EVALUATION OF "WASHINGTON NAVEL" ORANGE TREES ON SOUR ORANGE AND VOLKAMER LEMON GROWN ON SLIGHTLY ALKALINE CLAYEY SOIL CONDITIONS

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ABSTRACT

Growth, leaf mineral content, yield, and fruit quality of Washington Navel orange trees on sour orange and volkamer lemon rootstocks were evaluated during 1997–2001 seasons under North Delta conditions. The trees were planted in Sep.1993 at the Experimental Farm of Sakha Agricultural Research Station where the soil is slightly alkaline clayey soil.

Trees growth on volkamer lemon was larger (tree height, trunk diameter and cross sectional area, canopy volume, and leaf area and dry weight) than that on sour orange.

Trees on volkamer lemon were cropped one-year earlier, more productive and the cumulative yield per tree (over 6-years production period) were significantly higher compared with those on sour orange. Also, yield efficiency (fruit weight kg/m^3 of canopy or yield per TCSA kg/cm^2) was significantly affected.

Fruit of trees on volkamer lemon had greater weight, diameter, peel thickness TSS/acid ratio, while fruit of trees on sour orange had greater juice percentage, TSS and total acidity. Meanwhile, Vit.C was not significantly affected by the two rootstocks.

Leaf N, K, Ca, Mg and Zn contents of trees on volkamer lemon were higher, but had slightly lower leaf P in contrast to leaves of trees on sour orange. While leaf Mn and Fe was not significantly affected by the two rootstocks.

As a result of this study, and because of the susceptibility of sour orange to Tristeza, it could be suggest that volkamer lemon (which is tolerant to Tristeza), as a potential rootstock for "Washington Navel" orange trees under North Delta conditions.

Key Words: citrus rootstocks, variety, yield, fruit quality, leaf minerals.

INTRODUCTION

It is well known that, rootstocks exert a vital influence on the production of citrus trees. Rootstocks affect tree vigor (Roose *et al.*, 1989; Wheaton *et al.*, 1991; Fallahi and Rodney 1992; Gregoriou and Economides, 1994; and El-Sayed, 1999), fruitfulness (Holtzhausen *et al.*1988; Husak *et al.*, 1988; Tuzcu *et al.*, 1993 and Tuzcu *et al.*, 1999) fruit quality (Castel,

1995 and Protopapadakis *et al.*, 1998), leaf mineral content (Fallahi *et al.*, 1992; Taylor and Dimsey 1993; Kaplankiran and Tuzcu 1994 and El-Sayed, 1999), and insect and disease tolerance or resistance (Carpenter and Furr, 1962; Bitters, 1972).

Sour orange (the most commonly used rootstock for citrus orchards in Egypt) is considered a satisfactory rootstock, but its high susceptibility to Tristeza disease, and the spread of this disease in the Mediterranean region (Bitters *et al.*, 1973) and its detection in Israel (Moreno, 1988) have stimulated a search for alternative rootstock.

Choice of a rootstock becomes a matter of individual judgment when the merit of a rootstock depends on several characteristics and when none is superior in all respects.

Volkamer lemon (*citrus volkameriana* Ten & Pasq) is found to be tolerant to Tristeza (Bitters, 1972), Phytophthora root rot (Carpenter and Furr, 1962), flooding (Protopapadakis *et al.*, 1998), water logging (Salem, 1991), salinity (Nieves *et al.*, 1991 and Garcia-Legaz, 1993), and alkalinity (Sagee *et al.*, 1994 and Sudahono *et al.*, 1994). Moreover, it was the most promising rootstock for Valencia orange trees in several countries (Montilia *et al.*, 1994; Salem *et al.*, 1994 and Dawood, 2001). But success of this rootstock in these areas does not mean success in other areas.

Therefore, the purpose of this investigation was to evaluate the effect of sour orange and volkamer lemon on growth, yield, fruit quality, and leaf mineral content of "Washington Navel" orange trees grown on slightly alkaline clayey soil.

MATERIALS AND METHODS

The present study was initiated at the end of 1993 and continued till 2001 year on "Washington Navel" orange trees budded on sour orange (*C. aurantium* L), and volkamer lemon (*C. volkameriana* Ten & Pasq) rootstocks at the Experimental Farm of Sakha Agricultural Research Station, Kafr El-Sheikh.

Field soil and plant: The experimental plants were planted in Sep. 1993 at 6 x 6 meters apart. All the chosen trees were selected at uniform vigor as possible, and replicated by two trees plot five times in a randomized complete block design. All trees received the regular fertilization and horticultures managements as recommended by the Ministry of Agriculture in Egypt.

The planting soil is classified as clayey (60% clay), the depth of water table was about 120-130 cm. Other physical and chemical properties of the soil are presented in Table (1). Soil chemical, physical properties were determined according to Chapman and Pratt (1978).

Table (1): Some chemical and physical properties of the experimental soil (0-120 cm).

Some chemical properties				Some physical properties					Total carbo-nate %	Texture grade
EC (ds/m)	pH	SAR	Na/Ca	W.S.A (%)	A.I	M.W.D	I.R	Cr		
4.12	8.3	7.88	2.31	8.34	0.15	0.82	237	1.27	3.10	Clayey

W.S.A = Water stable aggregates. M.W. D = Mean Weight Diameter. A.I = Aggregation index. Cr = Structure coefficient. I.R = Infiltration rate (time in minutes).

Some weather observations: Average weather observations (1993-2001) were recorded. The climatologically parameters of Sakha Agricultural Research Station, as well as, the total effective heat (F^{o}) are tabulated in table (2).

Table (2): Average of the climatologically parameters of Sakha Agricultural Research Station and total effective heat (1993 till 2001).

Total effective heat (F^{o})	Relative humidity /day	Wind velocity (km/hr)	Solar radiation		Pan evaporation (mm/day)	Rain (mm/day)
			Rimco (day)	Gunn (day)		
4539.43	60.28	5.76	412.92	16.57	0.581	0.228

The following parameters were determined:

1- Vegetative growth: Vegetative growth was evaluated 4 years after planting (1997) and the last 2-seasons (2000and 2001). Tree height, width and trunk diameter (cm) 15 cm above the bud union was measured in Nov. of each season. Then, trunk cross sectional area (TCSA cm^2) was also calculated. Canopy volume (m^3) was calculated as indicated by Turrel (1946). Leaf area was measured according to Singh and Snyder (1984).

2-Yield: Yield was evaluated from 1996 till 2001 season. It was recorded at harvest time (Dec. 1996 to 2001 year) in both seasons (on an individual tree basis) and was expressed as kilograms per tree, and yield efficiency (fruit weight kg/m^3 of canopy or yield per TCSA kg/cm^2), as well as cumulative yield (1996 to 2001 years).

3-Fruit quality: It was evaluated in the last 3-seasons (1999, 2000 and 2001). Representative samples of 20 mature fruits were collected from each tree at harvest time for determination of fruit weight, diameter, peel thickness, juice percentage, acidity, TSS, TSS/acid ratio, and Vit.C content according to A.O.A.C (1975).

4-Leaf analysis: It was evaluated in the last 3-seasons (1999, 2000 and 2001). Sixty mature leaves per replicate were collected from non-fruiting terminal shoots of spring and summer growth cycles at the end of August and November of each season (Embleton *et al.*, 1983). The leaves

were cleaned with damp cloth, washed three times with redistilled water, dried at 60^0 c till a constant weight, and then leaf dry weight was determined. For leaf mineral content, the dried leaves were ground with porcelain mortar. Nitrogen was determined by micro-Kjeldahl method (Chapman and Pratt, 1978). Analysis of other elements (P, K, Mg, Ca, Fe, Zn and Mn) were conducted according to Carter (1993) after wet-digestion of a sub sample of 0.5g with H_2So_4 and H_2O_2 (Cottenie, 1980) by using atomic absorption.

5- Statistical analysis: The experiment was arranged in a randomized complete block design. All data were subjected to statistical analysis according to Steel and Torrie (1982).

RESULTS AND DISCUSSION

Effect of rootstocks on vegetative growth:

Data concerning the effect of volkamer lemon and sour orange rootstocks on "Washington Navel" orange trees vegetative growth are tabulated in Tables 3 and 4. It revealed that trees on volkamer lemon were higher (3.37 m), the maximum trunk diameter (9.29 cm) and trunk cross sectional area (TCSA = 67.84 cm^2), the greatest tree canopy volume (13.96 m^3), and larger leaf area (26.32 cm^2) and leaf dry weight (0.263 g) in comparison to trees on sour orange. Thus, vegetative growth of "Washington Navel" orange trees on volkamer lemon was more vigorous than "Washington Navel" orange trees on sour orange rootstock.

Table (3): Effect of rootstock on tree growth, yield (kgs) and yield efficiency of "Washington Navel" orange trees.

Rootstock	Tree height (m)	Trunk diameter (cm)	Canopy volume (m^3)	Leaf		Yield (Kg)	Yield efficiency (kg/m^3)
				Area (cm^2)	DW (mg)		
The first season (1997)							
Sour orange	1.92	4.41	2.19	23.37	0.221	2.27	1.04
Volkamer lemon	2.21	5.32	5.01	26.48	0.269	13.08	2.61
L.S.D. at 5%	0.068	0.61	0.83	1.16	0.021	1.36	0.63
The second season (2000)							
Sour orange	2.86	6.43	7.97	24.18	0.232	22.19	2.78
Volkamer lemon	3.01	7.98	11.85	26.72	0.268	36.31	3.06
L.S.D. at 5%	0.072	0.89	1.05	1.34	0.018	3.17	0.18
The third season (2001)							
Sour orange	3.06	7.38	10.23	23.46	0.223	28.63	2.80
Volkamer lemon	3.37	9.29	13.96	26.32	0.263	45.19	3.24
L.S.D. at 5%	0.093	0.91	1.26	1.06	0.024	3.68	0.32

This might be attributed to the ability of volkamer lemon to tolerate the adverse effects caused by flooding (Protopapadakis *et al.*, 1998), water logging (Salem, 1991), salinity (Nieves *et al.*, 1991 and Garcia-Legaz *et al.*,

1993), and alkalinity (Sagee *et al.*, 1994 and Sudahono *et al.*, 1994), which are commonly found in Kafr El-Sheikh soils, beside its tolerant to Phytophthora root rot (Carpenter and Furr, 1962).

These results came true in the three seasons and are in agreement with those reported by Roose *et al.*, (1989); Wheaton *et al.*, (1991); Fallahi and Rodney, (1992); Gregoriou and Economides, (1994); El-Sayed, (1999) and Dawood, (2001).

Effect of rootstocks on yield and yield efficiency:

With regard to the Effect of volkamer lemon and sour orange rootstocks on "Washington Navel" orange trees yield and yield efficiency (Table 4), it was obvious that trees on volkamer lemon cropped one-year earlier than those on sour orange rootstock. Thus, volkamer lemon rootstock reduced the time required for production of young trees. Graca, *et al.*, (1997) on Tahiti acid lime and Dawood (2001) on Valencia orange trees reported the same results.

The present data also, clear that over 6-years yield production period, the highest yield expressed as kilograms of "Washington Navel" orange trees was obtained from trees on volkamer lemon rootstock while the lowest one was observed on trees on sour orange rootstock. Also, these trees had the most yield efficiency measured as kilograms of fruit / m^3 tree canopy volume or kilograms of fruit / cm^2 trunk cross-sectional area (TCSA). Moreover, cumulative yield (1996 to 2001 year) was the greatest and significantly higher than those of trees on sour orange (*C. aurantium* L) the common rootstock used in Egypt.

Table (4): Effect of rootstock on tree trunk cross-sectional area (TCSA) and yield of "Washington Navel" orange trees.

Rootstock	TCSA 2000 (cm^2)	Average annual yield per tree (Kg)						Cumulative yield / tree (1996 -2001)	Cumulative yield / TCSA (Kg/cm^2)
		1996	1997	1998	1999	2000	2001		
Sour orange	42.78	----	2.27	6.34	14.39	20.19	28.63	71.82	1.69
Volkamer lemon	67.84	6.24	13.08	18.39	26.57	36.31	45.19	145.78	2.16
L.S.D 5%	5.29	----	3.56	4.63	3.82	3.91	4.22	----	0.36

This may be due to the greatest vegetative growth attained by volkamer lemon rootstock (Table 3) under the experimental conditions (Tables 1 and 2). These results are in accordance with those reported by Holtzhauser *et al.*, (1988); Husak *et al.*, (1988); Tuzcu *et al.*, (1993 and Tuzcu *et al.* 1999) on "Washington Navel" orange trees and Salem *et al.*, (1994) and Dawood (2001) on Valencia orange trees.

Effect of rootstocks on fruit quality: As for the effect of volkamer lemon and sour orange rootstocks on "Washington Navel" orange trees fruit quality, the present data (Table 5) indicated that trees on volkamer lemon produced the larger fruit diameter, the heavier fruit weight with thicker peel thickness and tended to increase fruit juice and TSS / acid ratio significantly. Trees on sour orange produced fruit with the high juice TSS percentage, and higher total acid content. Meanwhile, fruit of trees on volkamer lemon produced the lower values, in this respect. Trees on sour orange increased fruit juice (%) content per unit fruit weight significantly, while, Vit. C content was not significantly affected by the two rootstocks.

The same trend was found in the three seasons and was in agreement with the results of Castel (1995) and Protopapadakis *et al.*, (1998) on "Washington Navel" orange trees fruit and Dawood (2001) on Valencia orange trees.

Table (5): Effect of rootstock on fruit quality of "Washington Navel" orange trees.

Rootstock	Fruit weight (g)	Fruit diame-ter (cm)	Peel thick-ness (mm)	Juice weight (%)	Acidity (%)	TSS (%)	TSS/ acid ratio	Vit.C (mg/ 100 L)
The first season (1999)								
Sour orange	253.7	7.51	4.78	47.6	1.18	11.7	9.82	40.9
Volkamer lemon	286.4	8.39	5.18	44.3	1.02	10.8	10.59	41.3
L.S.D. at 5%	11.6	0.39	0.14	1.3	0.03	0.41	0.21	NS
The second season (2000)								
Sour orange	261.2	7.73	4.76	46.9	1.22	10.9	8.93	41.6
Volkamer lemon	295.3	8.67	5.23	43.8	1.08	9.8	9.24	41.7
L.S.D. at 5%	15.8	0.48	0.37	1.5	0.05	0.39	0.16	NS
The third season (2001)								
Sour orange	251.6	7.47	4.63	47.1	1.16	11.9	10.26	41.2
Volkamer lemon	279.7	8.32	5.27	42.9	0.98	10.7	10.92	42.3
L.S.D. at 5%	16.7	0.30	0.28	1.7	0.06	0.53	0.34	NS

Effect of rootstocks on leaf mineral contents:

With respect to the effect of volkamer lemon and sour orange rootstocks on "Washington Navel" orange trees leaf mineral contents, the obtained data (Table 6) showed that leaf mineral content (macro and micronutrient) of trees on the two rootstocks were significantly affected, although they were within the normal or high range according to leaf standards guide of Embleton *et al.*, (1983). Leaves of "Washington Navel" orange trees on volkamer lemon had higher N, K, Ca, Mg and Zn content but slightly lower leaf P than those on sour orange. The increase in leaf Zn was significantly higher while leaf Mn and Fe were not significantly affected.

Apparently, the higher levels of macro and micronutrient in leaves of "Washington Navel" orange trees on volkamer lemon rootstock can be attributed to the vigorous growth (Table 3), which in turn increases the demand for these nutrients to encourage new vegetative growth and yield.

These results are in harmony with the findings of Fallahi *et al.*, 1992; Mansour *et al.*, 1993; Taylor and Dimsey, 1993; Kalankiran and Tuzcu, 1994; El-Sayed, 1999 and Dawood 2001).

Table (6): Effect of rootstock on leaf mineral contents of "Washington Navel" orange trees.

Rootstock	Leaf macronutrient (DW %)				Leaf micronutrient (DW %)			
	N	P	K	Ca	Mg	Fe	Zn	Mn
The first season (1999)								
Sour orange	2.32	0.139	1.29	3.52	0.441	101	43	71
Volkamer lemon	2.61	0.126	1.58	3.94	0.493	91	56	77
L.S.D. at 5%	0.016	0.009	0.18	0.28	0.046	NS	4.71	NS
The second season (2000)								
Sour orange	2.36	0.143	1.27	3.62	0.436	98	47	73
Volkamer lemon	2.73	0.132	1.72	3.89	0.482	88	65	82
L.S.D. at 5%	0.019	0.006	0.19	0.17	0.039	NS	3.28	NS
The third season (2001)								
Sour orange	2.38	0.141	1.16	3.51	0.423	103	46	72
Volkamer lemon	2.69	0.133	1.67	3.98	0.518	89	62	79
L.S.D. at 5%	0.012	0.007	0.14	0.32	0.056	NS	4.32	NS

CONCLUSION

It could be concluded that, trees on volkamer lemon had large tree growth and yield (kgs or tree yield efficiency). Moreover, the cumulative yield of these trees was larger and came in production early in comparison to trees on sour orange. Thus, it could be suggest that volkamer lemon would be a potential rootstock for Washington Navel orange trees in this region.

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الملخص العربى

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معهد بحوث البساتين - مركز البحوث الزراعية - الجيزة - مصر

تقييم أشجار البرتقال أبو سره المطعمة على أصلى النارنج والفولكاماريانا والنامية تحت ظروف الأرض الطينية خفيفة القلوية

لدراسة وتقييم النمو الخضرى ، المحتوى المعدنى للأوراق ، المحصول وصفات جودة الثمار لأشجار البرتقال أبوسرة التى زرعت فى سبتمبر ١٩٩٣ والمطعمة على أصلى النارنج والفولكاماريانا تحت ظروف منطقة شمال الدلتا أجريت تجربة حقلية بالمزرعة البحثية لمحطة البحوث الزراعية بسخا محافظة كفرا لشيخ حيث التربة الطينية خفيفة القلوية ومستوى الماء الأرضى يتراوح مابين ١,٢

-١,٣م والظروف الجوية المناخية السنوية كالأتى : مجموع درجات الحرارة الفعالة ٤٥٣٩,٤٣ درجة فهرنهيتية ، متوسط الرطوبة النسبية اليومية ٦٠,٢٨ درجة ، ومتوسط سرعة الرياح ٥,٧٦ كم/ساعة ، ومتوسط المطر اليومى ٠,٢٢٨ مللى لتر/ يوم . وقد قيم النمو الخضرى أعوام ١٩٩٧ ، ٢٠٠٠ ، ٢٠٠١ وقيم المحصول من عام ١٩٩٦ حتى عام ٢٠٠١ ، وصفات جودة الثمار والمحتوى المعدنى للأوراق درست أعوام ١٩٩٩ ، ٢٠٠٠ ، ٢٠٠١م.

وقد أظهرت النتائج المتحصل عليها من هذه الدراسة مايلى:

- **النمو الخضرى:** أظهرت الأشجار المطعمة على أصل الفولكاماريانا أكبر نمو خضرى من حيث ارتفاع الشجرة وحجمها ، مساحة الورقة ووزنها الجاف ، قطر جذع الشجرة ومساحة مقطعة وذلك مقارنة بالأشجار المطعمة على أصل النارنج.
- **المحصول:** الأشجار المطعمة على أصل الفولكاماريانا كانت مبكرة عام فى حمل المحصول . وقد أعطت أكبر محصول ثمار للشجره كما أنها أظهرت أفضل كفاءة إنتاجية لوحدة الحجم (٣,٢٤ كجم / م٣ من حجم الشجرة) أو وحدة المساحة (٢,١٦كجم / سم٣ من مساحة جذع الشجرة) . كما أظهر المحصول التراكمى للشجرة أكبر زيادة معنوية وذلك مقارنة بالأشجار المطعمة على اصل النارنج.
- **صفات جودة الثمار:** الثمار على الأشجار المطعمة على أصل الفولكاماريانا كانت أكبر حجما ، قطرا وأسمك قشرة وكذلك نسبة المواد الصلبة الذائبة إلى الحموضة الكلية بينما ثمار الأشجار المطعمة على أصل النارنج كانت أكثر حموضة ومواد صلبة ذائبة كلية وكذلك النسبة المئوية للعصير ولم يتأثر معنويا فيتامين ج .
- **المحتوى المعدنى للأوراق:** احتوت أوراق الأشجار المطعمة على أصل الفولكاماريانا على زيادة فى محتواها من النتروجين ، البوتاسيوم ، والكالسيوم ، المغنيسيوم ، الزنك بينما احتوت أوراق الأشجار المطعمة على أصل النارنج على زيادة بسيطة من الفوسفور . وكانت الزيادة فى محتوى الأوراق من الزنك عالية المعنوية بينما محتوى الأوراق من المنجنيز، والحديد لم تتأثر معنويا .
- **من نتائج هذه الدراسة ونظرا لشدة قابلية أصل النارنج للإصابة بمرض التريستيزا والتى يتحملها أصل الفولكاماريانا ، فانه يمكن اقتراح أصل الفولكاماريانا أن يكون أصلا لاشجارالبرتقال أبو سره تحت ظروف هذه المنطقة.**