-30	30-60	60-90
Chemical properties			
Nitrogen (%)	0.17	0.10	0.11
Potassium (K^+) (meq L^{-1})	0.10	0.60	1.10
Calcium (Ca^{++}) (meq L^{-1})	6.00	5.60	12.00
Magnesium (Mg^{++}) (meq L^{-1})	2.80	2.60	5.80
Sodium (Na^+) (meq L^{-1})	2.40	2.80	7.20
Bicarbonates (HCO_3) (meq L^{-1})	6.00	5.20	4.60
Chloride (Cl^-) (meq L^{-1})	1.80	2.60	10.00
Sulfates (SO_4) (meq L^{-1})	3.60	3.90	11.80
$CaCO_3$ (%)	14.65	12.48	14.75
Physical properties			
Soil Electric Conductivity (mm hos cm^{-1})	0.90	1.10	2.60
Texture	Clay	Clay	Clay

Potassium fertilizer was applied at three different rates, i.e., 0.0 (K_0), 500 g (K_1) and 1000 g (K_2) per tree. Treatments were arranged in a randomized complete block design with 3 replicates for each treatment, using 2 trees for each replicate. Fertilizers were added to the soil surface 1.5-2.0 m apart from trunk of the tree and trees were irrigated immediately after application.

For investigating the effect of different potassium fertilization rate and rootstock type on the growth, fruit set, retention percentages, yield, fruit quality and leaf mineral content, four main branches per tree were chosen and tagged in March, 2018 and 2019 and their average spring shoots lengths were measured in July in both experimental seasons. Also, the numbers of flowers at full bloom on each branch was recorded. In addition, the number of fruits on each branch was counted at harvest date. Fruit set and fruit retention percentages at harvest date were calculated. In mid-October of each season, yield as kg per tree was recorded and average fruit weight (g) was determined.

Ten fruits/each replicate were used to determine fruit quality at harvest date of each season.

Fruit firmness (lb/inch^2) was measured by a penetrometer using 5/16" diameter tip size. Juice Total Soluble Solids (TSS) percentages was determined by a digital refractometer (Atago, Japan) and titratable acidity percentage was determined by diluting the fruit juice with distilled water then titrating with 0.1 N NaOH in the presence of phenolphthalein as an indicator to the end point and expressed as malic acid equivalent. The total soluble sugars were determined after hydrolysis with hydrochloric acid according to Nelson arsenate-molybdate colorimetric method, described by Malik and Singh[13]. Fruit skin carotenoids were determined according to Britton *et al.*[14]. About, 1 g was homogenized with 7 mL actone 95% and mixed in shaker machine and then carotenoids was determined at 460 nm using spectrophotometer (Model: 20, Milton Roy Company, USA). The fruit vitamin C content (mg V.C/100 mL juice) was determined with 2, 6-dichlorophenol-indophenol dye according to AOAC[15].

In order to determine the leaf mineral content, a leaf sample of 25 leaves was collected from each experimental tree in mid-July of both seasons. The samples were collected from the middle part of non-bearing shoots. Leaves were washed several times with tap water and then with distilled water and oven dried at 70°C until constant weight. The dried leaves tissues were grounded and digested with sulphuric acid and hydrogen peroxide according to Evenhuis and de Waard[16]. In the digested solution, N and P were determined using colorimetric method following procedures of Evenhuis[17] and Murphy and Riley[18], respectively. K and Na were estimated using a flame photometer. Ca, Mg, Fe, Mn and Ze were estimated using Atomic Absorption Spectrophotometer.

Statistical analysis: A factorial experiment with a split plot design with three replicates was performed. The factors were root-stock type (*D. kaki and D. lotus*) as being the main plot and potassium fertilization rate (0, 500, 1000 g K_2SO_4/tree) as the sub-plot. The analysis of variance of treatments differences was performed according to Steel and Torrie[19]. Statistical analysis was done by ANOVA, F-test and Least Significant Difference (LSD) procedures available within the SPSS software package (Version 18 PASW).

RESULTS

Shoot length: The effects of potassium fertilization rates on shoot length of 'Costata' persimmon during 2018 and 2019 seasons are shown in Table 2. Shoot lengths increased gradually with increasing the rate of potassium treatment. The application of potassium K_2 (500 g K_2 SO_4/tree) showed the highest significant shoot lengths (37.63 and 41.14 cm) as compared with the lowest values (26.14 and 33.25 cm) resulted from K_0 (control treatment), in the 1st and 2nd seasons, respectively.

Regardless of potassium fertilization treatments, data in Table 2 presented that shoots lengths were affected by rootstock type, being largest on *D. kaki*, while smallest on *D. lotus*. Moreover, Fig. 1 and 2 illustrated, a linear regression relationship between potassium fertilization rate and rootstock type with shoot length as r-values were 0.24 and 0.69 in 2018 season, respectively. The corresponding values for 2019 were 0.33 and 0.77.

As for the interactions between rootstock and potassium fertilization rate, the data revealed that K_2 treatment significantly caused the highest increase in the shoot length of *D. kaki* rootstock in both experimental seasons. Nevertheless, the lower shoot length value was recorded with trees receiving K_0 in *D. lotus* rootstock.

Fruit set and fruit retention (%): The results presented in Table 2 showed that potassium treatments (K_1 and K_2) significantly increased the percentages of fruit set and fruit retention at harvest date as compared with K_0 (control). The highest level (K_2) recorded the highest fruit set 69.18 and 72.16% as compared with the lowest fruit set 60.91 and 62.02% resulted from the K_0 (control) in the first and second seasons, respectively. The corresponding values for fruit retentions were 31.72 and 35.54% for K_2 compared with

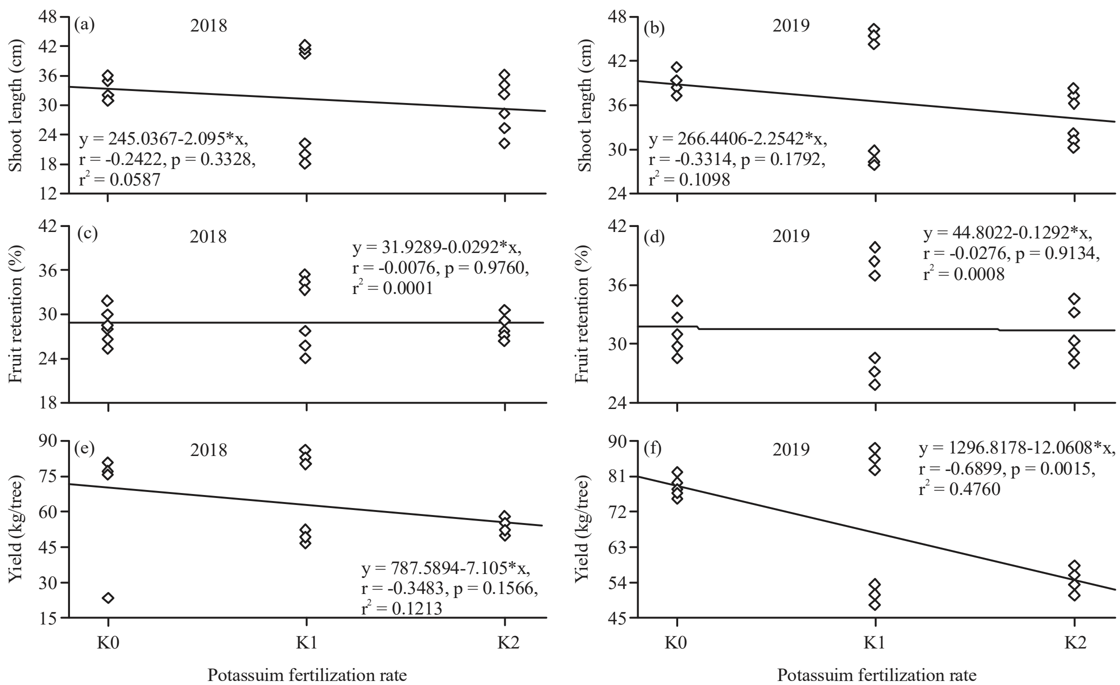

Fig. 1(a-f): Linear regression analysis for relationships between potassium fertilization rate with shoot length, fruit retention and yield for 'Costata' persimmon trees at harvest date during 2018 and 2019 seasons (a) Potassium fertilization: shoot length, (b) Potassium fertilization: shoot length 2, (c) Potassium fertilization: fruit retention, (d) Potassium fertilization: fruit retention 2, (e) Potassium fertilization: yield and (f) Potassium fertilization: yield2

Table 2: Effects of potassium fertilization rate and rootstock type on shoot length, fruit set and retention (%) at harvest and yield of "Costata" persimmon trees during 2018 and 2019 seasons

	Shoot length (cm)		Fruit set (%)		Fruit retention (%)		Yield (kg)	
Treatments	2018	2019	2018	2019	2018	2019	2018	2019
Rootstock (R)								
R_1	36.26^{a}	40.80^{a}	68.42^{a}	72.16^{a}	30.42^{a}	33.58^{a}	78.83^{a}	80.43^{a}
R_2	26.42^{b}	32.22^{b}	61.25^{b}	60.73^{b}	27.48^{b}	29.66^{b}	52.48^{b}	53.90^{b}
ANOVA	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.01$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$
Potassium rates (K)								
K_0	26.14^{c}	33.25^{c}	60.91^{c}	62.02^{c}	26.22^{c}	28.43^{c}	62.19^{c}	60.55^{c}
K_1	30.25^{b}	35.15^{b}	64.42^{b}	65.15^{b}	28.91^{b}	30.90^{b}	65.14^{b}	66.32^{b}
K_2	37.63^{a}	41.14^{a}	69.18^{a}	72.16^{a}	31.72^{a}	35.54^{a}	69.63^{a}	71.63^{a}
ANOVA	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.01$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$
C×K								
$R_1\times K_0$	32.17^{b}	38.10^{b}	63.71^{c}	38.10^{b}	26.65^{d}	68.25^{bc}	75.20^{bc}	76.60^{bc}
$R_1\times K_1$	35.36^{b}	39.18^{b}	68.35^{b}	39.18^{b}	30.12^{b}	70.10^{b}	78.14^{b}	79.53^{b}
$R_1\times K_2$	41.26^{a}	45.12^{a}	73.20^{a}	45.12^{a}	34.50^{a}	78.13^{a}	83.15^{a}	85.16^{a}
$R_2\times K_0$	20.12^{d}	28.40^{d}	58.11^{d}	28.40^{c}	25.80^{d}	55.80e	49.18^{d}	50.50^{d}
$R_2\times K_1$	25.14^{c}	31.11^{c}	60.50^{d}	31.11^{c}	27.70^{cd}	60.20^{d}	52.15^{cd}	53.11^{cd}
$R_2\times K_2$	34.00^{b}	37.16^{b}	65.16^{c}	37.16^{b}	28.95^{bc}	66.20^{c}	56.11^{b}	58.11^{bc}
ANOVA	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.01$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$

Means followed by different letters within column indicate significant differences between treatments based on LSD test, R_1: *Diospyros kaki*, R_2: *Diospyros lotus*, K_0: 0 g K_2SO_4/tree, K_1: 500 g K_2SO_4/tree and K_2: 1000 g K_2SO_4/tree

control 26.22 and 28.43% for the first and second season, respectively. Moreover, the percentages of fruit set and fruit retention of trees grafted onto *D. kaki* were higher than that of trees grafted onto *D. lotus* rootstock, in both seasons. Moreover, Fig. 2 illustrated a linear regression relationship between rootstock type with root retention (%) as r-values were 0.47 and 0.51 in both 2018 and 2019, respectively.

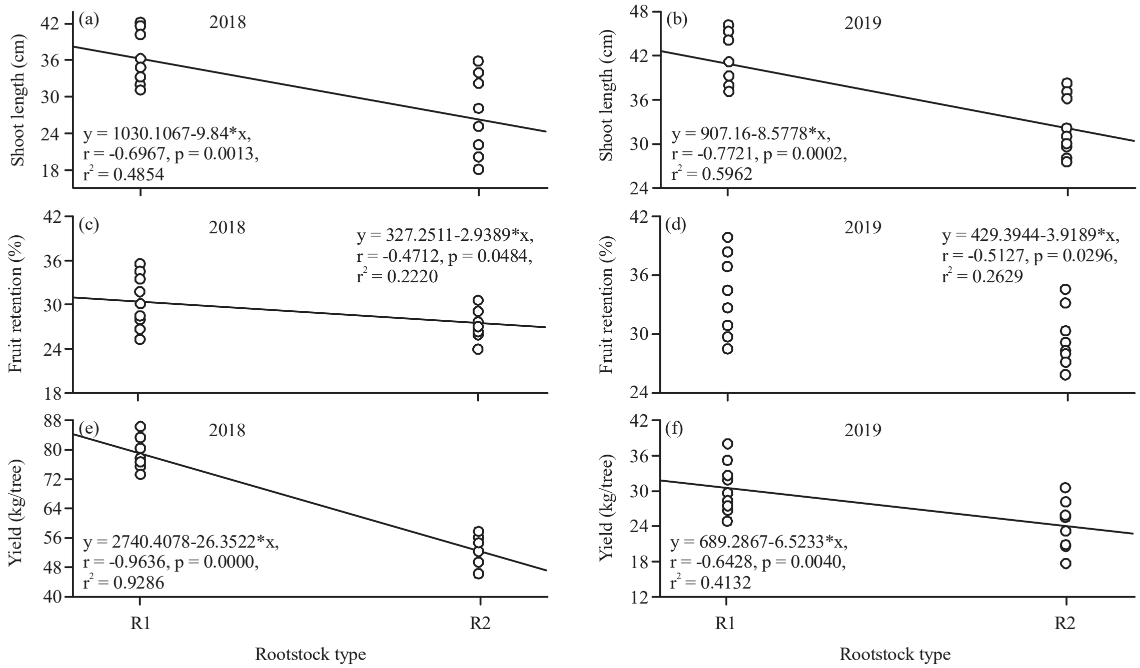

Fig. 2(a-f): Linear regression analysis for relationships between rootstock type with shoot length, fruit retention and yield for 'Costata' persimmon trees at harvest date during 2018 and 2019 seasons (a) Rootstock type:shoot length, (b) Rootstock type:shoot length2, (c) Rootstock type:fruit retention, (d) Rootstock type:fruit retention2, (e) Rootstock type:yield and (f) Rootstock type:yield2

The influences of the different potassium fertilization rates on either rootstock on fruit set and fruit retention percentages were shown in Table 2. The data revealed that the K_2 caused the highest fruit set and fruit retention percentages of the trees grafted on *D. lotus* in both seasons, whereas the lowest value was obtained from K_0 with *D. lotus* rootstock.

Yield: The effects of different potassium rates and rootstock type on fruit yield (kg/tree) of 'Costata' persimmon during 2018 and 2019 seasons are shown in Table 2. Fruit yield increased with increasing potassium rate, however, the highest significant yield values 69.63 and 71.63 kg/tree resulted from the highest rate (K_2) as compared with the lowest values 62.19 and 60.55 kg/tree resulted from the control (K_0) in the first and second seasons, respectively.

As for rootstock effect, the data obtained during both seasons shown in Table 2, cleared that the yield of persimmon trees grafted onto *D. kaki* was higher than that on *D. lotus*. The difference between the two rootstocks was presented regardless of potassium fertilization rates.

There was a linear regression relationship between potassium fertilization rate and rootstock type with yield as r-values were 0.34 and 0.96 in 2018 season, respectively. The corresponding values for 2019 were 0.68 and 0.64 (Fig. 1a-f and 2a-f).

Considering the interaction effect between rootstock and potassium fertilization rate, the data revealed that K_2 treatment significantly caused the highest increase in the yield of *D. kaki* rootstock in the first and second experimental seasons, respectively. Nevertheless, the lower yield values were recorded with trees receiving K_0 in *D. lotus* rootstock in the first and second seasons, respectively.

Fruit physical characteristics: Fruit physical characteristics (weight and firmness) as affected by rootstock type and different potassium rates are presented in Table 3. Fruit weight significantly increased with increasing the rates of potassium fertilization, however, the highest significant values obtained from the highest rate (K_2) as compared with the lowest values which obtained from the control (K_0) in both seasons.

Regardless of the different potassium fertilization rates, the data presented in Table 3 show the effect of rootstock type on fruit weight of the experimental trees. The results generally indicated that fruit weight of the trees grafted onto *D. kaki* was significantly higher than those on *D. lotus*, in both seasons and at harvest date.

Considering the interaction effect between rootstock and potassium fertilization rate, the data revealed that K_2 treatment significantly caused the highest weight (g)

Table 3: Effects of potassium fertilization rates and rootstock type on fruit weight, TSS (%), acidity (%) and fruit firmness of "Costata" persimmon trees during 2018 and 2019 seasons

	Fruit weight (g)		TSS (%)		Acidity (%)		Firmness (lb/In^2)	
Treatments	2018	2019	2018	2019	2018	2019	2018	2019
Rootstock (R)								
R_1	131.70[a]	138.58[a]	21.28[b]	22.03[b]	0.39[a]	0.38[a]	20.86[b]	21.37[b]
R_2	98.09[b]	110.45[b]	23.45[a]	25.06[a]	0.27[b]	0.27[b]	23.43[a]	23.90[a]
ANOVA	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.01$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$
Potassium rates (K)								
K_0	96.11[c]	106.43[c]	18.61[c]	19.50[c]	0.42[a]	0.42[a]	22.38[a]	22.06[a]
K_1	110.13[b]	118.38[b]	22.46[b]	24.45[b]	0.35[b]	0.34[b]	22.36[a]	22.55[a]
K_2	138.46[a]	148.75[a]	26.02[a]	26.70[a]	0.23[c]	0.21[c]	22.70[a]	23.29[a]
ANOVA	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.01$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$
C×K								
$R_1 \times K_0$	107.11[c]	112.5[d]	18.13[d]	17.90e	0.49[a]	0.47[a]	20.11[d]	20.51[c]
$R_1 \times K_1$	122.11[b]	131.1[b]	20.81[c]	23.10[cd]	0.41[a]	0.40[a]	20.98[c]	21.15[bc]
$R_1 \times K_2$	165.90[a]	172.15[a]	24.90[b]	25.11[bc]	0.29[a]	0.28[a]	21.50[c]	22.46[ab]
$R_2 \times K_0$	85.11e	100.36f	19.10[d]	21.1[d]	0.35[a]	0.37[a]	22.65[b]	23.62[a]
$R_2 \times K_1$	98.15[d]	105.66e	24.11[b]	25.8[b]	0.29[a]	0.29[a]	23.75[a]	23.96[a]
$R_2 \times K_2$	111.02[c]	125.35[c]	27.14[a]	28.3[a]	0.17[a]	0.15[a]	23.90[a]	24.12[a]
ANOVA	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.01$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$

Means followed by different letters within column indicate significant differences between treatments based on LSD test, R_1: *Diospyros kaki*, R_2: *Diospyros lotus*, K_0: 0 g K_2SO_4/tree, K_1: 500 g K_2SO_4/tree, K_2: 1000 g and K_2SO_4/tree

Table 4: Effects of potassium fertilization rates and rootstock type on fruits total sugars, carotenoids, tannins and vitamin C of "Costata" persimmon trees during 2018 and 2019 seasons

	Total sugars (%)		Carotenoids (mg/100 g f.w)		Tannins (mg tannic acid/ 100 mL fruit juice)		V.C (mg ascorbic acid/ 100 mL fruit juice)	
Treatments	2018	2019	2018	2019	2018	2019	2018	2019
Rootstock (R)								
R_1	15.68[b]	15.78[b]	2.81[b]	3.05[b]	3.14[a]	2.92[a]	18.36[a]	17.53[a]
R_2	16.86[a]	17.08[a]	3.74[a]	3.97[a]	2.51[a]	2.15[a]	11.94[b]	12.45[b]
ANOVA	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.01$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$
Potassium rates (K)								
K_0	14.89[b]	15.50[b]	1.77[c]	2.86[b]	3.64[a]	3.10[a]	17.93[a]	17.33[a]
K_1	16.18[ab]	15.82[b]	3.27[b]	3.27[b]	2.74[b]	2.57[ab]	14.96[b]	14.51[b]
K_2	17.75[a]	17.98[a]	4.77[a]	4.40[a]	2.11[b]	1.95[b]	12.56[c]	13.13[b]
ANOVA	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.01$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$
C×K								
$R_1 \times K_0$	14.33[b]	14.50[b]	1.45[d]	2.59[b]	3.90[a]	3.41[a]	20.50[a]	19.86[a]
$R_1 \times K_1$	15.71[ab]	15.83[b]	2.73[bcd]	2.86[b]	2.98[ab]	2.96[ab]	18.77[ab]	16.97[b]
$R_1 \times K_2$	17.01[ab]	17.03[ab]	4.25[ab]	3.71[b]	2.56[bc]	2.41[abc]	15.82[bc]	15.77[b]
$R_2 \times K_0$	15.46[b]	16.50[ab]	2.10[cd]	3.13[b]	3.38[ab]	2.79[ab]	15.37[c]	14.80[bc]
$R_2 \times K_1$	16.65[ab]	15.82[b]	3.82[abc]	3.68[b]	2.50[bc]	2.18[bc]	11.15[d]	12.06[cd]
$R_2 \times K_2$	18.49[a]	18.93[a]	5.30[a]	5.10[a]	1.66[c]	1.50[c]	9.31[d]	10.50[d]
ANOVA	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.01$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$	$p\leq 0.001$

Means followed by different letters within column indicate significant differences between treatments based on LSD test, R_1: *Diospyros kaki*, R_2: *Diospyros lotus*, K_0: 0 g K_2SO_4/tree K_1: 500 g K_2SO_4/tree K_2: 1000 g and K_2SO_4/tree

of *D. kaki* rootstock 165.90 and 172.15 g in the first and second experimental seasons, respectively. Nevertheless, the lower weight (g) values were recorded with trees receiving K_0 in *D. lotus* rootstock 85.11 and 100.36 g in the first and second seasons, respectively.

As for fruit firmness, potassium fertilization rates had no effects on fruit firmness in both experimental seasons (Table 3). Fruits of trees grafted onto *D. lotus* were firmer than those on *D. kaki* at harvest date, in both seasons. Regarding the interaction effects, data in Table 3 revealed that the K_1 and K_2 caused the highest fruit firmness of the trees grafted on *D. lotus* in both seasons, whereas the lowest value was obtained from K_0 with *D. kaki* rootstock.

Fruit chemical characteristics: Results in Table 3 and 4 revealed that, the effects of rootstock type and different

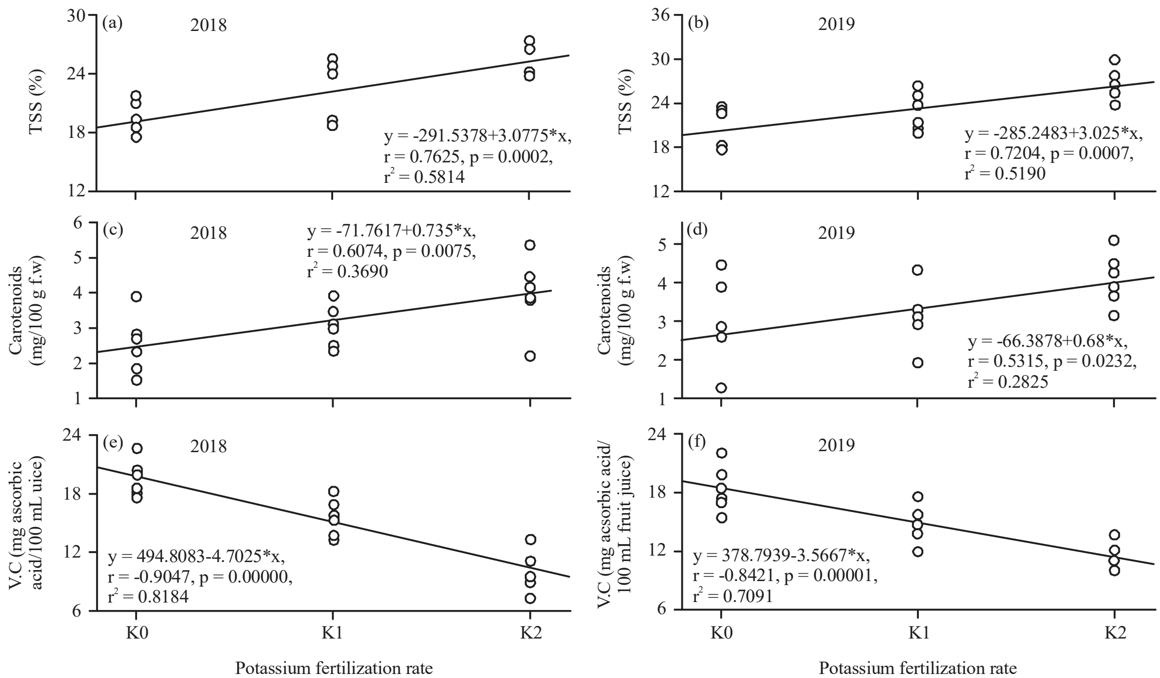

Fig. 3(a-f): Linear regression analysis for relationships between potassium fertilization rate with total soluble solids (TSS) content, fruit skin carotenoids content and fruit juice vitamin C content at harvest date for 'Costata' persimmon trees at harvest during 2018 and 2019 seasons (a) Potassium fertilization: TSS, (b) Potassium fertilization: TSS 2, (c) Potassium fertilization: carotinoide, (d) Potassium fertilization: carotinoide 2, (e) Potassium fertilization: V.C and (f) Potassium fertilization: V.C2

potassium rates on fruit chemical characteristics (TSS, acidity, total sugars, carotenoids, Tannins and vitamin C) of 'Costata' persimmon during 2018 and 2019 seasons. Total Soluble Solid (TSS) (%), total sugars and carotenoids increased significantly with increasing the rates of potassium, however, the highest significant values obtained from the highest rate (K_2) as compared with the lowest values which obtained from the control in both seasons. On the contrary, all treatments (K_1 and K_2) decreased acidity (%), tannins (%) and vitamin C as compared to the control (K_0), however, the lowest significant values obtained from the highest rate (K_2) as compared with the highest values which obtained from the control in both seasons. Figure 3a-f illustrated a linear regression relationship between potassium fertilization rate with TSS, carotenoids and vitamin C as r-values were 0.76, 0.60 and 0.90 in 2018 season. The corresponding values for 2019 were 0.72, 0.53 and 0.84.

Regarding the variation in the effect of the two rootstocks, the data in Table 3 and 4 indicated that *D. lotus* rootstock had significantly higher TSS (%), total sugars and carotenoids and lower acidity (%) and vitamin C than *D. kaki*. In addition, Fig. 4a-f illustrated a linear regression relationship between rootstock with TSS, carotenoids and vitamin C as r-values were 0.32, 0.47 and 0.75 in 2018 season. The corresponding values for 2019 were 0.36, 0.43 and 0.73.

As for the interaction between rootstock type and different potassium rates on fruit chemical characteristics (TSS, acidity, total sugars, carotenoids, Tannins and vitamin C), it was shown that K_2 treatment significantly caused the highest increase in the TSS (%), total sugars and carotenoids of *D. kaki* rootstock. Nevertheless, the highest acidity (%), tannins (%) and vitamin C values were recorded with trees receiving K_0 in *D. lotus* rootstock (Table 3, 4).

Leaf mineral content: The effects of different potassium rates and rootstock type on leaf mineral content of 'Costata' persimmon during 2018 and 2019 seasons are shown in Table 5 and 6. The results generally indicated that different potassium fertilization rates did not significantly affect leaf nitrogen, leaf phosphorus in the first season and calcium in the second season. However, leaf potassium, magnesium, zinc, manganese, iron content in both seasons and leaf phosphorus content in the second season were significantly increased and leaf calcium content decreased in the first season with increasing the rate of potassium fertilization. The application

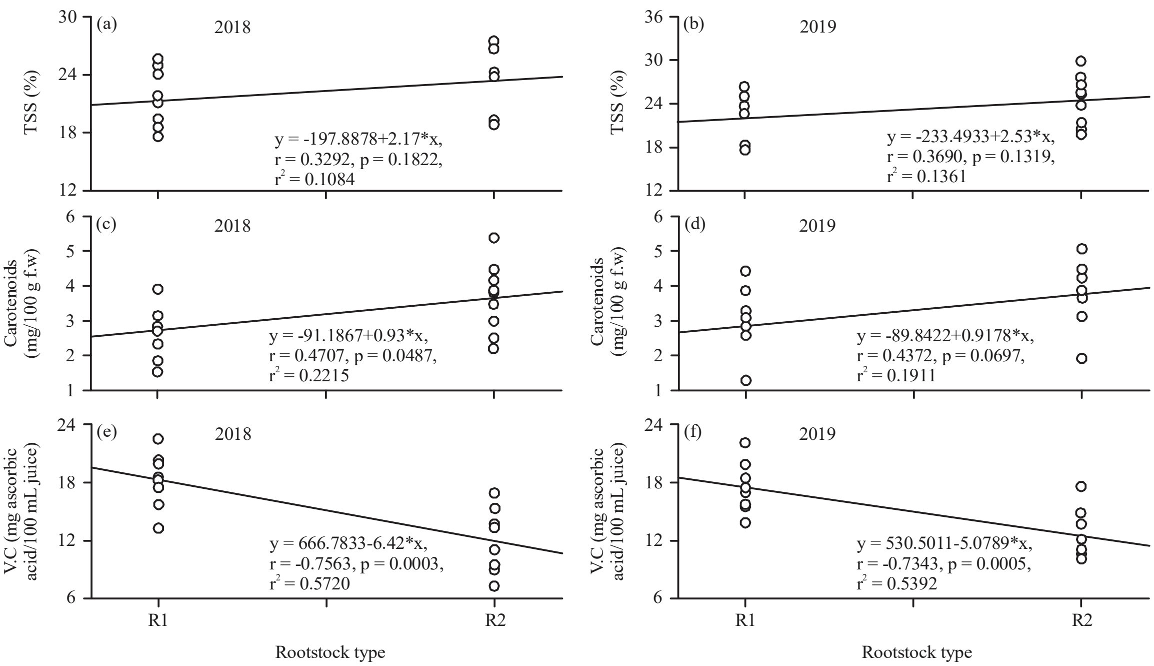

Fig. 4(a-f): Linear regression analysis for relationships between rootstock type with total soluble solids (TSS) content, fruit skin carotenoids content and fruit juice vitamin C content at harvest date for 'Costata' persimmon trees at harvest during 2018 and 2019 seasons, (a) Rootstock type: TSS, (b) Rootstock type: TSS2, (c) Rootstock type: carotinoide, (d) Rootstock type: carotinoide 2, (e) Rootstock type: V.C and (f) Rootstock type: V.C2

Table 5: Effects of potassium fertilization rates and rootstock type on leaf nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca) of "Costata" persimmon trees during 2018 and 2019 seasons

	N (%)		P (%)		K (%)		Ca (%)	
Treatments	2018	2019	2018	2019	2018	2019	2018	2019
Rootstock (R)								
R_1	2.28^{a}	2.67^{a}	0.22^{b}	0.23^{b}	1.39^{a}	1.29^{a}	2.52^{a}	2.49^{a}
R_2	1.81^{b}	2.24^{a}	0.28^{a}	0.28^{a}	1.65^{a}	1.54^{a}	1.43^{b}	1.45^{b}
ANOVA	$p\leq0.001$	$p\leq0.001$	$p\leq0.01$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$
Potassium rates (K)								
K_0	1.90^{a}	2.33^{a}	0.24^{a}	0.24^{b}	0.96^{c}	1.21^{c}	2.50^{a}	2.30^{a}
K_1	2.03^{a}	2.38^{a}	0.25^{a}	0.26^{ab}	1.42^{b}	1.45^{b}	1.96^{b}	1.93^{a}
K_2	2.20^{a}	2.65^{a}	0.26^{a}	0.27^{a}	2.18^{a}	1.57^{a}	1.48^{b}	1.69^{a}
ANOVA	$p\leq0.001$	$p\leq0.001$	$p\leq0.01$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$
C×K								
R_1 X K_0	2.11^{a}	2.47^{abc}	0.21^{a}	0.22^{a}	0.92^{d}	1.20^{d}	3.05^{a}	2.76^{a}
R_1 X K_1	2.23^{a}	2.66^{ab}	0.22^{a}	0.23^{a}	1.3^{cd}	1.32^{c}	2.52^{ab}	2.50^{ab}
R_1 X K_2	2.50^{a}	2.88^{a}	0.23^{a}	0.25^{a}	1.96^{ab}	1.35^{c}	2.01^{bc}	2.23^{ab}
R_2 X K_0	1.70^{a}	2.19^{bc}	0.27^{a}	0.27^{a}	1.00^{cd}	1.23^{d}	1.95^{bc}	1.84^{bc}
R_2 X K_1	1.83^{a}	2.11^{c}	0.29^{a}	0.29^{a}	1.55^{bc}	1.59^{b}	1.40^{cd}	1.36^{c}
R_2 X K_2	1.90^{a}	2.43^{abc}	0.30^{a}	0.30^{a}	2.40^{a}	1.80^{a}	0.95^{d}	1.15^{c}
ANOVA	$p\leq0.001$	$p\leq0.001$	$p\leq0.01$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$

Means followed by different letters within column indicate significant differences between treatments based on LSD test, R_1: *Diospyros kaki*, R_2: *Diospyros lotus*, K_0: 0 g K_2SO_4/tree, K_1: 500 g K_2SO_4/tree, K_2: 1000 g and K_2SO_4/tree

of potassium at 500 g K_2SO_4/tree (K_2) was more effective and recorded the highest significant leaf mineral content values as compared with control (K_0).

Quite aside from potassium fertilization rates, the data in Table 5 and 6 indicated that leaf nitrogen in the first season and calcium content values of trees grafted onto *D. kaki* were the highest, whereas leaf phosphorus, zinc and manganese content values were the lowest, in both seasons. Moreover, no significant differences were found in leaf nitrogen content in the second season, potassium, magnesium and iron content, in both seasons.

Table 6: Effects of potassium fertilization rates and rootstock type on leaf magnesium (Mg), zinc (Zn), manganese (Mn) and iron (Fe) of "Costata" persimmon trees during 2018 and 2019 seasons

	Mg (%)		Zn (ppm)		Mn (ppm)		Fe (ppm)	
Treatments	2018	2019	2018	2019	2018	2019	2018	2019
Rootstock (R)								
R_1	0.38^a	0.37^a	26.66^b	28.55^b	43.33^b	43.66^b	141.66^a	147.66^a
R_2	0.37^a	0.36^a	30.66^a	33.00^a	49.00^a	48.00^a	141.00^a	147.66^a
ANOVA	$p\leq0.001$	$p\leq0.001$	$p\leq0.01$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$
Potassium rates (K)								
K_0	0.32^c	0.33^c	22.50^c	23.83^c	41.50^c	41^c	136.00^c	144.5^b
K_1	0.38^b	0.36^b	27.00^b	32.00^b	46.00^b	44^b	140.50^b	149.0^a
K_2	0.42^a	0.41^a	36.50^a	36.50^a	51.00^a	52.5^a	147.50^a	149.5^a
ANOVA	$p\leq0.001$	$p\leq0.001$	$p\leq0.01$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$
C×K								
$R_1\times K_0$	0.32^d	0.34^d	21^e	0.34^a	40^d	40^d	138^{ab}	146^{bc}
$R_1\times K_1$	0.39^c	0.36^c	25^d	0.36^a	43^c	42^d	135^{bc}	148^{ab}
$R_1\times K_2$	0.43^a	0.42^a	34^b	0.42^a	47^b	49^b	132^c	149^{ab}
$R_2\times K_0$	0.33^d	0.33^d	24^d	0.33^a	43^c	42^d	140^a	143^c
$R_2\times K_1$	0.38^c	0.37^c	29^c	0.37^a	49^b	46^c	138^{ab}	150^a
$R_2\times K_2$	0.41^b	0.40^b	39^a	0.40^a	55^a	56^a	142^a	150^a
ANOVA	$p\leq0.001$	$p\leq0.001$	$p\leq0.01$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$	$p\leq0.001$

Means followed by different letters within column indicate significant differences between treatments based on LSD test, R_1: *Diospyros kaki*, R_2: *Diospyros lotus*, K_0: 0 g K_2SO_4/tree, K_1: 500 g K_2SO_4/tree, K_2: 1000 g and K_2SO_4/tree

As for the interaction between rootstock type and different potassium rates on leaf mineral content, it was shown that K_2 treatment significantly caused the highest increase in leaf potassium, manganese, iron content in both seasons and zinc content in the first season of *D. lotus* rootstock. Nevertheless, the highest leaf calcium content values were recorded with the trees receiving K_0 in *D. lotus* rootstock (Table 5, 6).

DISCUSSION

Results from this study showed that average shoot lengths significantly increased in response to the potassium fertilizer application. The application of potassium K_2 showed the highest significant shoot length as compared with the lowest values from control treatment, in the first and second seasons, respectively. The present results are inconsistent with those obtained by Kassem[20] on 'Costata' persimmon, El-Seginy[21] on 'Canino' apricot, as well as El-Salhy *et al.*[22] on 'Balady' mandarin. The stimulating effects of fertilizing persimmon with potassium on the studied vegetative growth parameter (shoot length) could be attributed to the greatly improved photosynthetic process and nitrogen metabolism. Also, the increase in leaves numbers, which provided more photosynthates. The influence of potassium on the metabolism and its stimulating effect on enzyme activity and photosynthetic pigments promotes vegetative growth of plant[23]. Besides, the average shoots lengths affected by rootstocks, being largest on *D. kaki*, while smallest on *D. lotus*. These results are in agreement with Kassem[20], who reported that trees on *D. kaki* were larger and had more vigorous roots than trees on *D. lotus*. Omarov and Erokhina[24] found that the tree on *D. lotus* had a better root system and strong fibrous roots than the tree on *D. virginiana*.

In both seasons, all potassium treatments significantly increased the percentages of fruit set and fruit retention at harvest date as compared with control. The highest potassium level recorded the highest fruit set and fruit retention compared with control. The mentioned results were in line with those previously obtained by Attala[25] on 'Anna' apple, Kassem[20] on 'Costata' and Kassem and El-Seginy[26] on 'Florida Prince' peach and El-Salhy *et al.*[22] on 'Balady' mandarin. The percentages of fruit set and fruit retention of trees grafted onto *D. kaki* were higher than that of trees grafted onto *D. lotus* rootstock. Tetsumura *et al.*[27] found that early fruit drop, an undesirable trait for fruit cultivation, rarely occurred in trees grafted onto MKR1 (dwarfing rootstock). Early fruit drop of Japanese persimmon trees is promoted by vigorous shoot growth and incidence of water sprouts[28], both of which are inhibited by MKR1 a dwarfing rootstock.

In our results, the two level of potassium fertilizer significantly increased the yield as compared with the control, in both seasons and the highest significant yield values resulted from the highest rate of potassium fertilizer. This increase could be attributed to the significant increase in fruit weight obtained in both seasons. Similar results were also reported by numerous investigators, such as: Kassem[20], El-Seginy[21], El-Salhy *et al.*[22], Kassem and El-Seginy[26], Meyer[29], Reidel *et al.*[30] and Teixeira *et al.*[31]. In addition, the increased in yield following increased potassium fertilization rates might be explained by the stimulation effect of K fertilizers on buds fertility index, which resulted in a markedly significant yield increase[32,33]. On the contrary, Muhammad *et al.*[33] reported that potassium rate applications did not show any significant effect on yield. The yield of persimmon trees grafted onto *D. kaki* was higher than that on *D. lotus*. This result is inconsistent with Kassem[20], who found that the yield of the trees grafted onto *D. kaki* was greater than that on *D. lotus*.

In this study, fruit weight significantly increased with increasing the rates of potassium fertilization. These results are in line with those previously reported by Kassem[20], El-Salhy *et al.*[22], Teixeira *et al.*[31] and El-Ansary[34]. Potassium plays an important role for growth and fruit production as it regulated water relations, stimulates enzymes activity and transport into cellular membranes and activates translocation of photosynthates into fruits[35]. Fruit weight of the trees grafted onto *D. kaki* was significantly higher than those on *D. lotus*, in both seasons and at harvest date. These findings were previously reported by several investigators such as Tetsumura *et al.*[2], Kassem[20], Autio[36] and Webster and Wertheim[37]. They all agreed that the fruit weight values varied depending on rootstock[2].

The results of the recent study indicated that the high potassium treatment (K_2) significantly caused the highest increase in the TSS (%), total sugars and carotenoids of *D. kaki* rootstock. Nevertheless, the highest acidity (%), tannins (%) and vitamin C values were recorded with trees receiving K_0 in *D. lotus* rootstock. Rootstocks are well known to affect all quality parameters of fruits[36,37]. Increased sugar accumulation in potassium fertilized trees might be attributed to relocation of photosynthates between the source and the sink providing a higher allocation of sugars to the fruits[35,38]. Potassium is essential for proper development and quality of fruits such as apricot, olive, peach and strawberry[39-42]. Therefore, the sufficient potassium application enhances the ascorbic acid contents[43], color and fruit quality[44,45] by increasing fruits weights, sugar and anthocyanins concentration, firmness and potassium uptake[46]. Leaf potassium, magnesium, zinc, manganese, iron content in both seasons and leaf phosphorus content in the second season were significantly increased with increasing rate of potassium fertilization. The positive effect of potassium fertilization on nutrient status of fruit trees were previously reported by Kassem[20], El-Salhy *et al.*[22], Lu *et al.*[47], Abd-Allah[48], Abdel-Rahman[49], Aly *et al.*[50] and Quaggio *et al.*[51]. Leaf nitrogen in the first season and calcium content values of trees grafted onto *D. kaki* were the highest, whereas leaf phosphorus, zinc and manganese content values were the lowest, in both seasons. In addition, no significant differences were found in leaf nitrogen content in the second season, potassium, magnesium and iron content, in both seasons. These results were supported with the findings of Kassem[20,52] working on 'Costata' persimmon trees.

CONCLUSION

It is concluded that potassium fertilization at 1000 g/tree was more effective application for the persimmon trees grafted on *D. kaki* which is a better choice for more shoot growth, fruit set and retention (%), yield and fruit weight compared with the trees grafted on *D. lotus*. However, the trees grafted on *D. lotus* have fruit with more quality.

SIGNIFICANCE STATEMENT

This study discovers the synergistic effect of potassium fertilization rate and rootstock type that can be beneficial for improving shoot growth, fruit set and retention (%), yield, fruit weight and fruit quality. This study will help the researcher to uncover the critical area of controlling June drop and pre-harvest fruit drop, especially in a parthenocarpic cultivar that many researchers were not able to explore. Thus, a new theory on these two factors combination may be arrived at.

REFERENCES

1. Kassem, H.A., A.M. El-Kobbia., H.A. Marzouk and M.M. El-Sebaiey, 2010. Effect of foliar sprays on fruit retention, quality and yield of Costata persimmon trees. Emir. J. Food Agric., 22: 259-274.
2. Tetsumura, T., S. Ishimura, T. Hidaka, E. Hirano and H. Uchida *et al.*, 2015. Growth and production of adult Japanese persimmon (*Diospyros kaki*) trees grafted onto dwarfing rootstocks. Sci. Hortic., 187: 87-92.
3. Nimbolkar, P.K., C. Awachare, Y.T.N. Reddy, S. Chander and F. Hussain, 2016. Role of rootstocks in fruit production-a review. J. Agric. Eng. Food Technol., 3: 183-188.
4. Reddy, Y.T.N., R.M. Kurian, P.R. Ramachander, G. Singh and R.R. Kohli, 2003. Long-term effects of rootstocks on growth and fruit yielding patterns of 'Alphonso' mango (*Mangifera indica* L.). Sci. Hortic., 97: 95-108.
5. Edward, J.C. and G. Shankar, 1964. Rootstock trial for guava (*Psidium guajava* L.). Allahabad Farmer, 38: 249-250.
6. Sharma, D.D. and J.S. Chauhan, 1990. Effect of different rootstocks and training systems on growth and cropping of 'delicious' apples. Indian J. Hortic., 47: 365-370.

7. Singh, R.N. and P.N. Gupta, 1972. Rootstock problem in stone fruits and potentialities of wild species of Prunus found in India. Punjab Hortic. J., 12: 157-175.
8. Hansen, C., B. Lownrbery and C. Hesse, 1956. Nematode resistance in peaches: Resistance to two widespread species of root-knot nematode ranged from almost immunity to none in peach seedling study. California Agric., 10: 5-11.
9. Tagliavini, M. and B. Marangoni, 2002. Major nutritional issues in deciduous fruit orchards of Northern Italy. HortTechnology, 12: 26-31.
10. Arquero, O., D. Barranco and M. Benlloch, 2006. Potassium starvation increases stomatal conductance in olive trees. HortScience, 41: 433-436.
11. Saykhul, A., T. Chatzistathis, C. Chatzissavvidis, S. Koundouras, I. Therios and K. Dimassi, 2013. Potassium utilization efficiency of three olive cultivars grown in a hydroponic system. Sci. Hortic., 162: 55-62.
12. Zekri, M. and T. Obreza, 2013. Potassium (K) for citrus trees. Document No. SL381, Department of Soil and Water Sciences, UF/IFAS Extension Service, University of Florida, Gainesville, FL., USA.
13. Malik, C.P. and M.B. Singh, 1980. Plant Enzymology and Histo-enzymology: A Text Manual. Kalyani Publishers, New Delhi, India, Pages: 286.
14. Britton, G., S. Liaaen-Jensen and H. Pfander, 2004. Carotenoids: Handbook. Birkhäuser-Verlag, Basel, Switzerland, ISBN: 978-3-7643-6180-8, Pages: 647.
15. AOAC., 2012. Official Methods of Analysis of AOAC International. 19th Edn., AOAC International, Gaithersburg, MD., USA.
16. Evenhuis, B. and P.W. de Waard, 1980. Principle and practices in plant analysis. FAO Soils Bull., 38: 152-163.
17. Evenhuis, B., 1976. Nitrogen determination. Department of Agricultural Research, Royal Tropical Institute, Amsterdam, The Netherlands.
18. Murphy, J. and J.P. Riley, 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta, 27: 31-36.
19. Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2nd Edn., McGraw Hill Book Co., New York, USA., ISBN-13: 9780070609266, Pages: 633.
20. Kassem, H.A., 2002. Response of Costata persimmon trees to different rootstocks and NK fertilization. I. Growth, yield and leaf mineral content. J. Adv. Agric. Res., 7: 749-760.
21. El-Seginy, A.M., 2006. Response of “Canino” apricot trees to different irrigation and potassium treatments. Alexandria Sci. Exchange J., 27: 64-75.
22. El-Salhy, A.M., H.A. Abdel-Galil, E.F.M. Badawy and E.A. Abou-Zaid, 2017. Effect of different potassium fertilizer sources on growth and fruiting of Balady Mandarin trees. Assiut J. Agric. Sci., 48: 202-213.
23. Tausz, M., W. Trummer, A. Wonisch, W. Goessler, D. Grill, M.S. Jimenez and D. Morales, 2004. A survey of foliar mineral nutrient concentrations of *Pinus canariensis* at field plots in Tenerife. For. Ecol. Manage., 189: 49-55.
24. Omarov, M.D. and A.I. Erokhina, 1989. The distribution of the persimmon root system in the soil in relation to rootstocks. Subtropicheskie kul'tury, 3: 78-82.
25. Attala, E.S., 1997. Effect of potassium fertilization on 'Anna' apple trees grown in sandy soils of Egypt. Egypt. J. Agric. Res., 75: 1069-1080.
26. Kassem, H.A. and A.M. El-Seginy, 2002. Response of Florida Prince peach trees to soil and foliar application of potassium. J. Adv. Agric. Res., 7: 103-116.
27. Tetsumura, T., S. Ishimura, T. Hidaka, E. Hirano, S. Kuroki, Y. Uchida and C. Honsho, 2013. MKR1, a dwarfing rootstock for kaki, decreases early fruit drop. Acta Hortic., 996: 257-263.
28. Choi, S.T., S.C. Kim, D.S. Park and S.M. Kang, 2008. Tree growth and physiological fruit drop of 'Hachiya' persimmon on *D. kaki* and *D. lotus* rootstocks. Acta Hortic., 772: 345-349.
29. Meyer, R.D., 1999. Potassium fertilizer regimes on almond. Proceedings of the 27th Annual Almond Industry Conference, (AIC'99), Almond Board of California, Modesto, CA., USA., pp: 111-119.
30. Reidel, E.J., P.H. Brown, R.A. Duncan and S.A. Weinbaum, 2001. Almond productivity as related to tissue potassium. Better Crops, 85: 21-23.
31. Teixeira, L.A.J., J.A. Quaggio, H. Cantarella and E.V. Mellis, 2011. Potassium fertilization for pineapple: Effects on plant growth and fruit yield. Rev. Bras. Fruticult., 33: 618-626.
32. Ruiz, R., 2006. Effects of different potassium fertilizers on yield, fruit quality and nutritional status of 'Fairlane' nectarine trees and on soil fertility. Acta Hortic., 721: 185-190.
33. Muhammad, S., B.L. Sanden, S. Saa, B.D. Lampinen and D.R. Smart *et al*., 2018. Optimization of nitrogen and potassium nutrition to improve yield and yield parameters of irrigated almond (*Prunus dulcis* (Mill.) DA webb). Sci. Hortic., 228: 204-212.
34. El-Ansary, D.O., 2015. Effects of seasonal deficit irrigation, potassium fertilization and bunch thinning on growth, yield and quality of flame seedless grapes. Alexandria J. Agric. Sci., 62: 11-30.
35. Mpelasoka, B.S., D.P. Schachtman, M.T. Treeby and M.R. Thomas, 2003. A review of potassium nutrition in grapevines with special emphasis on berry accumulation. Aust. J. Grape Wine Res., 9: 154-168.
36. Autio, W.R., 1991. Rootstock affect ripening and other qualities of 'delicious' apples. J. Am. Soc. Hortic. Sci., 116: 378-382.
37. Webster, A.D. and S.J. Wertheim, 1993. Comparisons of species and hybrid rootstocks for European plum cultivars. J. Hortic. Sci., 68: 861-869.

38. Santesteban, L.G., C. Miranda and J.B. Royo, 2011. Regulated deficit irrigation effects on growth, yield, grape quality and individual anthocyanin composition in *Vitis vinifera* L. cv. 'Tempranillo'. Agric. Water Manage., 98: 1171-1179.
39. Mimoun, M.B., J.B. Yahmed and B. Gaaliche, 2017. Effect of foliar potassium application on fruit quality of fig cv. Bouhouli in the North West of Tunisia. Proceedings of the 18th International Plant Nutrition Colloquium, August 19-24, 2017, Copenhagen, Denmark, pp: 777-778.
40. Saykhul, A., T. Chatzistathis, C. Chatzissavvidis, I. Therios and G. Menexes, 2016. Root growth of cultivated and "wild" olive in response to potassium mineral nutrition. J. Plant Nutr., 39: 1513-1523.
41. Song, M., S. Wang, L. Chai, S. Zhang and Y. Shen, 2017. Characterization of an ABA-induced and K^+ channel gene *FaKAT1* that regulates strawberry fruit ripening. J. Plant Growth Regul., 36: 312-322.
42. Dbara, S., K. Lahmar and M.B. Mimoun, 2018. Potassium mineral nutrition combined with sustained deficit irrigation to improve yield and quality of a late season peach cultivar (*Prunus persica* L. cv 'Chatos'). Int. J. Fruit Sci., 18: 369-382.
43. Zareei, E., T. Javadi and R. Aryal, 2018. Biochemical composition and antioxidant activity affected by spraying potassium sulfate in black grape (*Vitis vinifera* L. cv. Rasha). J. Sci. Food Agric., 98: 5632-5638.
44. Neilsen, G.H., D. Neilsen, L.C. Herbert and E.J. Hogue, 2004. Response of apple to fertigation of N and K under conditions susceptible to the development of K deficiency. J. Am. Soc. Hortic. Sci., 129: 26-31.
45. Nava, G., A.R. Dechen and G.R. Nachtigall, 2007. Nitrogen and potassium fertilization affect apple fruit quality in Southern Brazil. Commun. Soil Sci. Plant Anal., 39: 96-107.
46. Solhjoo, S., A. Gharaghani and E. Fallahi, 2017. Calcium and potassium foliar sprays affect fruit skin color, quality attributes and mineral nutrient concentrations of 'Red delicious' apples. Int. J. Fruit Sci., 17: 358-373.
47. Lu, J., F. Chen, D. Liu, Y. Wan, C. Yu and Y. Wang, 2002. Potassium chloride on growth of citrus tree, yield and quality of fruits. Soil Fertilizers, 4: 34-39.
48. Abd-Allah, A.S.E., 2006. Effect of spraying some macro and micro nutrients on fruit set, yield and fruit quality of Washington Navel orange trees. J. Applied Sci. Res., 2: 1059-1063.
49. Abdel-Rahman, M.M., 2010. Effect of different sources of nitrogen and potassium fertilizers on growth and fruiting of Balady mandarin trees. Ph.D. Thesis, Faculty of Agriculture, Assiut University, Egypt.
50. Aly, O.A., A.M. El-Salhy, H.A. Abdel-Galil and S.M. El-Masry, 2011. Effect of different potassium fertilizer sources and antioxidant application on vegetative growth, nutrient status and fruiting of Balady mandarin trees. Assiut J. Agric. Sci., 42: 317-331.
51. Quaggio, J.A., D. Mattos Jr. and R.M. Boaretto, 2011. Sources and rates of potassium for sweet orange production. Sci. Agric., 68: 369-375.
52. Kassem, H.A., 1996. Effect of four apple rootstocks on Anna and Ein Shemer apple cultivars. 1. Tree size, yield and leaf mineral content. Alexandria J. Agric. Res., 41: 285-297.