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**Original Article**

# Physicochemical Traits of Younesi tangerine (*Citrus reticulata*) on Different Rootstocks

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## Abstract

The aim of this study was to determine organic acids and individual sugars in fruit of Younesi tangerine (*Citrus reticulata*) on different rootstocks. On other hand, the purpose of this study was to identify the rootstock that could produce the highest amount of sugars. The content of individual sugars and organic acids in fruits were determined by HPLC. Total acidity (TA), total soluble solids (TSS) and pH value of juice was also evaluated. The results showed that, the highest of total sugars (126.94mg/ mL), pH (3.40), TSS (11.30%), TSS/TA (10.00) and juice (55.62%) were in fruit of Younesi tangerine (*Citrus reticulata*) grafting on the Orlando tangelo rootstock. According to results, the amount of citric acid (15.20mg/mL) of Younesi tangerine grafted on Flying Dragon was higher than those of other rootstocks. Among the sugars, sucrose was determined in the highest concentration in all investigated fruits. The results of correlation showed that there were a high positive correlation between the amount of TSS and sucrose. Results showed that Orlando tangelo rootstock had an important role in increasing of sugars, pH, TSS, as well as TSS/TA. Finally based on the obtained results it can be concluded that although the concentration of sugars and organic acids is strongly related to the genotype of fruit, it seems that rootstocks affect the amount of sugars and organic acids.

**Keywords:** Chemical characteristics, Physical characteristics, Rootstocks, Younesi tangerine.

## Introduction

Younesi tangerine widely grown today probably originated from nucellar tissue of ponkan tangarine. Although it is a popular cultivar, no studies have been recorded on individual sugars and acids of Younesi tangerine.

Fructose, glucose and sucrose are three major sugars of citrus fruits. Sucrose is known as the dominant sugar in citrus fruit and is plentiful. Sugars usually display 80% of the total soluble solids of juice [1]. Soluble solids are mixture of organic acids and sugars that applied as an index of maturity and taste quality [2].Ascorbic acid is an antioxidant and exhibits a key functionin the reduction of diseases.

Ratio of sugars to acids affects the flavor of citrus fruit and has been considered as quality indicator by both fresh consumption group and juice factories [3]. Citrus juice is a fantastic resource of sugars and acids. The amount of citrus sugars is changeable and is dependent on the rootstock [4], cultivar [5] and etc.A number of researches have indicated that the rootstocks can influence the physicochemical traits of Younesi tangerine [6].

Mashayekhi *et al.* [7] showed that rootstocks can influence total sugar, glucose and sucrose content in fruits of Parson Brown and Mars Oranges. They found that the highest total sugar was with trees of Parson Brown and Mars Oranges grafted on Rough lemon rootstock. Navarro *et al.* [8] showed that rootstocks can influence on total sugar, glucose and sucrose content of Clemenules mandarin. They mentioned that content of total sugar, glucose and

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sucrose of Clemenules mandarin grafted on ‘Carrizo’ citrange and Cleopatra’ mandarin was higher than control trees. Legua *et al*. [9] showed that rootstocks can influence on sucrose, glucose, fructose, citric acid and ascorbic acid content of ‘Clemenules’ mandarin. They found that juice of ‘Clemenules’ mandarin grafted on Cleopatra mandarin had a much higher content of sucrose and fructose than the others rootstocks. However, the highest of citric acid and ascorbic acid were found in ‘Clemenules’ mandarin grafted on Volkameriana rootstock. Legua *et al*. [10] showed that rootstocks can influence on sucrose, glucose, fructose, citric acid and ascorbic acid content of ‘Lane Late’ navel orange. They found that the highest total sugar was with trees grafted on *C. macrophylla* and Cleopatra. Filho *et al*. [11] reported that rootstocks can influence on TSS and TA content of ‘Fallglo’ and ‘Sunburst’ mandarin. They reported that fruits of ‘Fallglo’ and ‘Sunburst’ mandarin on Orlando tangelo had higher TSS/TA ratio and lower acidity. Legua *et al.* [12] showed that rootstocks can influence on total sugars and TA content of ‘Lane late’ navel orange. They found that the highest content of total sugars was in fruits from trees on F&A 418 rootstock. Rafat *et al.* [6] compared Younesi tangerine fruits grafted on three rootstocks and found that Orlando tangelo stimulated higher TSS/TA and lower acidity. Raddatz-Mota*et al*. [13] reported that fruits from trees grafted on Volkamerian lemon and Flying dragon had the highest content of citric acid. They found that rootstocks had no effect on juice, pH, TA, ascorbic acid and sugars content (fructose, glucose and sucrose). Babazadeh and Jaimand [14] found that the highest total sugar was with trees of Clementine mandarin grafted on Orlando tangelo rootstock. Cantuarias-Aviles *et al*. [15] reported the lowest TSS was with trees of Okitsu’ mandarins grafted on Orlando tangelo and the highest TSS was with trees grafted on Flying Dragon. They found that the highest of fruit size and weight were from trees on Orlando tangelo, Carrizo citrange and ‘Cravo FCAV’ Rangpur lime whereas smallest fruits were from trees grafted on the Flying Dragon and ‘FCAV’ trifoliates. Cantuarias-Aviles *et al.* [16] reported that fruits of ‘FolhaMurcha’ sweet orange on Flying Dragon had higher TSS and TA, but lower juice.Gonzatto *al.* [17] reported that trees of ‘Oneco’ mandarin grafted on Flying Dragon, Swingle citrumelo and Troyer citrange rootstocks had the highest of TSS contents. They showed that Flying Dragon had the highest of TA content, whereas fruits on 'Volkamer' lemon had the lowest. They reported that fruits harvested from trees grafted on 'Flying Dragon' had the smallest fruits among the tested rootstocks, while 'Volkamer' lemon produced the largest and heaviest ones. They showed that fruits from trees grown on Flying Dragon were more spherical than those on the other tested rootstocks, which were more oblong. Yonemoto *et al*. [18] observed that 'Shirakawa' satsuma grafted on Flying Dragon had higher soluble solids in comparison to those on Poncirus trifoliata. Noda *et al*. [19] reported that fruits of Satsuma mandarin ‘Yamakawa’ on Flying Dragon had higher TSS and lower weight. Caruso *et al*. [20] observed that the highest of peel-thickness was on Flying Dragon.

In this paper, we compared the Citrus rootstocks with the aim of determining whether the Physicochemical characteristics and fruit production influenced by the rootstocks.

## Materials and Methods

### Chemicals and standards

Standards of fructose, glucose, sucrose, ascorbic acid, citric acid and acetonitrile were purchased from Sigma Chemical Co. (St. Louis, MO). Sodium hydroxideand phosphoric acid were purchased from Merck (Darmstadt, Germany).

### Rootstocks

In 2001, rootstocks were planted at 8×4 m with three replications at Ramsar research station [Latitude 36°54’ N, longitude 50° 40’ E; Caspian Sea climate, average rainfall and temperature were 970 mm and16.25˚C per year respectively; soil was classified as loam-clay, pH ranged from 6.9 to 7]. Sour orange, Swingle citrumelo, Trifoliate orange, Flying dragon, Orlando tangelo and Murcott were used as rootstocks in this experiment (Table 1).

### Preparation of Juice Sample

Fruits were collected from different parts of the same trees in January 2016, early in the morning (6 to 8 am) and only during dry weather. The selection method was on the basis of completely randomized design with six treatments and three replicates. Fruits juice was extracted using juicer. Then, Juices were centrifuged at 15,000 rpm for 20 min at 4 ˚C [9].

**Table 1** Common and botanical names for citrus taxa used as rootstocks and scion.

| Common name | Botanical name | Parents | Category |
|---|---|---|---|
| Younesi (Scion) | *Citrus reticulata cv. Younesi* | Ponkan tangarine | Tangerine |
| Sour orange (Rootstock) | *Citrus aurantium L.* | Mandarin ×Pomelo | Sour orange |
| Swingle citrumelo (Rootstock) | *Swingle citrumelo* | *C.paradisi cv. Duncan ×P.trifoliata (L.) Raf* | Poncirus hybrids |
| Trifoliate orange (Rootstock) | *Poncirus trifoliata (L.) Raf* | Unknown | Poncirus |
| Flying dragon (Rootstock) | *Ponciru strifoliata (L.) Raf cv.Flying dragon* | Unknown | Poncirus |
| Orlando tangelo (Rootstock) | *Citrus sp. cv. Orlando* | *Citrus reticulata cv. Dancy × Citrus paradisi cv. Duncan* | Tangelo |
| Murcott (Rootstock) | *Citrus sp. cv. Murcot* | *C.reticulata× C.sinensis* | Tangor |

Juice analyses technique

The total titratable acid was determined by titration with sodium hydroxide (0.1 N) and displayed as citric acid percent. Total soluble solids were measured using a refractometer (Kruss, Germany). The pH value was determined using a digital pH meter (Jenway, Model: 3510). Sugars, citric acid and ascorbic acid were measured by HPLC [9].

Analysis of Sugars Using HPLC

The HPLC analysis was performed with a Platin blue system (Knauer, Berlin, Germany) equipped with binary pump and a Refractive Index (RI) detector. The separation was carried out on a Shodex Asahipak NH2 P-50 4E column (250×4.6 mm). Column temperature was maintained at 25 ˚C, and the injection volume for all samples was 10 $\mu$L. Elution was performed isocratically with the mobile phase consisting of 75% (v/v) acetonitrile (eluent A) and 25% (v/v) water (eluent B) at a flow rate of one mL/ min. Identification of sugars was based on retention times of unknown peaks in comparison with standards. The concentration of the sugars was calculated from peak area according to calibration curves. Standard solutions of sugars (fructose, glucose and sucrose) and organic acids (ascorbic acid and citric acid) were prepared by dissolving the required amount of each standard in deionized water. Calibration was performed by injecting the standard three times at four different concentrations. Standard solution of fructose at concentrations of 0, 1.04, 2.08 and 3.12 mg/ mL, used to obtain a standard curve. Standard solutions of glucose at concentrations of 0, 1.41, 2.82 and 3.76 mg/ mL, used to obtain a standard curve. Standard solutions of sucrose at concentrations of 0, 2.97, 5.20 and 10.40 mg/ mL, used to obtain a standard curve. Standard solutions of ascorbic acid at concentrations of 0, 0.22, 0.45 and 0.67 mg/ mL, used to obtain a standard curve. Standard solutions of citric acid at concentrations of 0, 0.20, 0.61 and 1.03 mg/ mL, used to obtain a standard curve. (Fig 1 to 5).

Sugars concentration was estimated from calibration curve and the result was expressed as milligrams of compound per milliliter (mg/ mL).

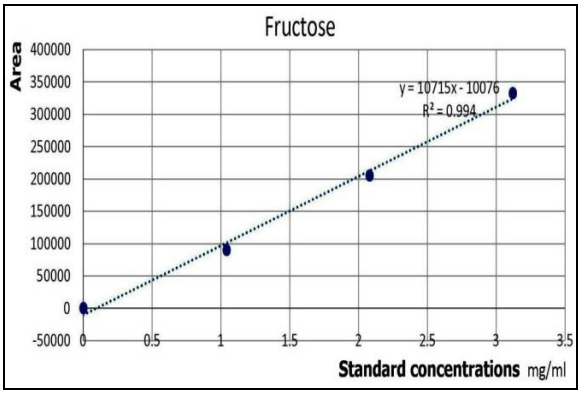


**Fig. 1** The standard curve of fructose

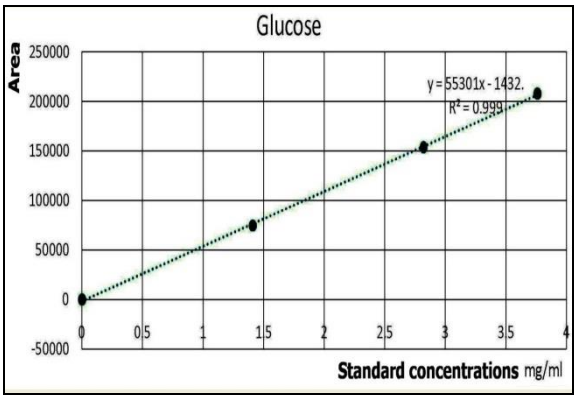


**Fig. 2**The standard curve of glucose

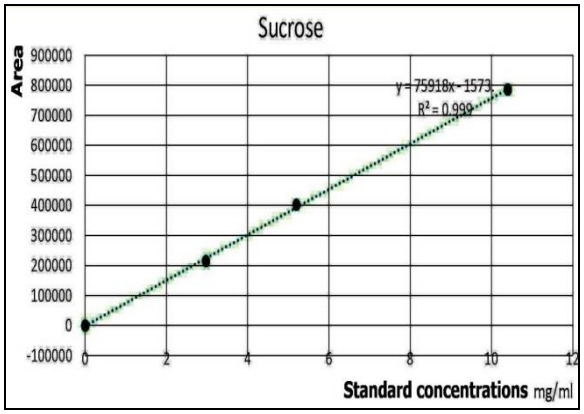


**Fig. 3** The standard curve of sucrose

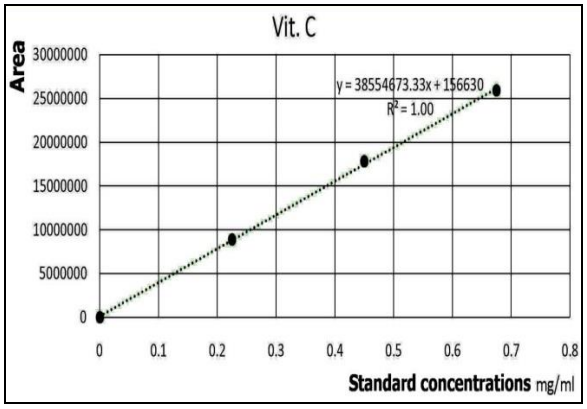


**Fig. 4** The standard curve of ascorbic acid

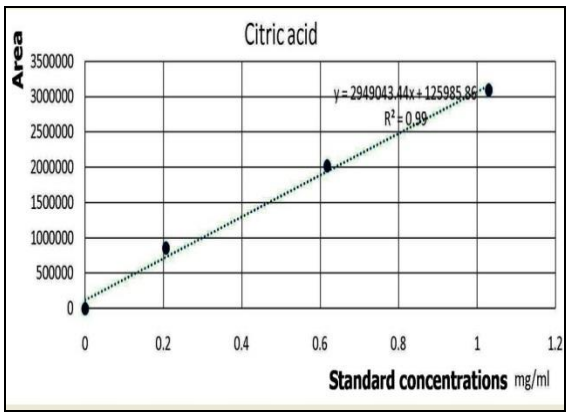


**Fig. 5** The standard curve of citric acid

Analysis of Acids Using HPLC

A same HPLC was applied for this study. It fitted with an ODS-2 C-18 reversed phase column (250 ×4 mm) and a photodiode array (PDA) detector. The column temperature was set on 25˚C.Elution was performed isocratically with the mobile phase consisting of 0.05% (v/v) aqueous phosphoric acid (eluent A) and acetonitrile (eluent B) at a flow rate of 0.6 mL/ min. Chromatograms were recorded at 254 nm for citric acid and ascorbic acid. Acids concentration was estimated from calibration curve and the result was displayed as milligrams of compound per milliliter (mg/ mL). The selection method was on the basis of completely randomized designwith 6 treatments and 3 replicates.

Identification of Sugars and Organic Acids

Identification of sugars and organic acids was based on retention times of unknown peaks in comparison with standards.

Physical Traits of Fruit and Fruit Production (yield)

Fifty fruits were randomly sampled and evaluated for each tree. Fruit physical traits were presented in Table 2. Total dry matter was determined by dehumidify of fruits in an oven at 80˚C. Ash was measured by placing the weighed fruits in a furnace at 560 ˚C. Scale used to determine the fresh weight of fruit. The weight of dried fruit evaluated with oven. Fruit length, fruit diameter and rind thickness were determined using a caliper. Fruit shape index was explained as the ratio of fruit diameter to length. The fruit yield was measured separately for each tree. Fruits for each tree were measured using a digital scale.

Data analysis

SPSS 18 was used for analysis of the data obtained from the experiments. Analysis of variance (ANOVA) was based on the measurements of 20 traits. Mean comparisons were made using Duncan's multiple range tests. Differences were considered to be significant at $P \leq 0.01$. The correlation between pairs of characters was evaluated using Pearson's correlation coefficient.

## Results

Result of the HPLC Analyses

The HPLC analyses of juice allowed to identification of three sugars (fructose, glucose and sucrose) and two acids (citric acid and ascorbic acid) (Fig. 6 to 7, Table 2).

Determination of Sugars

Fructose, glucose and sucrose were three sugars that recognized in this study. Moreover, the amount of total sugars ranged from 83.89 to 126.94 mg/ mL. Sucrose was the dominant sugar in this study. For all the sugars, the differences among rootstocks were found significant on the 1% level. Fruits on

Orlando tangelo showed significantly increase of fructose and glucose and sucrose. Among six rootstocks evaluated, Orlando tangelo indicated the maximum level of sugars (Table 2).

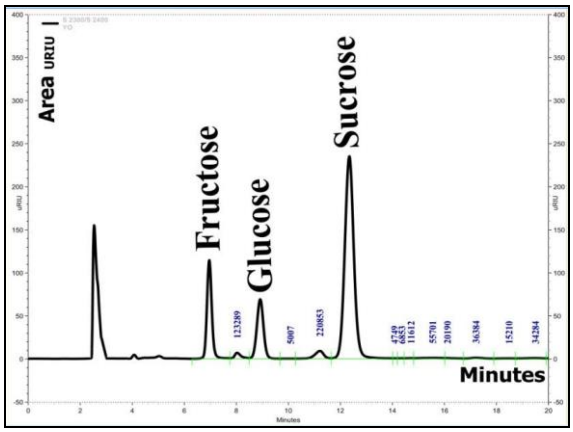


**Fig. 6** The HPLC chromatogram of sugars of Younesi tangerine

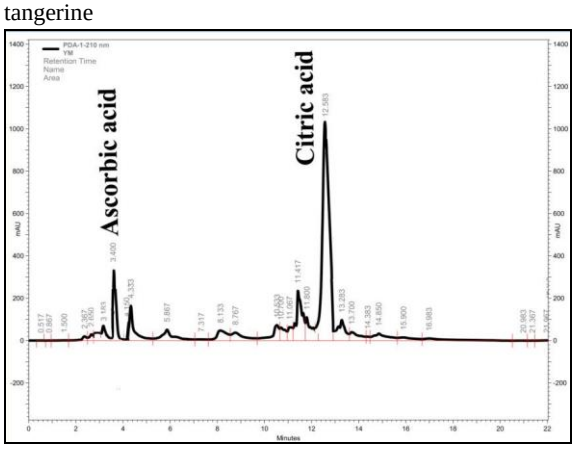


**Fig. 7** The HPLC chromatogram of acids of Younesi tangerine

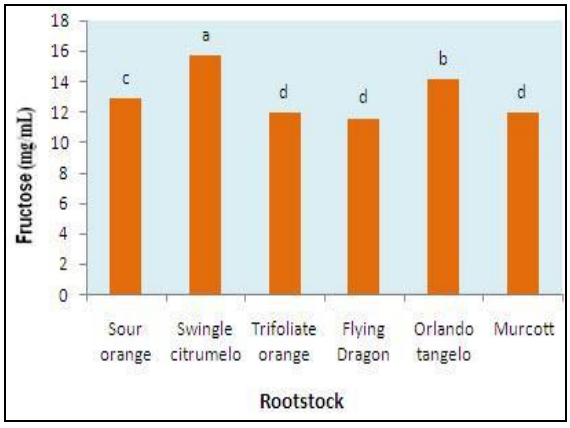


**Fig. 8** The effect of rootstocks on fructose

Determination of Organic Acids

Citric acid and ascorbic acid were two acids that recognized in this study. Moreover, the amount of total acids ranged from 13.79 to 15.53 mg/ mL. There was statistically significant difference on the 5% level in citric acid. The highest citric acid content was found in fruits from trees on Flying Dragon (15.20 mg/ mL) and sour orange (14.84 mg/ mL) while the lowest was found on fruits of Orlando tangelo (13.40 mg/ mL).

The fruits from trees on Trifoliate orange showed ascorbic acid content significantly lower than those on Sour orange and Swingle citrumelo (Table 2).

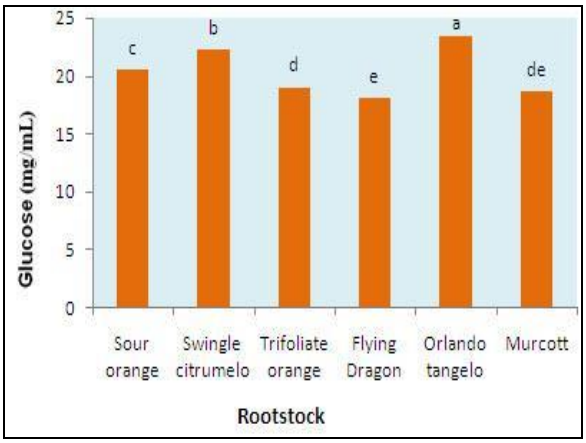


**Fig. 9** The effect of rootstocks on glucose

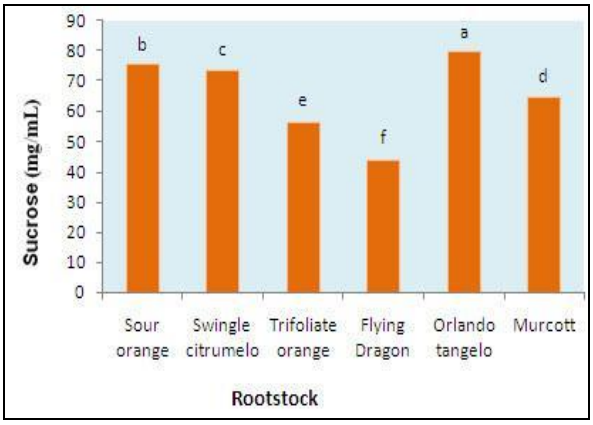


**Fig. 10** The effect of rootstocks on sucrose

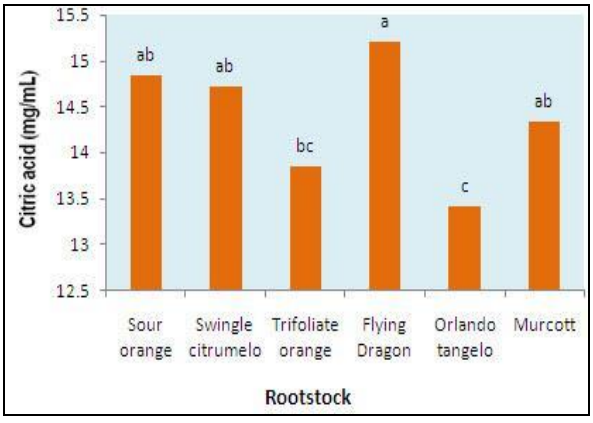


**Fig. 11** The effect of rootstocks on citric acid

Results of Total Titratable Acid (TA)

The amount of total titratable acid ranged from 1.13 to 1.40%. Titratable acid content (TA) was not significantly affected by the rootstocks. The highest percentage of total acids (TA) was in fruits from trees on Flying Dragon, followed by Sour orange, whereas the lowest TA was detected in fruits from trees on Orlando tangelo (Table 2).

Results of pH, TSS, TSS/TA and juice content

The amount of pH, TSS, TSS/TA and juice content were given in Table 2. There was significant difference on the 1% level in the content of pH, TSS, TSS/TA and juice of Younesi tangerine on different rootstocks. Among six rootstocks evaluated, Orlando tangelo indicated the maximum level of pH, TSS, TSS/TA and juice.Despite the little differences recorded for juice percentage on some rootstocks, Younesi tangerine fruits from Orlando tangelo gave the highest juice percentage (55.62 %) while those from Flying Dragon gave the least juice percentage (46.89%). The highest percentage of TSS was for fruits from Orlando tangelo (11.30%), while the least was for those from both Murcott and Flying Dragon (9.85 and 8.30%, respectively). The highest pH was recorded for Orlando tangelo which was significant over those from Flying Dragon and Sour orange. TSS: TA ratio was lowest for Flying Dragon.

Results of Fruit Physical Traits and Fruit Production (yield)

The amount of fruit physical traits and fruit production were given in Table 2. For more the physical traits, the differences among rootstocks were found significant. The results indicated that trees grafted on Orlando tangelo significantly gave the heaviest fruit (143.32g), while those grafted on Flying dragon gave the lightest fruit (94.63g). With respect to fruit length and diameter, fruits from the trees on Orlando tangelo significantly gave the longest fruit (55.79 mm) and diameter (70.30 mm), while the least values were recorded for those grafted on Trifoliate orange (50.38, 65.00 mm) and Flying dragon (44.37, 60.60 mm). Although no significant differences for fruit shape index (Fd/Fl) were observed among the six rootstocks, fruits from trees on Sour orange and Flying dragon gave the highest content. In addition, fruits from the trees on Flying dragon significantly gave the thickest rind (3.30 mm) followed by those from Murcott (3.00 mm) and Sour orange (2.70 mm). Yield of trees grafted on Orlando tangelo and Swingle citrumelo was significantly higher than those of trees grafted on the other rootstocks. Trees grafted on Sour orange, Murcott and Trifoliate orange gave intermediate yield, whereas trees on Flying dragon rootstock gave the lowest yield.

## Discussion

According to our results, fruits of trees grafted on Orlando tangelo had higher TSS/TA and lower acidity that was agreed to work of Filho*et al*. [11] on 'Fallglo' mandarin and Rafat *et al.* [6] on mandarin cultivars. In other hand, Our results were agreed to work of Gonzatto *et al.* [17] on 'Oneco' mandarin and Cantuarias-Aviles *et al*.[16] on 'Folha Murcha' sweet orange who found that the highest percentage of total acids (TA) was in fruits from trees on Flying Dragon rootstock. In present work, the highest of fruit size and weight were with trees on Orlando tangelo and the smallest fruits were with trees grafted on the Flying Dragon that was agreed to work of Cantuarias-Aviles *et al*. [15] on 'Okitsu' Satsuma mandarin. Our studies indicated that the fruits harvested from trees on Flying Dragon had the smallest fruit among the tested rootstocks that was agreed to work of Gonzatto *al*. [17] on 'Oneco' mandarin and Noda *et al*. [19] on 'Yamakawa' Satsuma mandarin.Our findings were agreed to work of Caruso *et al*. [20] who observed the highest of peel-thickness with trees grafted on Flying Dragon. Gonzatto *et al.* [17] reported that the fruits from trees grown on Flying Dragon were more spherical than those on the other tested rootstocks which were more oblong. In other hand, Cantuarias-Aviles *et al*. [15], Cantuarias-Aviles *et al*. [16], Gonzatto *et al*. [17], Yonemoto *et al*. [18], Noda *et al*. [19] reported that trees grafted on Flying Dragon had higher TSS which these results were not in line with the results in the present study.

Based on the our results, fruits of trees grafted on different rootstocks had TSS (8.30 to 11.30%), TA (1.13 to 1.40%), TSS/TA (5.92 to 10.00), Fresh fruit weight (94.63 to 143.32g), fruit length (44.37to55.79mm), fruit diameter (60.60 70.30mm), fruit production (13 to 101kg/tree).

**Table 2** Statistical analysis of variation in juice compositions and fruit physical traits of Younesi tangerine on six different rootstocks.

| Compounds | Sour orange | | Swingle citrumelo | | Trifoliate orange | | Flying Dragon | | Orlando tangelo | | Murcott | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SEM | Mean | SEM | Mean | SEM | Mean | SEM | Mean | SEM | Mean | SEM | F value |
| Sugars | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1) Fructose (mg/ ml) | 22.87 bc | 0.29 | 25.68 a | 0.31 | 21.96 c | 0.22 | 21.59 c | 0.25 | 24.10 ab | 0.33 | 21.95 c | 0.26 | ** |
| 2) Glucose (mg/ ml) | 20.48 ab | 0.40 | 22.30 ab | 0.39 | 19.03 b | 0.31 | 18.09 b | 0.28 | 23.43 a | 0.43 | 18.68 b | 0.25 | ** |
| 3) Sucrose (mg/ ml) | 75.31 b | 0.60 | 73.57 b | 0.63 | 56.77 d | 0.58 | 44.21 e | 0.45 | 79.41 a | 0.56 | 64.48 c | 0.53 | ** |
| Total | 118.66 | 1.29 | 121.55 | 1.33 | 97.76 | 1.11 | 83.89 | 0.98 | 126.94 | 1.32 | 105.11 | 1.04 | |
| Organic acids | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1) Citric acid (mg/ ml) | 14.84 ab | 0.44 | 14.72 ab | 0.52 | 13.84 bc | 0.29 | 15.20 a | 0.32 | 13.40 c | 0.26 | 14.33 ab | 0.19 | * |
| 2)Ascorbic acid (mg/ ml) | 0.41 a | 0.02 | 0.40 ab | 0.02 | 0.19 c | 0.01 | 0.33 b | 0.01 | 0.39 ab | 0.02 | 0.34 b | 0.01 | ** |
| Total | 15.25 | 0.58 | 15.12 | 0.66 | 14.03 | 0.42 | 15.53 | 0.44 | 13.79 | 0.40 | 14.67 | 0.32 | - |
| Total titratable acid (%) | 1.35 a | 0.10 | 1.31 a | 0.08 | 1.17 a | 0.06 | 1.40 a | 0.12 | 1.13 a | 0.05 | 1.24 a | 0.07 | ns |
| pH | 2.95 cd | 0.05 | 3.15 bc | 0.08 | 3.35 ab | 0.09 | 2.90 d | 0.07 | 3.40 a | 0.11 | 3.20 ab | 0.06 | ** |
| TSS (%) | 11.10 a | 0.23 | 11.20 a | 0.29 | 9.90 b | 0.19 | 8.30 c | 0.35 | 11.30 a | 0.26 | 9.85 b | 0.24 | ** |
| TSS/TA | 8.22 b | 0.49 | 8.54 b | 0.52 | 8.46 b | 0.37 | 5.92 c | 0.34 | 10.00 a | 0.41 | 7.94 b | 0.25 | ** |
| Juice (%) | 53.56 b | 0.92 | 52.04 b | 0.97 | 47.85 c | 0.78 | 46.89 c | 0.80 | 55.62 a | 0.95 | 50.12 bc | 0.86 | ** |
| Total dry matter (%) | 12.54 b | 0.46 | 13.71 a | 0.57 | 11.16 c | 0.34 | 10.63 c | 0.26 | 12.74 b | 0.32 | 12.32 b | 0.24 | ** |
| Ash (%) | 3.66a b | 0.33 | 4 a | 0.00 | 3 b | 0.00 | 3 b | 0.00 | 3.66 ab | 0.33 | 3 b | 0.00 | ** |
| Fresh fruit weight (g) | 118.26 b | 2.33 | 122.67 b | 2.44 | 103.95 cd | 2.10 | 94.63 d | 2.00 | 143.32 a | 3.00 | 109.86 bc | 2.30 | ** |
| Dry fruit weight [z] (g) | 7.51 b | 0.31 | 8.22 a | 0.42 | 6.36 d | 0.24 | 5.88 e | 0.34 | 7.63 b | 0.32 | 6.68 c | 0.18 | ** |
| Fruit diameter (mm) | 67.10 ab | 1.46 | 68.60 a | 1.30 | 65.00 ab | 1.41 | 60.60 b | 1.26 | 70.30 a | 1.34 | 66.30 ab | 1.38 | ** |
| Fruit length (mm) | 48.62 bc | 1.30 | 52.76 ab | 1.15 | 50.38 bc | 1.26 | 44.37 c | 1.10 | 55.79 a | 1.15 | 50.22 bc | 1.24 | ** |
| Fruit shape index (Fd/Fl) | 1.38 a | 0.09 | 1.30 a | 0.07 | 1.29 a | 0.07 | 1.36 a | 0.08 | 1.26 a | 0.06 | 1.32 a | 0.09 | ns |
| Rind fruit weight [z] (g) | 15.62 ab | 0.57 | 12.43 c | 0.53 | 13.29 bc | 0.63 | 18.33 a | 0.49 | 13.98 bc | 0.41 | 18.01 a | 0.71 | ** |
| Rind thickness (mm) | 2.70 c | 0.15 | 2.3 d | 0.11 | 2.4 d | 0.12 | 3.30 a | 0.09 | 2.5 cd | 0.10 | 3.0 b | 0.14 | ** |
| Fruit production (Kg /tree) | 90 b | 4.5 | 96 ab | 5 | 72 c | 4 | 13 d | 2 | 101 a | 4.8 | 89 b | 3 | ** |

Mean is average of traits applied with three replicates. SEM = standard error of the mean. Results of analysis of variance: ns = not significant, * significant difference at $P \leq 0.05$, ** significant difference at $P \leq 0.01$.Any two means within a row not followed by the same letter are significantly different at $P \leq 0.01$ or $P \leq 0.05$.

[z] For 60g fruit.

**Table 3** Pearson correlation between eight traits in a correlation matrix

| | Fructose | Glucose | Sucrose | Citric acid | Ascorbic acid | TA | pH |
|---|---|---|---|---|---|---|---|
| Glucose | 0.88** | | | | | | |
| Sucrose | 0.71** | 0.84** | | | | | |
| Citric acid | -0.006 | -0.25 | -0.29 | | | | |
| Ascorbic acid | 0.59** | 0.58* | 0.60** | 0.36 | | | |
| TA | -0.14 | -0.24 | -0.27 | 0.92** | 0.31 | | |
| pH | 0.27 | 0.45 | 0.35 | -0.42 | -0.22 | -0.27 | |
| TSS | 0.76** | 0.85** | 0.97** | -0.28 | 0.50* | -0.28 | 0.40 |

*=significant at 0.05, **=significant at 0.01

The value of these results were higher than the results of Rafat *et al.* [6] that reported that fruits of 'Younesi' tangerine had TSS (9.8%), TA (0.93%), TSS/TA (10.97), fresh fruit weight (96.30g), fruit length (51.77mm) , fruit diameter (59.80mm) production (20.30kg/tree) respectively. TA findings provided from this study were higher than the results of Rafat *et al.* [6] on 'Younesi' tangerine reported. Different results may be related to harvesting time, alternate bearing, fertilization, irrigation and environment factors. It was observed that the application of fertilizer and irrigation affected the content of sugars present in crops [21].

Results of Correlation

TA and citric acid showed a high positive correlation with each other. TSS also showed a high positive correlation with sucrose. (Table 3).

The discovery of sucrose -6- phosphate, as an intermediate between UDP- Glucose and sucrose, led to a rapid description of the biosynthetic pathway of sugar compounds. The biosynthetic pathway of sugar compounds in higher plants is as follows:

Photosynthesis→Triose-P → Fructos- 6-phosphate→ Glucose- 6- phosphate→Glucose- 1-phosphate→UDP- Glucose→ Sucrose -6-phosphate→Sucrose → Glucose and Fructose [22].

Reaction pathway catalyzed bysucrose-6-phosphate synthase and sucrose-6-phosphate phosphatase respectively [23]. An increase in the amount of sugars, when Orlando tangelo, used as the rootstock, showed that either the synthesis of Triose-P was enhanced or activities of both enzymes increased.

Studies have shown that plant hormones affect sugars of fruit [24]. On the other hand,the level of plant hormones can also be changed by rootstocks [25].

Considering that Triose-P is necessary for the synthesis of sugars, it can be assumed that there is a specialized function for this molecule and it may be better served by Orlando tangelo.

Differences among rootstocks could be attributed to the differential ability of the rootstocks to absorb water and nutrients and to the physical differences among the root systems[26] and inability to produce, conduct or utilize some endogenous growth promoters such as auxins and giberlins[27].

## Conclusion

In the present study we found that the amount of sugars and acids were significantly impressed by rootstocks and there was a great variation in most of the measured characters among six rootstocks. The present study demonstrated that the relative concentration of sugars and acids was different according to the type of rootstock. Among six rootstocks examined, Orlando tangelo showed the highest content of sugars (126.94 mg/ mL), pH (3.40), TSS (11.30%),TSS/TA (10.00) and juice (55.62%). The lowest of sugars (73.89 mg/ mL), pH (2.90), TSS (8.30%), TSS/TA (5.92) and juice content (46.89%) were produced by Flying dragon. Further research on the relationship between rootstocks and sugars is necessary.

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