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YIELD AND FRUIT QUALITY OF WASHINGTON NAVEL ORANGE AS AFFECTED BY SOUR ORANGE AND VOLKAMER LEMON ROOTSTOCKS

El-Sayed, Somaia A.*; S.A.G.El-Saiada and Hassan A. Ennab***

*** Hort. Dept., Sakha Agric.Res. St., Kafr El-Sheikh, Egypt.**

****Hort. Res. Inst., ARC, Egypt.**

ABSTRACT

This study was carried out during 2002 and 2003 seasons on 11 years old Washington navel orange trees budded on Volkamer lemon and Sour orange rootstocks to evaluate yield, and fruit quality. The obtained results showed that, Washington navel orange on Volkamer lemon produced significantly higher yield, fruit length, diameter, volume, weight, rind thickness, peel weight, and juice volume than those recorded on Sour orange rootstock. Trees on Volkamer lemon produced fruits with highest juice acidity and ascorbic acid but presented lower SSC and SSC/acid ratio at harvest time in both seasons. Also, data showed highest value of chlorophyll (a-b) and the lost value of carotenidos in fruit peel produced on Volkamere lemon compared with those on sour orange rootstock.

It is not recommended to buded for Washington navel orange cultivar on Volkamer lemon. Since the fruits produced have poor physical and chemical properties.

INTRODUCTION

Washington navel orange (*Citrus sinensis* L) occupies an important cultivar among the citrus grown in Egypt, due to it has good productive potential and acceptable juice quality. Rootstocks have had a substantial role in the development of the citrus industry in the world. The effect of rootstocks on citrus production and fruit quality has been studied on many citrus producing areas (Protopapadakis *et al* 1998, Dawood 2001, Smith *et al* 2004, Zayan *et al* 2004b and Al-Jaleel *et al* 2005). Fallahi *et al* 1989 and Dawood 2002 conducted that, cumulative yields of grapefruit and Washington navel orange were higher from trees on Volkamer lemon and Rangpur lime than those on Swingle citrumelo, Cleopatra mandarin and Sour orange. Also, Georgiou, 2002 reported that Volkamer lemon has been reported to significantly increase cumulative yield of Clementine mandarin compared with Sour orange up to 45%. In this respect, Al-Jaleel and Zekri 2003 revealed that, Parent Washington navel on Volkamer lemon, Macrophylla and Rough lemon were the most productive as compared with trees on Sour orange and Cleopatra mandarin. This result was also concluded by Zayan *et al* 2004b who reported that yield as number of fruits/tree and weight (kg/tree) of Washington navel orange was higher on Volkamer lemon and Rangpur lime than those on Troyer citrange, Sour orange and Cleopatra mandarin.

Many external and internal fruit characteristics including size, shape, peel thickness, juice content and juice soluble solids concentration are affected by rootstocks (Castle 1995, Perez-Zamora 2004 and Monteverde, 1989). In this respect, Forner-Giner *et al* 2003 showed that, fruits from Navelina orange trees on Volkamer lemon showed the largest, heaviest and

thicker rind as compared with Cleopatra mandarin and other rootstocks. Also, Al-Jaleel and Zekri 2003 revealed that, Parent Washington navel trees on Volkamer lemon, Macrophylla and Rangpur lime gave the highest values of fruit size and peel thickness, whereas trees on Sour orange gave the highest values of total soluble solids. Similar results were obtained by Perez-Zamora 2004 who state that Volkamer lemon and Macrophylla presented the lowest quality of SSC and SSC /acidity. Moreover, Zayan *et al* 2004b concluded that, Valkamer lemon and Rangpur lime as rootstock for Washington navel orange produced higher yield with good physical fruit characters in terms of length, diameter, volume and weight whereas produced fruit with lower SSC.

In Egypt, Sour orange is still and probably continues to be the most widely planted rootstock for citrus plantation, in sipte of its susceptibility to gummossis, treisteza and other virus disease. On the other side, cultivars on Volkamer lemon are more tolerant to tristeza, Xyloporosis and malsecco (Davies and Albrigo 1994), phytophthora sp (Carpenter and Furr 1962), flooding (Castle, 1987), water logging (Salem, 1991), salinity and drought (El-Hammady *et al* 1995, Azab and Hegazy, 1995), and alkalinity (Zayan *et al* 2004a). Therefore, the purpose of this study was to evaluate the effect of Sour orange and Volkamer lemon on yield, physical fruit quality of Washington Navel orange fruits.

MATERIALS AND METHODS

The present study was carried out on 11 years old trees of Washington navel orange budded on Sour orange (*Citrus aurantium* L.) and Volkamer lemon (*Citrus volkamriana*) rootstocks in the experimental farm of Sakha Agricultural Research Station, Kafr El-Sheikh governorate, Egypt during 2002 and 2003 seasons. The trees were planted at 5 × 5 meters in a randomized complete design with three replicates each of three trees replicated three times for a total of nine tree /rootstock budded with Washington navel orange .All trees received the following fertilization programe: 300gm/tree ammonium sulphate in March, 450gm/tree ammonium sulphate in June, 200gm/tree ammonium nitrite and 200gm/tree potassium sulphate in August .The soil texture was clay (58.2% clay, 32.2% silt and 9.6% sand), 3.1% total carbonate content, 4.12 ds m^{-1} an electrical conductivity and a pH of 8. 2.

At harvest time (15 December in both seasons), yield of each tree was determined as number and weight (kg) of fruits/tree, then divided according to their fruit diameter to three categories, large fruit more than (< 8 cm), moderate fruit (8 - 6 cm) and small fruit less than (> 6 cm). To determine fruit quality, 10 fruits were taken at random from each tree at harvest time of both seasons, then fruit length and diameter (cm), were measured fruit shapes, fruit weight (gm), fruit volume (cm^3), juice volume/fruit, skin weight, peel weight, peel thickness, Navel weight and size were determined. In 15 December 10 fruits were picked up at random from the four direction of each tree to determine: total soluble solids by hand refractometer, total acidity as citric acid according to (A. O. A. C 1967), ascorbic acid as mg/100 ml juice by using 2, 6 dichlorophenol indophenol according to Jacobs 1951) SSC/acid ratio was estimated, chlorophyll a, b and carotenoids were determined in fruit

peel according to Wettestein 1957 as indicator to fruit color. Statistical analysis was conducted using analysis of t-test in groups to compare between the main values.

RESULTS AND DISCUSSION

1. Effect of rootstocks on yield:

Data in Table (1) showed that, yield as number of fruits per tree and weight (kg/tree) of Washington navel orange was significantly higher on Volkamer lemon rootstock than on Sour orange rootstock. Also, yield in the first season was higher than the second one. Similar results about high productivity of Valkamer lemon were found by Dawood 2001, 2002; Zayan *et al* 2004b. Such conclusions agree with those presented by Valbuen 1996 who reported that Persian lime trees on Volkamer lemon rootstock had more fruit number and weight (kg) per tree than those grown on Cleopatra mandarin rootstock. In this respect Protopapadakis *et al* 1998 stated that Washington navel orange trees grafted on valkamer lemon rootstock had larger and heavier fruits than those on Sour orange rootstock.

Furthermore, the yield per tree was classified into three categories according to their fruit diameter as shown in Table (1). From this table, it is clear that yield as large (more than < 8 cm) and moderate fruit (8 - 6 cm) was higher on tree budded on Volkamer lemon rootstock than that on Sour orange rootstock. The differences were significant in both seasons. On the other hand, small fruits which less than (> 6 cm) recorded highest number and weight (kg) of fruits per tree on Sour orange rootstock than on Volkamer lemon with significant differences between them in both seasons (Table 1).

Table (1). Yield of Washington navel orange trees as affected by sour orange and Volkamer lemon rootstocks.

Rootstock	Yield per tree		Yield as three categories according to their fruit diameter								
	kg	No.	< 8 cm			8 - 6 cm			> 6 cm		
			kg	No.	%	kg	No.	%	kg	No.	%
	2002										
S.O	62.9	334.8	19.5	85.0	31	32.7	183.0	52	10.7	66.8	17
V.L	89.5	400.1	48.3	186.6	54	34.0	169.9	38	7.2	43.6	8
t-test	**	**	**	**	**	**	**	**	**	**	**
t-value	42.77	45.66	47.13	162.69	19.29	2.61	13.03	8.40	12.50	18.57	9.51
	2003										
S.O	46.0	246.8	14.7	66.6	32	24.4	134.6	53	6.9	45.6	15
V.L	73.5	322.0	41.0	154.1	56	27.2	135.0	37	5.3	32.9	7
t-test	**	**	**	**	**	**	ns	**	**	**	**
t-value	21.67	58.93	53.68	79.98	15.17	5.83	ns	8.76	9.23	15.16	5.24

ns = non significant ** high significant
*** % of fruit weight (kg).**
S.O - Sour orange, V.L = Volkamer lemon.

Generally, it is clear that, Washington navel orange trees on Volkamer lemon rootstock produce higher yield with large fruit size since, the percent reached about 54% when compared with sour orange rootstock, table (1).

These results are in line with those reported by Georgiou 2002 who found that, Volkamer lemon has been significantly increase cumulative yield of Clementine mandarin compared with Sour orange up to 45%. These results supported with Wutscher 1988 who reported that, trees on Sour orange can be expected to produce medium - sized to large fruit.

2- Effect of sour orange and Volkamer lemon rootstocks on physical fruit quality:

Data in Table (2) reveal that, most characters fruit quality were significantly affected by the tested rootstocks except fruit length and shape in the first season. As for fruit length and diameter, it is obvious that fruits from trees budded on Volkamer lemon had longer length and diameter as compared with Sour orange rootstock. The results are in line with those obtained by Forner-Giner *et al* 2003 who reported that, Volkamer lemon produced the larger fruits of Navelina orange than that recorded on Sour orange and other tested rootstocks. In this respect, Al-Jaleel *et al* 2005 revealed that, the largest fruit size were obtained from Eureka lemon trees on Volkamer lemon and Macrophylla, whereas the smallest fruits were found on trees on Amblycarpa and Cleopatra mandarin. Also, fruit length and diameter were used for estimating length/diameter ratio as indicator to fruit shape as shown in Table (2).

Table (2). Physical fruit quality of washington navel orange trees as affected by rootstocks.

Rootstocks	Fruit length cm	Fruit diameter cm	Fruit shape	Fruit volume cm^3	Fruit weight (gm)	Juice volum cm^3
	2002					
S.O	7.58	6.89	1.10	254	220.36	65.8
V.L	8.23	7.67	1.07	285	228.22	77.7
t-test	ns	**	ns	**	ns	**
t-value	ns	18.55	ns	10.33	ns	6.54
	2003					
S.O	7.55	6.88	1.09	253	194.5	65.6
V.L	8.12	7.61	1.06	282	203.02	76.8
t-test	**	**	**	**	ns	**
t-value	4.25	3.92	5.19	18.98	ns	14.51

ns = non significant ** high significant
S.O - Sour orange, V.L = Volkamer lemon.

It is clear that, fruits from trees budded on Volkamer lemon produced fruit of cycloid shape when compared with that on Sour orange. These results are in agreement with those obtained by Zayan *et al* 2004b. Fruit volume and weight were greater from fruits on Volkamer lemon rootstock than those recorded on Sour orange rootstock (Table 2). These results agree with these of Dawood 2001 and 2002 who reported that, heavier fruit weight was obtained from Valencia and Washington navel orange trees budded on Volkamer lemon rootstock as compared with trees on Sour orange rootstock. Concerning juice volume/fruit, it was more in fruits from trees budded on Valkamere lemon rootstock when compared with Sour orange rootstock. The obtained results are agree with those found by Fallahi *et al* 1991,

Economides and Gregoriou 1993 and Georgiou 2000. In this respect, Al-Jaleel and Zekri 2003 stated that, Parent Washington navel orange trees on Volkamer lemon gave larger fruit with thicker peel.

2.1- Physical characters of peel and navel of Washington Navel orange:

Data in table (3) and Photo (1) clear that rind thickness was thicker in fruits from trees on Volkamer lemon rootstock, whereas it was thinner in fruits from trees on sour orange rootstock. Also data in Table (3) showed that, fruit from trees budded on Volkamer lemon gave the highest values of peel weight, Navel weight and bigger size (length, width) of the Navel when compared with fruit from trees budded on Sour orange rootstock .

The obtained results are agree with those found by Fallahi *et al* 1991, Economides and Gregoriou 1993 and Gregoriou 2000 .In this respect AL-Jaleel and Zekri 2003 on Washington Navel orange trees buded on Volkamer Lemon gave fruit with thicker peel.

Table (3) Physicl characters of peel and Navel as affect by rootstocks

Rootstocks	Rind thickens m.m	Peel weight gm	Bulb weight gm	Navel weight gm	Navel size	
					Length	width
2002						
S.O	5.38	50.11	170.25	1.40	0.52	0.40
V.L	5.78	55.44	172.89	2.28	1.30	1.05
T.test	**	*	NS	*	**	*
T.value	7.11	2.67	NS	2.78	6.76	2.50
2003						
S.O	5.20	45.21	149.32	1.32	0.67	0.40
V.L.	5.88	48.83	154.19	2.26	1.42	0.96
T.test	**	NS	NS	**	**	*
T.value	6.57	NS	NS	28.12	4.03	2.71

T5% =2.45 NS= non significant
T1% =3.71 *= significant **=High significant
S.O - Sour orange, V.L = Volkamer lemon.

Generally, Tables 1, 2 and 3 showed that, Volkamer lemon as rootstock for Washington navel orange cultivar produced higher yield with good physical fruit characters in terms of length, diameter, volume and juice volume. Similar results were reported by Davies and Albrigo 1994, Dawood 2002, Al-Jaleel and Zekri 2003 and Zayan *et al* 2004b.

3. Chemical fruit characters:

3.1. SSC, total acidity, SSC/acid ratio and vitamin C:

Data in Table (4) showed that, juice of fruit from trees budded on sour orange rootstock gave higher values of SSC than that recorded on Volkamer lemon rootstock in both seasons. The differences were significant in both seasons. It was found that soluble solids content were considered among the highest for fruit trees on Rangpur lime, Volkamer lemon and Milan rootstocks (Economides and Gregoriou 1993 and Ennab 2003. In this respect, Perez-Zamora 2004 reveal that, lemon on Volkamer lemon and Macrophylla presented a lowest quality of SSC and acidity. Also, this result agrees with that reported by Jackson 1999. On the other hand, data showed

that fruits juice from trees on Volkamer lemon rootstock recorded higher values of total acidity than that on Sour orange rootstock and the differences were significant in both seasons (Table 4).

Also, data in Table (4) showed that fruits from trees budded on Sour orange gave the highest ratio of SSC/acid ratio, but fruits from trees budded on Volkamer lemon gave the lowest one in this respect. Similarly, were reported by Davies & Albrigo 1994, they reported that *C. volkameriana* produced relatively poor fruit quality fruit with less SSC characterized by high acidity and course peel.

Concerning to the effect of V.C, it is clear from data in Table (4) that, ascorbic acid was higher in juice fruit from trees budded on Volkamer lemon rootstock than those recorded on Sour orange rootstock. This result agrees with that reported by Davies & Albrigo, 1994.

Table (4):SSC, total acidity and V.C of Washington navel orange as affected by rootstocks.

Rootstocks	SSC%	Acidity %	SSC/acid ratio	V.C gm/100 ml
2002				
S.O.	11.35	0.96	11.82	38.1
V.L.	10.10	1.16	8.71	39.2
t-test	**	**	**	NS
t-value	44.19	8.16	7.88	NS
2003				
S.O.	11.80	1.04	11.35	35.8
V.L.	10.50	1.20	8.75	37.4
t-test	**	**	**	**
t-value	21.51	8.00	6.83	5.43

3.2. Chlorophyll a, b and carotenoids:

It was clear from Table (5), fruit rind from trees on Sour orange rootstock had lower values of chlorophyll (a and b) values than that on Volkamer lemon rootstock. On the other hand, fruit rind from trees on Volkamere lemon rootstocks gave a higher values of total carotenoids than that on sour orange rootstock as shown in Table (5).

Table (5):Peel, chlorophyll (a & b) and carotenoids of Washington navel orange in 2002 and 2003 seasons.

Rootstocks	Chlorophyll mg/100 mg		carotenoids (mg/100 mg)
	a	b	
	2002		
S.O	3.05	1.21	35.05
V.L	7.13	5.97	27.68
t-test	**	**	**
t-value	103.07	154.43	115.10
	2003		
S.O	3.18	1.51	35.28
V.L	7.14	6.05	27.91
t-test	**	**	**
t-value	216.89	237.09	121.43

Photo (1):Effect of both sour orange and Volkamer lemon on peel color and navel size of Washington navel orange cultivar.

These results clear the differences of fruit color on Sour orange and Valkamere lemon rootstocks (Photo 1). However, similar results were reported by Wutscher 1988 who found that vigorous rootstocks like Rough lemon delay color break and induce thick rinds., whereas Wutscher and Shull 1972 concluded that, rootstocks did not significantly affected on peel color of grapefruit. Also, Froner- Giner *et al* 2003 reported that, peel color index in fruits of Navelinia orange trees on Cleopatra mandarin rootstock was significantly lower. On the other hand, no differences were found due to other tested rootstocks including Volkamer lemon.

From this study, we can conclude that, In spite of Washington Navel orange variety produce enough yield as number and weight of fruits (kg) on volkamere lemon root stocks, it is not recommended as rootstock for Washington navel orange cultivar .Since fruits on this rootstock have poor physical and chemical properties such as thick with poor color peel, large navel high acidity and lower SSC values in fruit juice. Therefore, more studies are needed on other new rootstock, substitute sour orange and Volkamere lemon as rootstock for Washington navel orange cultivar to assure high productivity with good physical and chemical fruit quality.

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المحصول وصفات الجودة لثمار البرتقال أبو سرة المطعومة على أصلي النارنج والفولكاماريانا

سمية أحمد السيد* - سمير احمد جابر الصياده وحسن أبو الفتوح عناب***
*قسم البساتين - محطة البحوث الزراعية بسخا – كفر الشيخ
معهد بحوث البساتين بالقاهرة

أجريت هذه الدراسة خلال عامي 2002 و2003 على أشجار برتقال بسرة عمرها 11 سنة مطعومة على أصلي النارنج والفولكاماريانا وذلك لتقدير المحصول وجودة الثمار وكذا الصفات الكيماوية لثمار البرتقال أبو سرة وقد بينت النتائج أن:-

1. أشجار البرتقال أبو سرة المطعومة على اصل الفولكا ماريانا اعطت اعلى قيم للمحصول مع زيادة معنوية فى طول الثمرة وقطرها وحجمها ووزنها بالمقارنة بالثمار الماخوذة من الاشجار المطعومة على اصل النارنج.
2. الثمار الناتجة من الاشجار المطعومة على اصل الفولكا مرايانا اعطت قشرة ذات سمك ووزن اكبر من تلك التى على اصل النارنج وهذا يقلل من جودة الثمار .
3. اعطت الثمار التى على اصل الفولكا ماريانا ثمارا ذات سرة كبيرة فى الحجم والوزن مما يؤدى الي تشوه شكل الثمرة ويجعلها اكثر عرضة للاصابة بالحشرات والتشقق.
4. الثمار التى على اصل الفولكا ماريانا احتوت على مستوى عالى من الحموضة وفيتامين C وكذا الكلوروفيل (أ – ب) بينما احتوت الثمار التى على اصل النارنج على نسبة عالية من المواد الصلبة الذائبة الكلية و كذا النسبة بين المواد الصلبة الذائبة الكلية والحموضة و الكاروتينات وهذا يوضح الاختلاف فى لون وطعم ونكهة الثمار الناتجة على كلا الاصلين.

ويمكن القول من هذه الدراسة انه على الرغم من ان البرتقال ابو سرة يعطى محصولا كبيرا على اصل الفولكا ماريانا عن النارنج الا انه لا ينصح به كأصل لهذا الصنف لرداءة صفات الجودة الطبيعية والكيماوية للثمار الناتجة عليه مثل زيادة سمك القشرة ورداءة لونها وزيادة وزن وحجم السرة وكذلك زيادة الحموضة ونقص فى قيمة نسبة المواد الصلبة الذائبة فى عصير الثمار .