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Performance of three sweet orange varieties grafted on four rootstocks under Jordan Valley conditions

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Abstract:

Fruit quality of three orange varieties: 'Salustiana', 'Pineapple' and 'Hamlin' grafted on four rootstocks *viz.,* Sour orange (*Citrus aurantium*), 'Cleopatra' mandarin (*C. reticulata*), *C. volkameriana* and *C. macrophylla* were evaluated in Jordan Valley. Results indicated that sweet orange grafted on *C. macrophylla* and *C. volkameriana* gave the largest fruit weight, diameter and length, while those grafted on 'Cleopatra' mandarin gave the smallest fruit. In addition, 'Salustiana' on *C. macrophylla*, 'Pineapple' on 'Cleopatra' mandarin and 'Hamlin' on both *C. volkameriana* and 'Cleopatra' mandarin gave the highest juice percentage, however, 'Salustiana' on sour orange, 'Pineapple' on *C. macrophylla* and 'Hamlin' on sour orange and *C. macrophylla* had the least. Orange trees on sour orange and 'Cleopatra' mandarin gave the highest TSS percentage, while on *C. volkameriana* and *C. macrophylla* it was low. Moreover, 'Salustiana' grafted on *C. macrophylla* gave low juice pH while on 'Cleopatra' mandarin it gave high juice pH, the opposite was observed for 'Pineapple' and 'Hamlin'.

Key words: Fruit quality, rootstocks, sweet orange, *Citrus sinensis,* juice content

Introduction

Citrus is a major crop throughout the world as well as in Jordan covering about 6200 hectare (Ministry of Agriculture, 2002). In Jordan, most of citrus trees are grafted on sour orange, which is known for its resistance to gummosis, and high tolerance to wet calcareous soils (Wutscher, 1979), making it well adapted to surface irrigation system used by many farmers in the Jordan Valley. The fact that sour orange is susceptible to viral diseases such as 'Tristeza', and to avoid risk of incidence in future in citrus orchards in Jordan Valley, several rootstocks had been introduced and tested for its compatibility, tolerance and adaptability.

Citrus rootstocks have been used for a long time and their effects on the performance and characteristics of citrus scion cultivars have been reported and it differ in their effects on tree size, vigour, productivity and fruit quality, disease and pest resistance, and tolerance to different soil conditions such as salinity and acidity (Wutscher, 1979). Differences in production and tree size has been noticed from 'Washington navel', 'Valencia' orange, and 'Minneola' tangelo grafted on several rootstocks (Roose *et al.*, 1989). In addition, 'Shamouti', 'Jaffa', 'Valencia' and 'Navel' sweet orange grafted on different rootstocks differed in respect to tree size and growth and fruit quality (Ghnaim, 1993; Mehrotra *et al.*, 2000 and Zekri and Al-Jaleel, 2004).

'Valencia' orange grafted on *C. volkameriana* rootstock gave the highest production and rind thickness compared with those on sour orange and 'Cleopatra' mandarin, while trees grafted on both rootstocks gave the highest juice content (Reyes *et al.*, 1984). 'Hamlin' and 'Valencia' sweet orange produced smaller trees, better yield and fruit quality and economic returns on a moderate vigour rootstock than those on a vigorous rootstock (Wheaton *et al.*, 1991 and Wheaton *et al.*, 1995). 'Hamlin' orange grafted on *C. volkameriana* gave the largest fruit weight and diameter and rind thickness than those on sour orange which gave moderate values except for juice %, TSS, and acidity which were the highest (Wutscher and Bistline, 1988). 'Marsh' and 'Red blush' grapefruit grafted on Palestine sweet lime and *C. volkameriana* gave the highest production compared to those on sour orange, also, rootstocks affected grapefruit volume, weight, rind thickness, juice content, and TSS % (Economides *et al.*, 1993; Fallahi *et al.*, 1989 and Ramin and Alirezanezhad, 2005).

This study was carried out to evaluate fruit characteristics of three sweet orange varieties ('Salustiana', 'Pineapple' and 'Hamlin') grafted on four citrus rootstocks grown in the Jordan Valley.

Material and methods

Citrus orchard was established in 1980 to study the performance of sweet orange varieties (*C. sinensis* Osbeck) grafted on four rootstocks: Sour orange (*C. aurantium* L.), 'Cleopatra' mandarin (*C. reticulata* Blanco.), Volkamer lemon (*C. volkameriana* L.*)*, and Macrophylla (*C. macrophylla* Wester.) and spaced at 6 x 6 m. The trees received uniform standard cultural practices as practiced by orchardists in the Jordan Valley. The experiment was designed in Randomised Complete Block Design with three replicates and one tree on each rootstock per replicate.

Presented data is the average of 1992 to 2000 seasons and for three sweet orange varieties: 'Salustiana', 'Pineapple' and 'Hamlin'. Rootstock effect on sweet orange varieties was evaluated in relation to fruit characteristics, so in each season 10 kg of fruit from each replicate for each variety on different rootstocks were collected and analysed for fruit weight, length and diameter, seed number, peel thickness, juice % (w/w), total soluble solids and juice pH.

Data was statistically analysed by ANOVA and mean separation was by Least Significant Differences (LSD) value (P=0.05).

Results and discussion

Physical Fruit Characteristics

Average fruit weight: Results indicated that sweet orange varieties grafted on 'Cleopatra' mandarin had the smallest fruit. 'Salustiana' trees grafted on *C. macrophylla* gave the highest fruit weight (213.5 gm) but with no significant difference with *C. volkameriana* and Sour orange rootstocks (Table 1). While 'Pineapple' trees grafted on *C. volkameriana* gave the highest fruit weight (184.1 gm) but with no significant difference with those on *C. macrophylla*. Moreover, 'Hamlin' grafted on *C. macrophylla* significantly gave the highest fruit weight (199.7 gm) (Table 1).

Table 1. Effect of rootstocks on average fruit weight (g) for three sweet orange varieties

Treatments	Average fruit weight (g)		
	'Salustiana'	'Pineapple'	'Hamlin'
'Cleopatra' mandarin	167.8 b	163.3 c	154.4 b
Sour Orange	193.3 a	167.6 bc	155.2 b
C. macrophylla	213.5 a	178.5 ab	199.7 a
C. volkameriana	204.8 a	184.1 a	170.1 b

* Mean separation within columns by LSD test, values that don't share the same letters are significantly different (P=0.05).

Fruit diameter and length: Results also indicate that sweet orange varieties grafted on 'Cleopatra' mandarin had least fruit diameter. 'Salustiana' trees on *C. volkameriana* rootstock recorded the largest fruit diameter (78.4 mm) but with no significant differences with Sour orange and *C. macrophylla* (Table 2). For 'Pineapple', no significant differences were observed among the rootstocks. However, 'Hamlin' trees grafted on *C. macrophylla* significantly gave the largest fruit diameter (71.5 mm) followed by those on *C. volkameriana* and Sour orange (69.1 and 67.7, respectively) (Table 2).

Table 2. Effect of rootstocks on average fruit diameter for three sweet orange varieties

Treatments	Average fruit diameter (mm)		
	'Salustiana'	'Pineapple'	'Hamlin'
'Cleopatra' mandarin	70.9 b	69.5 a	65.5 c
Sour Orange	74.3 ab	70.9 a	67.7 b
C. macrophylla	73.8 ab	70.1 a	71.5 a
C. volkameriana	78.4 a	70.5 a	69.1 b

* Mean separation within columns by LSD test, values that don't share the same letter are significantly different (P=0.05).

As in fruit diameter, the similar trend was observed for fruit length in which sweet orange varieties grafted on 'Cleopatra' mandarin significantly gave the least fruit length. 'Salustiana' trees grafted on *C. macrophylla* rootstock gave the largest fruit length (76.0 mm) but with no significant differences with *C. volkameriana* (Table 3). 'Hamlin' trees grafted on *C. macrophylla* significantly gave the largest fruit length (72.9 mm) followed by those on *C. volkameriana* and Sour orange (Table 3).

Table 3. Effect of rootstocks on average fruit length for three sweet orange varieties

Treatments	Average fruit length (mm)		
	'Salustiana'	'Pineapple'	'Hamlin'
Cleopatra mandarin	67.7 c	67.6 a	65.1 c
Sour Orange	71.2 bc	68.7 a	66.4 bc
C. macrophylla	76.0 a	70.9 a	72.9 a
C. volkameriana	74.1 ab	70.1 a	67.8 b

* Mean separation within columns by LSD test, values that don't share the same letters are significantly different (P=0.05).

Fruit seed number: Results show that there was no significant difference among rootstocks for both 'Salustiana' and 'Pineapple' oranges, however, trees grafted on *C. macrophylla* gave the highest seed number. The opposite was observed for 'Hamlin', in which trees grafted on *C. macrophylla* gave the lowest seed number (2.2 seeds), while trees grafted on 'Cleopatra' mandarin, Sour orange and *C. volkameriana*, gave high fruit seed number (Table 4).

Table 4. Effect of rootstocks on seed number per fruit for three sweet orange varieties

Treatments	Average seed number		
	'Salustiana'	'Pineapple'	'Hamlin'
Cleopatra' mandarin	2.7 a	16.0 a	4.1 a
Sour Orange	2.4 a	16.8 a	3.9 a
C. macrophylla	3.0 a	17.4 a	2.2 b
C. volkameriana	2.4 a	16.3 a	3.8 a

* Mean separation within columns by LSD test, values that don't share the same letter are significantly different (P=0.05).

Chemical Fruit Characteristics

Juice percentage (w/w): Data in Table 5 indicate that 'Salustiana' trees grafted on *C. macrophylla* rootstock had highest fruit juice percentage (46.9 %), followed by those grafted on *C. volkameriana*, and 'Cleopatra' mandarin, however, trees grafted on Sour orange gave the lowest fruit juice content (40.7 %). For 'Pineapple', no significant difference was observed among rootstocks. In addition, 'Hamlin' trees grafted on *C. volkameriana* and 'Cleopatra' mandarin significantly gave high fruit juice percentage (52.4 and 50.0%, respectively), however, trees on Sour orange and *C. macrophylla* significantly gave low fruit juice percentage (45.5 and 45.6%, respectively) (Table 5).

Table 5. Effect of rootstocks on juice % (w/w) for three sweet orange varieties

Treatments	Juice % (w/w)		
	'Salustiana'	'Pineapple'	'Hamlin'
'Cleopatra' mandarin	42.6 b	44.4 a	50.0 a
Sour Orange	40.7 c	43.0 a	45.5 b
C. macrophylla	46.9 a	42.4 a	45.6 b
C. volkameriana	42.1 bc	41.8 a	52.4 a

* Mean separation within columns by LSD test, values that don't share the same letters are significantly different (P=0.05).

Total soluble solids: Results indicated that sweet orange varieties grafted on Sour orange gave the highest total soluble solids percentage followed by those grafted on 'Cleopatra' mandarin. For 'Salustiana', trees grafted on *C. volkameriana* gave the lowest fruit TSS (10.8 %) (Table 6). For 'Pineapple', trees grafted on *C. macrophylla* significantly gave the lowest fruit TSS percentage (11.7 %). In addition, 'Hamlin' trees on *C. macrophylla* significantly gave the lowest TSS (10.0 %) (Table 6).

Juice pH: No significant difference was observed among rootstocks for 'Salustiana' trees, however, trees grafted on *C.*

Table 6. Effect of rootstocks on total soluble solids of three sweet orange varieties

Treatments	TSS (%)		
	'Salustiana'	'Pineapple'	'Hamlin'
'Cleopatra' mandarin	12.6 a	12.3 ab	12.0 b
Sour Orange	13.1 a	13.1 a	13.0 a
C. macrophylla	11.6 b	11.7 b	10.0 c
C. volkameriana	10.8 c	12.4 ab	11.2 b

* Mean separation within columns by LSD test, values that don't share the same letters are significantly different (P=0.05).

macrophylla gave low fruit juice pH (3.76), while trees grafted on 'Cleopatra' mandarin had high juice pH (4.08) (Table 7). The opposite was observed for 'Pineapple' and 'Hamlin' oranges, in which trees grafted on *C. macrophylla* gave high juice pH (3.84 and 4.01, respectively) while those on Sour orange and 'Cleopatra' mandarin gave low fruit juice pH (Table 7).

Table 7. Effect of rootstocks on juice pH for three sweet orange varieties

Treatments	Juice pH		
	'Salustiana'	'Pineapple'	'Hamlin'
'Cleopatra' mandarin	4.08 a	3.64 b	3.71 b
Sour Orange	3.77 a	3.63 b	3.80 b
C. macrophylla	3.76 a	3.84 a	4.01 a
C. volkameriana	3.94 a	3.75 ab	3.75 b

* Mean separation within columns by LSD test, values that don't share the same letters are significantly different (P=0.05).

Several investigations have been conducted on the rootstock effect on citrus fruit quality and there are conflicting results since it would not be realistic to expect a rootstock to induce a radical change in fruit quality. Results indicated that rootstocks and scions interact in many ways including at least 14 fruit quality factors influenced by the rootstock (Wutscher, 1979). In general, several researchers found that trees on sour orange can produce medium-sized to large fruit (Wutscher, 1979), and this was observed in this study for all the three varieties in respect to fruit weight, diameter and length.

In addition, trees grafted on sour orange produce fruit with high total soluble solids (TSS) and high juice acidity (Wutscher, 1979) and this statement agrees with our findings. Trees grafted on sour orange are also expected to produce fruit with high juice acidity and this statement generally agrees with our findings. However, for fruit juice percentage, the result of this study do not agree with the results of Wutscher and Bistline (1988), who found that 'Hamlin' orange grafted on sour orange gave the highest fruit juice percentage.

On the other hand, many researchers found that trees grafted on lemon rootstocks (*C. volkameriana* and *C. macrophylla*), produce usually larger fruit with poor fruit quality: thick rinds, low total soluble solids and low juice acidity (Reyes *et al.*, 1984; Salibe and Mischan, 1984 and Wutscher and Bistline, 1988) and this view corroborates with our results.

Trees grafted on 'Cleopatra' mandarin produced small fruits with high total soluble solids and juice acidity than on other rootstocks (Wutscher, 1979). These findings are, in general, agreement with the results of this study except for juice acidity in 'Salustiana' variety.

The study revealed that Sour orange, 'Cleopatra' mandarin, Volkamer lemon (*C. volkameriana* L.) and Macrophylla (*C. macrophylla* Wester.) rootstocks affected external and internal fruit quality of 'Salustiana', 'Pineapple' and 'Hamlin' sweet orange varieties including fruit weight, length, diameter, seed number, juice content, total soluble solids and juice pH. Trees on sour orange produced medium-sized fruits with high TSS and juice acidity. While, those on *C. volkameriana* and *C. macrophylla* produced larger fruit with low TSS and juice acidity. Whereas, trees on 'Cleopatra' mandarin produced small fruits with high TSS and juice acidity.

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