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ORIGINAL ARTICLE

The Effect of Rootstocks on the Physicochemical Characteristics and Fruit Production of Clementine Mandarin (*Citrus clementina*)

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ABSTRACT
Studies have shown that some physicochemical characteristics such as fruit juice, TSS and TSS/TA are important for beverage industries. It seems that rootstock has a profound influence on these factors. The goal of the present study is to investigate on rootstocks and physicochemical characteristics. The total titratable acidity was assessed by titration with sodium hydroxide (0.1 N) and ascorbic acid was determined by titration with Potassium iodide. Total soluble solids, were determined using a refractometer. The pH value was measured using a digital pH meter. The density of the juice was measured using a pycnometer. In the chemical characteristics, the amount of TSS / TA ranged from 22.27 to 24.02. It is of interest to point out that juice obtained from Troyer citrange showed the highest content of TSS/TA. As since the TSS/TA content of citrus juice is considered as one of the most important indicators of high quality, rootstock apparently has a profound influence on this factor.
Keywords*: Citrus rootstocks, Clementine mandarin, fruit production, physicochemical characteristics.*

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INTRODUCTION

Citrus is one of the most economically important crops in Iran. In the period 2009- 2010, the total Citrus production of Iran was estimated at around 87000 tones [1].

Clementine (*Citrus clementina*) is one of the most important mandarins cultivated in Iran. It has been regarded as a mandarin fruit with potential commercial value because of its attractive and pleasant aroma. Although it is as important mandarin, the physicochemical characteristics of Clementine mandarin have been investigated very little previously in Iran [2].

Among the Physicochemical characteristics, fruit weight of Citrus is considered as an important trait in the fresh consumption group. Fruit shape or size is very important for packaging and transportation. The quality of citrus juice is an important economic factor in an industry that buys its fruit based on the juice sugar content and processes over 95% [3]. Juice, TSS and TA content are the main internal parameters used to determine Citrus quality in the world [4]. TSS content also forms the basis of payment for fruit by some juice processors in a number of countries, especially where the trade in juice is based on frozen concentrate [5].

Fruit weight, shape, size and juice quality are variable and depend upon a number of factors including: rootstock [6], fertilizer [7], irrigation [8] and etc.

Several studies have shown that the rootstocks used can influence the fruit production and physicochemical characteristics in Clementine mandarin (6, 9).

In Iran, All citrus trees are mainly budded on sour orange. Although sour orange is an excellent rootstock, it is highly susceptible to tristeza virus. So we need a research program to replace the Sour orange with other rootstocks.

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

Rootstocks

In 2007, rootstocks were planted at 8×4 m with three replication at Ramsar research station [Latitude 36° 54' N, longitude 50° 40' E; Caspian Sea climate, average rainfall and temperature were 970 mm and 16.25°C per year respectively; soil was classified as loam-clay, pH ranged from 6.9 to 7]. Sour orange, *Swingle citrumelo* and *Troyer citrange* were used as Rootstocks in this experiment (Table 1).

Fruit production (yield)

The fruit yield was measured separately for each tree. Fruits for each tree were measured using a digital balance.

Physical characteristics of fruit

Fifty fruits for each tree were randomly sampled and measured in the last week of January 2012. Physical characteristics were fresh fruit weight (g), dried fruit weight (g) fruit length (mm), fruit diameter (mm) and fruit shape index. Fresh fruit weight was measured using a digital balance with a sensitivity of 0.01 g. Dried fruit weight measured with oven drying. Fruit length and diameter were measured using a digital vernier caliper with a sensitivity of 0.01 mm. Fruit shape index was explained as the ratio of fruit diameter to fruit length. Ash was determined by igniting a weighed sample in a muffle furnace at 550 c to a constant weight [10]. (Table 2).

Preparation of juice sample

In the last week of January 2012, at least 10 mature fruit were collected from many parts of the same trees at Ramsar research station. Juice was obtained using the Indelicate Super Automatic, Type A2 104 extractor. After extraction, juice was screened to remove peel, membrane, pulp and seed pieces according to the standard operating procedure. Three replicates were carried out for the quantitative analysis (n=3). Ten fruits were used for each replicate.

Chemical methods

The total titratable acidity was assessed by titration with sodium hydroxide (0.1 N) and expressed as % citric acid. Total soluble solids, expressed as Brix, were determined using a Carl Zeiss, Jena (Germany) refractometer. The pH value was measured using a digital pH meter (WTW Inolab pH-L1, Germany). Ascorbic acid was determined by titration with Potassium iodide. The density of the juice was measured using a pycnometer [10]. (Table 2).

Table 1. Common and botanical names for citrus taxa used as scions and rootstock.

Common name	Botanical name	Parents	Category
Clementine (scion)	*Citrus clementina cv. Cadox*	Unknown	Mandarin
Sour orange (Rootstock)	*C. aurantium (L.)*	Mandarin ×Pomelo	Sour orange
Swingle citrumelo (Rootstock)	*Swingle citrumelo*	*C.paradisi var dancan × P.trifoliata (L.) Raf.*	Poncirus hybrids
Troyer citrange (Rootstock)	*Troyer citrange*	*C.paradisi var dancan × P.trifoliata (L.) Raf.*	Poncirus hybrids

Table 2. Physicochemical characteristics in this study

X1	Fruit Production (kg/tree)	X10	TSS (%)
X2	Fresh fruit weight (g)	X11	Total Acids (%)
X3	Dried fruit weight (g)	X12	TSS /TA rate
X4	Fruit diameter (mm)	X13	Ascorbic acid (%)
X5	Fruit length (mm)	X14	PH
X6	Fruit diameter / length (shape index)	X15	Moisture
X7	Rind fruit weight(g)	X16	Total dry matter (%)
X8	Rind thickness(mm)	X17	Ash (%)
X9	Juice (%)		

Data analysis

SPSS 18 was used for analysis of the data obtained from the experiments. Analysis of variations was based on the measurements of 17 characters. Comparisons were made using one-way analysis of variance (ANOVA) and Duncan's multiple range tests. Differences were considered to be significant at $P < 0.01$. Correlation between pairs of physicochemical characters was evaluated using Pearson's correlation coefficient.

RESULTS

Fruit production (yield)

Yield ranged from 56 to 71 kg/tree. Among rootstocks examined, Sour orange showed the highest content of fruit production.

Physical characteristics of fruit

The physical characteristics of the fruit are given in table 3. Fresh fruit weight ranged from 69.15 g (Sour orange) to 69.36 g (*Swingle citrumelo*). Dried fruit weight ranged from 11.04g (*Troyer citrange*) to 11.12 g (*Swingle citrumelo*). Fruit diameter ranged from 53.09 mm (*Troyer citrange*) to 54.24mm (*Swingle citrumelo*). Fruit length ranged from 44.75 mm (*Troyer citrange*) to 47.13 mm (*Swingle citrumelo*). Fruit shape index ranged from 1.15 (*Swingle citrumelo*) to 1.19 (*Troyer citrange*). Rind fruit weight ranged from 21.96 (*Troyer citrange*) to 22.23 (Sour orange). Rind thickness ranged from 4.05 (*Troyer citrange*) to 4.1 (Sour orange). Total dry matter ranged from 15.93% (*Troyer citrange*) to 16.04% (*Swingle citrumelo*).Ash was 3% for all rootstoks.

Among rootstocks examined, *Swingle citrumelo* showed the highest content of fresh fruit weight, dried fruit weight, fruit diameter, fruit length, total dry matter. (Table 3).

Juice quality parameters

Juice quality parameters are given in table 3. Brix (total soluble solids) ranged from 9.77% (*Swingle citrumelo*) to 9.85% (*Troyer citrange*) and the content of total acidity ranged from 0.41% (*Troyer citrange*) to 0.44% (Sour orange). TSS/TA rate ranged from 22.27 (Sour orange) to 24.02 (*Troyer citrange*). Ascorbic acid ranged from 52.72% (*Troyer citrange*) to 54.15% (*Swingle citrumelo*). The pH value ranged from 4.02 (Sour orange) to 4.34 (*Troyer citrange*). The juice yield ranged from 70.14% (*Swingle citrumelo*) to 70.66% (*Troyer citrange*). Among rootstocks examined, *Troyer citrange* showed the highest content of juice, TSS, TSS /TA and pH (Table 3).

Results of statistical analyses

Differences were considered to be significant at $P < 0.01$. These differences on the 1% level occurred in fruit production, fresh fruit weight, dried fruit weight, fruit diameter, fruit length, fruit shape index, rind fruit weight, rind thickness, juice, TSS/TA, ascorbic acid, pH, moisture and total dry matter. This difference on the 5% level occurred in total acid. The non affected characters were TSS and ash (Table 3).

Result of correlation

Simple inter correlations between 17 characters are presented in a correlation matrix (Table 4). The significant positive correlations were observed between fruit length (X5) and fruit diameter (X4). Moisture (X15) also showed a high positive correlation with Juice (X9). Fruit diameter (X4) and fruit length (X5) showed a high positive correlation with total dry matter (X16). Not only Juice (X9) and Moisture (X15) showed a high negative correlation with fruit diameter (X4) but also they showed a high negative correlation with fruit length (X5) (Table 4).

DISCUSSION

Our observation that rootstocks had an effect on the yield and physicochemical characteristics was in accordance with previous findings [6, 9].

Comparison of our data with those in the literatures revealed some inconsistencies with previous studies [6, 9]. It may be related to environmental factors, alternate bearing and etc that can influence results. Fertilizer [7] and irrigation [8] affects the content of fruit production and physicochemical characteristics. Fertilization, irrigation and other operations were carried out uniform in this study so we did not believe that this variability was a result of these factors.

Cytokinins play an important role in fruit development, especially cell division. It is generally accepted that Cytokinins in higher plants are synthesized mainly in the root system and transported via the transpiration stream in xylem to the shoot. In addition, cytokinin level in the xylem sap also can vary by rootstock and exhibit a source-sink relationship by making strong sink tissues for mineral elements and other metabolites including amino acids [11]. The pronounced enhancement in fruit size, when Swingle citromelo were used as the rootstock, showed that either the synthesis of cytokinins is enhanced or activities of endogenous enzymes increased.

Micro and macro nutrients have a positive relationship with fruit quality of Citrus [12].
Rootstocks can affect on mineral element uptake [13]. They also can affect root hydraulic conductivity and water uptake (14).
High positive correlations between pairs of characters suggest a genetic control [15] and such dependence between pairs of characters was due to genetic linkage that was not known. Non-significant negative and positive correlations can imply genetic independence (15).

Table 3. Statistical analysis of variation in yield and physicochemical characteristics of Clementine mandarin budded on different rootstocks. Mean is average of physicochemical characteristics in different rootstocks used with three replicates. F value is accompanied by its significance, indicated by: NS = not significant, * = significant at P = 0.05, ** = significant at P = 0.01.

Rootstocks	Fruit Production (kg/tree) (2011-2012)	Fresh fruit weight (g)	Dried fruit weight (g)	Fruit diameter (mm)	Fruit length (mm)	Fruit shape index (Fd/Fl)	Rind fruit weight(g)
Sour orange (Rootstock)	71	69.15	11.07	54.0	46.3	1.17	22.23
Swingle citrumelo (Rootstock)	63	69.36	11.12	54.24	47.13	1.15	22.01
Troyer citrange (Rootstock)	56	69.31	11.04	53.09	44.75	1.19	21.96
F-value	F**	F**	F**	F**	F**	F**	F**

Rootstocks	Rind thickness (mm)	Juice (%)	TSS (%)	Total Acids (%)	TSS /TA rate	Ascorbic acid (%)	PH	Moisture (%)	Total dry matter (%)	Ash (%)
Sour orange (Rootstock)	4.1	70.33	9.8	0.44	22.27	53.33	4.02	83.99	16.01	3
Swingle citrumelo (Rootstock)	4.06	70.14	9.77	0.43	22.72	54.15	4.21	83.96	16.04	3
Troyer citrange (Rootstock)	4.05	70.66	9.85	0.41	24.02	52.72	4.34	84.07	15.93	3
F-value	F**	F**	NS	F*	F**	F**	F**	F**	F**	NS

Table 4. Correlation matrix (numbers in this table correspond with physicochemical characteristics mentioned in Table 2)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X2	-0.73*															
X3	0.35	0.37														
X4	0.72*	-0.09	0.87**													
X5	0.60	0.05	0.92**	0.98**												
X6	-0.35	-0.16	-0.75*	-0.84**	-0.87**											
X7	0.95**	-0.90**	0.04	0.47	0.34	-0.12										
X8	0.93**	-0.81**	0.12	0.46	0.33	0.00	0.95**									
X9	-0.58	-0.07	-0.91**	-0.98**	-0.99**	0.90**	-0.32	-0.30								
X10	-0.25	0.01	-0.39	-0.55	-0.56	0.75*	-0.13	0.02	0.59							
X11	0.88**	-0.43	0.57	0.73*	0.65	-0.24	0.75*	0.87**	-0.61	-0.05						
X12	-0.94**	0.51	-0.58	-0.90**	-0.82**	0.64	-0.81**	-0.76*	0.81**	0.46	-0.82**					
X13	0.38	0.30	0.97**	0.91**	0.96**	-0.88**	0.09	0.10	-0.97**	-0.54	0.50	-0.65				
X14	-0.97**	0.79**	-0.24	-0.67*	-0.55	0.38	-0.96**	-0.88**	0.54	0.33	-0.76*	0.92**	-0.32			
X15	-0.63	0.04	-0.83**	-0.98**	-0.98**	0.93**	-0.39	-0.33	0.98**	0.65	-0.58	0.85**	-0.92**	0.62		
X16	0.68*	-0.01	0.92**	0.98**	0.98**	-0.77*	0.42	0.45	-0.97**	-0.46	0.77*	-0.85**	0.93**	-0.60	-0.94**	
X17	0.13	0.09	0.24	0.01	0.01	0.44	0.06	0.35	0.03	0.56	0.54	0.01	0.01	0.06	0.17	0.17

*=significant at 0.05; **=significant at 0.01

CONCLUSION

In the present study we found that the yield and physicochemical characteristics were significantly affected by rootstocks and there was a great variation in most of the measured characters among rootstocks. The present study demonstrated that yield and physicochemical characteristics can vary when different rootstocks utilized. Among rootstocks examined, *Troyer citrange* showed the highest content of TSS/TA. Studies like this are very important to determine excellent traits in different rootstocks. Further research on the relationship between physicochemical characteristics and rootstocks is necessary

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