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# GROWTH, YIELD, FRUIT QUALITY AND MINERAL COMPOSITION OF FIVE CITRUS ROOTSTOCKS

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## ABSTRACT

This study was carried out on 12 years old citrus rootstocks namely: Sour orange, Rangpur lime, Volkamer lemon, Troyer citrange and Cleopatra mandarin to evaluate their growth, yield, fruit quality and mineral composition of roots and leaves.

**The obtained results are summarized as follows:**

1. Volkamer lemon and Rangpur lime have the largest tree size and leaf or shoot growth characters. Sour orange was moderate while, Troyer citrange and Cleopatra mandarin had the lowest values of all tested growth parameters.
2. Volkamer lemon and Rangpur lime, had the greatest weight of fibrous roots at all distances from tree trunk, but the lowest weight of fibrous roots was found for Cleopatra mandarin rootstock.
3. Volkamer lemon and Rangpur lime had significantly heavier fruit yield as (kg) per tree as compared with the other tested rootstocks. Fruits in Volkamer lemon and Sour orange was large and heavier, but in Troyer citrange, it was moderate, while fruit of Rangpur lime and Cleopatra mandarin was small. Rangpur lime gave numerous seeds per fruit, however Sour orange, Volkamer lemon and Troyer citrange were moderate, while Cleopatra mandarin gave the lowest number of seeds per fruit.
4. On the other hand, Sour orange gave the highest percentage of seed germination, followed by Cleopatra mandarin, while, troyer citrange recorded the least value. Volkamer lemon and Rangpur lime recorded moderate value of seed germination percentage.
5. Leaves of Volkamer lemon and Rangpur lime contained higher N, P, K, Ca, Mg, Fe, Mn and Cu but lower Na and Cl levels than that of the other tested rootstocks. However, macro and micronutrients in the roots of all tested rootstoc1ks were not consistent in their trend.

## INTRODUCTION

Rootstocks selection is a major consideration in every growing operation. It is fundamental to the orchard success. Besides supporting the tree, the root system is responsible for absorption of water and nutrients (Fallahi *et al.,* 1992, Mansour *et al.,* 1993, El-Sayed, Somaia, 1999 and Ennab, 2003), adapting the scion to particular soil conditions and potentially providing tolerance to some disease (Louzada *et al.,* 1992). Moreover, there is no single rootstock reisant to all diseases, tolerant to poor soil, drought, salinity and produce more yield with good quality. Due to the physiological and genetical characters of the used rootstock such as: 1) Volkamer lemon and Rangpur lime have been used as rootstocks because trees on those stocks are vigorous, high yielding, and tristerza, drought and salinity tolerant (Fallahi and Rodeny, 1992; Louzada *et al;.,* 1992 and El-Hammady *et al.,* 1995). 2) Cleopatra mandarin has become an important rootstock because of its tolerant to tristeza. Trees budded on Cleopatra mandarin rootstock

moderately vigours but are slow to reach full bearing potential (Davies and Albrigo, 1994) and 3) Sour orange is still the most important rootstock in Egypt because of its resistance to gummosis and rot in the heavy soil and compatibility with almost commercial citrus varieties in growth and fruit quality.

The aim of the present study was to evaluate and compare the growth, yield, fruit quality and mineral composition of five citrus rootstocks under Kafr El-Sheikh condition.

## MATERIALS AND METHODS

The present study was carried out on 12 years old citrus rootstocks in the experimental farm of Sakha Horticulture Research Station, Kafr El-Sheikh Governorate, Egypt during 2003 and 2004 seasons. The tested rootstocks were: Sour orange (*C. aurantium*); Rangpur lime (*C. limonia,* Osbeck); Volkamer lemon (*C. volkamariana* Ten. & Pasq); Cleopatra mandarin (*C. reshni*, Hort. ex. Tan.) and Troyer citrange (*P. trifoliate* x *C. sinensis*).

The rootstocks were planted at 5 x 5 meters in a complete randomized block design with three rootstocks plot replicated three times for a total of nine rootstock. All trees received regular and usual horticultural practices. Mechanical and chemical analysis of experimental field soil was done as shown in Table (1).

**Table (1):Mechanical and chemical analysis of experimental field soil.**

| Mechanical | | | | Chemical | | | Available ppm | | |
|---|---|---|---|---|---|---|---|---|---|
| Sand % | Silt % | Clay % | T. clay | pH | EC | O.M. % | N | P | K |
| 9.65 | 32.15 | 58.20 | Clay | 8.2 | 3.35 | 1.90 | 18.53 | 7.78 | 237.47 |

In this study four branches of 2 inches in diameter form each replicate were selected in the four directions and tagged, then all measurements and sampling materials were taken from this branches as follows:

**A. Vegetative growth:**

Tree height (cm) of each replicate was measured form the soil surface to the end of growth in both seasons. Canopy volume ($m^3$) was calculated by using the equation 0.5238 x tree height x diameter square, according to Turrell (1946). Area per leaf ($cm^2$) three leaves base, medium and terminal were collected from spring, summer and autumn flushes and leaf area was measured using leaf area meter mode Li 31000,m then average leaf area was calculated according to Singh and Snyder (1984). Leaf area per shoot $cm^2$ and leaf area per branch $m^2$ were calculated. Leaf number per shoot was counted from spring, summer and autumn flushes, then leaf number per branch was calculated. Shoot length (cm) was measured from spring, summer and autumn flushes. Then total shoot length (cm) was calculated. Shoot number per branch was counted from spring, summer and autumn flushes.

**B. Root growth:**

In September of both seasons, fibrous root samples were taken from four directions at distances of 50, 100 and 150 cm from tree trunk. Samples were obtained by a method described by Ellis and Bornes (1971) using an auger 10 cm in diameter and 30 cm length. The auger was driven into the soil to a depth of 30, 60 and 90 cm each from the soil surface. The soil samples were washed through 1 cm mesh to separate root from soil. Fibrous ($\leq$ 2 mm diameter) root weight as gm/auger was determined according to Newman (1966) and Hassan *et al.* (1984).

**C. Yield and fruit quality:**

At harvest time in December the yield of each rootstock was detemriend as weight (kg) per tee. Also, fruit quality was detemriend as fruit length (cm), diameter (cm), weight (gm), volume ($cm^3$), number of seeds per fruits, SSL and acidity according to (A.O.A.C. 1970).

One hundred and fifty seeds from the three replicates (50 seeds/rep.) for each rootstock were washed with tap water, and washed again with distilled water. Seeds were sown in plastic boxes, each box was filled with a mixture of sand and peat moss (1: 1), all boxes were irrigated immediately after sowing. The number of germinated seeds was counted weekly until the completion of seed germination, then, the percentage of seed germination was calculated according to Hartmann and Kaster (1983).

$$\text{Seed germination percentage} = \frac{\text{Number of germinated seeds}}{\text{Initial number of seeds}} \times 100$$

**D. Leaf and root mineral content:**

In September of both seasons, 50 spring flush leaves as well as samples from fibrous roots were washed and oven dried at 70 C to constant weight. The dried leaves and roots were ground and digested by $H_2SO_4$ and $H_2O_2$ according Evehius and DeWaard (1980). Total nitrogen was detemriend by microkjeldahl gunning method A.O.A.C. (1970). Phosphorus was determined by colorimeter, potassium and sodium by using flame photometer according to Chapman and Pratt (1978). Ca, Mg, Fe, Zn, Mn and Cu were detemriend by Perkin Elemer Atomic Absorption Spectrophotometer model 2380 Al according to Jackson and Ulich (1959). Chloride was detemriend by silver nitrate methods due to Brown and Jackson (1955).

All obtained data were statistically analyzed according to Snedecor and Cochran (1967).

## RESULTS AND DISCUSSION

**A. Vegetative growth behaviour:**

Data in Table (2) revealed that Troyer citrange and Volkamer lemon had the highest tree height with significant differences between them only in the first season, Rangpur lime came the second with significant differences as compared with all tested rootstocks. On the other hand, Sour orange and Cleopatra mandarin gave the lowest values of tree height in both seasons. These results are in line with those reported by Levy *et al.* (1993) and Dawood (1996) who stated that Coleolptara mandarin gave the lowest plant

height and trunk diameter as compared with Rough lemon, macrophylla and Volkamer lemon.

As for canopy volume, it is clear from the data in Table (2) that Volkamer lemon had greater canopy volume than that of the other tested rootstocks. Rangpur lime gave second values of canopy volume in both seasons. On the other side Cleopatra mandarin had the least values in this respect. Sour orange and Troyer citrange gave intermediate value of this parameter. The differences were significant among al tested rootstocks in both seasons. Similar results were obtained by Abou-Rawash *et al.* (1995) and Dawood *et al.* (2002) they found that Volkamer lemon and Rangpur lime showed the best growth parameters represented by plant height, diameter, fresh and dry weight of whole plant.

**Table (2): Tree vigor parameters of five citrus rootstocks during 2003 and 2004 seasons.**

| Rootstock | Tree height (cm) | | Canopy volume ($m^3$) | |
|---|---|---|---|---|
| | 2003 | 2004 | 2003 | 2004 |
| Sour orange | 4.35 | 4.65 | 7.28 | 8.06 |
| Volkamer lemon | 5.39 | 5.74 | 17.85 | 18.65 |
| Troyer citrange | 5.63 | 5.86 | 6.98 | 7.71 |
| Rangpur lime | 4.78 | 5.23 | 11.57 | 12.20 |
| Cleopatra mandarin | 4.12 | 4.29 | 4.53 | 5.43 |
| L.S.D. at 5% | 0.09 | 0.51 | 0.17 | 0.10 |

As for leaf growth characters data in Table (3) revealed that leaf growth characters in the different rootstocks such as leaf area per shoot, total leaves area per branch, leaves number per shoot per branch were greater during spring flush than the other flushes. Similar trend of results was noted by Keleg *et al.* (1970), El-Barkouky *et al.* (1987a) and El-Barkouky *et al.* (1987b).

Regarding the variations among rootstocks on leaf growth parameters, data indicated that Volkamer lemon and Sour orange gave the highest values of area per leaf, leaf area per shoot, total leaves area per branch and leaves number per shoot or branch with significant differences between them in both seasons. Rangpur lime had intermediate values of most leaf growth parameters with significant differences between Rangpur lime and all tested rootstocks. On the other hand, Cleopatra mandarin and Troyer citrange had the lowest values of leaf growth parameters with significant differences between them and all tested rootstocks. This result was true in both seasons. These results are in line with those reported by Saad-Allah *et al.* (1985), El-Barkouky *et al.* (1987a) and Azab and Hegazy (1995). They found that leaf growth parameters such as leaf area, leaf number per shoot, leaf length and width were larger in Rough lemon, Rangpur lime and Volkamer lemon, while moderate in Troyer citrange, but small in Cleopatra mandarin. Such conclusion find support with those obtained by Dawood (1996) and Dawood *et al.* (2002) who reported that area per leaf, total leaves number per plant or total leaves area per plant were greatest on Volkamer lemon followed by Rangpur lime. However, Sour orange and Troyer citrange were intermediate whereas Cleopatra mandarin recorded the least values in this respect.

**Table (3): Leaf growth parameters of five citrus rootstocks during 2003 and 2004 seasons.**

| Rootstock | Av. area per leaf $cm^2$ | | | Av. leaf area per shoot $cm^2$ | | | Av. total leaves area per branch $m^2$ | | | Av. no. leaves per shoot | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spr. | Sum. | Aut. | Spr. | Sum. | Aut. | Spr. | Sum. | Aut. | Spr. | Sum. | Aut. |
| | 2003 | | | | | | | | | | | |
| Sour orange | 19.95 | 19.05 | 19.42 | 501.93 | 347.91 | 325.64 | 4.18 | 1.35 | 1.44 | 24.22 | 18.44 | 16.88 |
| Volkamer lemon | 20.04 | 19.06 | 20.54 | 525.37 | 388.71 | 279.91 | 3.62 | 1.46 | 1.16 | 26.22 | 20.44 | 13.55 |
| Troyer citrange | 11.07 | 9.31 | 12.92 | 285.53 | 184.46 | 202.51 | 1.93 | 0.67 | 0.86 | 25.77 | 19.77 | 16.22 |
| Rangpur lime | 20.88 | 19.11 | 20.11 | 459.17 | 329.24 | 345.31 | 2.03 | 0.85 | 1.04 | 22.22 | 17.11 | 17.11 |
| Cleopatramandarin | 13.75 | 12.23 | 14.92 | 283.11 | 197.24 | 228.43 | 1.71 | 0.65 | 0.87 | 20.44 | 16.22 | 15.77 |
| L.S.D. at 5% | 2.27 | 2.41 | 2.94 | 64.69 | 59.74 | 60.93 | 0.52 | 0.22 | 0.24 | 2.95 | 2.91 | 2.67 |
| | 2004 | | | | | | | | | | | |
| Sour orange | 20.78 | 19.92 | 18.60 | 481.5 | 389.1 | 280.5 | 3.96 | 1.39 | 1.23 | 23.16 | 19.53 | 15.06 |
| Volkamer lemon | 21.36 | 20.23 | 19.48 | 520.5 | 410.5 | 233.4 | 3.24 | 1.40 | 0.95 | 24.40 | 20.26 | 11.96 |
| Troyer citrange | 12.57 | 11.91 | 11.84 | 277.1 | 220.3 | 171.0 | 1.66 | 0.69 | 0.71 | 22.06 | 18.50 | 14.46 |
| Rangpur lime | 21.42 | 20.38 | 20.20 | 439.3 | 377.4 | 297.0 | 2.01 | 0.95 | 0.91 | 20.50 | 18.46 | 14.66 |
| Cleopatra mandarin | 14.40 | 12.31 | 13.78 | 285.2 | 220.9 | 184.2 | 1.84 | 0.74 | 0.67 | 19.79 | 17.96 | 13.36 |
| L.S.D. at 5% | 1.70 | 17.2 | 0.90 | 3.95 | 2.07 | 4.13 | 0.30 | 0.20 | 0.14 | 1.10 | N.S | 1.24 |

**Spr. = Spring Sum. = Summer Au. = Autumn**

Concerning shoot growth characters, data in Table (4) indicated that all rootstocks had the longest shoot length in summer growth cycle when compared with spring and autumn growth cycles.

**Table (4): Shoot growth parameters of five citrus rootstocks during 2003 and 2004 seasons.**

| Rootstock | Av. total number of leaves per branch | | | Shoot length Cm | | | Av. total shoot length per branch (m) | | | Av. total shoot number per branch | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spr. | Sum. | Aut. | Spr. | Sum. | Aut. | Spr. | Sum. | Aut. | Spr. | Sum. | Aut. |
| | 2003 | | | | | | | | | | | |
| Sour orange | 2028.2 | 723.8 | 754.2 | 38.22 | 59.44 | 34.44 | 31.85 | 23.25 | 14.92 | 83.33 | 39.11 | 44.55 |
| Volkamer lemon | 1809.5 | 772.6 | 586.0 | 45.88 | 71.44 | 42.88 | 31.61 | 26.98 | 18.60 | 68.88 | 37.77 | 43.33 |
| Troyer citrange | 1758.4 | 724.6 | 706.6 | 42.00 | 57.11 | 40.00 | 28.65 | 20.86 | 17.22 | 68.11 | 36.55 | 43.11 |
| Rangpur lime | 913.7 | 437.0 | 521.1 | 35.22 | 59.66 | 34.66 | 15.63 | 14.85 | 10.46 | 44.33 | 24.88 | 30.22 |
| Cleopatra mandarin | 1253.5 | 544.8 | 600.6 | 33.44 | 50.55 | 32.44 | 20.58 | 16.88 | 12.39 | 61.33 | 33.44 | 38.22 |
| L.S.D. at 5% | 8.39 | 4.03 | 4.14 | 3.01 | 2.52 | 3.17 | 3.33 | 1.75 | 1.85 | 2.82 | 3.40 | 2.96 |
| | 2004 | | | | | | | | | | | |
| Sour orange | 1807.6 | 700.7 | 666.7 | 39.52 | 62.88 | 37.40 | 30.83 | 22.61 | 16.53 | 78.06 | 35.93 | 44.23 |
| Volkamer lemon | 1522.6 | 694.4 | 492.4 | 43.98 | 74.44 | 43.56 | 27.42 | 25.53 | 17.85 | 62.46 | 34.30 | 41.06 |
| Troyer citrange | 1326.4 | 582.9 | 605.9 | 43.91 | 60.68 | 43.13 | 26.35 | 19.19 | 18.01 | 60.06 | 31.60 | 41.86 |
| Rangpur lime | 942.2 | 466.5 | 452.2 | 36.63 | 61.87 | 36.90 | 16.80 | 15.52 | 11.63 | 46.00 | 25.26 | 31.50 |
| Cleopatra mandarin | 1281.5 | 611.1 | 490.1 | 35.19 | 53.69 | 35.70 | 22.79 | 18.25 | 13.11 | 64.73 | 33.96 | 36.70 |
| L.S.D. at 5% | 3.16 | 7.79 | 4.72 | 2.83 | 0.68 | 2.20 | 1.12 | 1.81 | 1.56 | 3.25 | 2.72 | 3.17 |

**Spr. = Spring Sum. = Summer Au. = Autumn**

Volkamer lemon had the longest shoot length and total shoot length per branch followed by Troyer citrange and Sour orange with significant differences among them in both seasons. Rangpur lime gave intermediate values, but Cleopatra mandarin had the lowest values in this respect. These results were true in both seasons and in all growth cycles. Regarding total shoot number per branch data in Table (4) showed that more shoots were formed in spring growth cycle than summer or autumn growth cycles. Sour orange and Volkamer lemon had the highest values followed by Troyer citrange without significant differences among them in most cases. Cleopatra

mandarin gave intermediate value, but the least values belonged to Rangpur lime. These results are similar to those obtained by El-Barkouky *et al.* (1987b), Abou-Rawash *et al.* (1995), Dawood (1996) and Dawood (2002).

The results presented in Tables (2, 3 and 4) indicated that Volkamer lemon and Rangpur lime had larger tree size, vigorous growther presented by leaf and shoot growth parameters than other tested rootstocks. Sour orange gave intermediate values in this respect. On the other hand, Troyer citrange and Cleopatra mandarin had small tree size, and less leaf and shoot growth parameters. These results are in agreement with those of Azab and Hegazy (1995) who found that Rangpur lime, Volkamer lemon and Macrophylla exhibited after transplanting better survival, stem diameter, leaf area, higher number of shoots and dry mater production than other rootstocks such as Cleopatra mandarin, Yuma citrange, Sacaton citrumelo and citrus amblycarpa. Data also indicated that the largest total of new growths was formed during spring growth cycle than other ones. Moreover, in spring more shoots as number were formed but their length was less than those formed in summer or autumn growth cycles. These results generally agree with those of Minessy *et al.* (1970).

**B. Root growth:**

It is clear from Table (5) that Volkamer lemon had the greatest dry weight of fibrous roots at all distances (50, 100 and 150 cm) from tree trunk followed by Rangpur lime as compared with other tested rootstocks.

**Table (5): Root dry weight (gm/auger) of vie citrus rootstocks during 2003 and 2004 seasons.**

| Rootstock | 50 cm from tree trunk | | | 100 cm from tree trunk | | | 150 cm from tree trunk | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 cm depth | 60 cm depth | 90 cm depth | 30 cm depth | 60 cm depth | 90 cm depth | 30 cm depth | 60 cm depth | 90 cm depth |
| | **2003** | | | | | | | | |
| Sour orange | 1.168 | 0.526 | 0.187 | 1.507 | 0.787 | 0.386 | 2.244 | 1.514 | 0.937 |
| Volkamer lemon | 2.033 | 0.721 | 0.257 | 2.623 | 1.080 | 0.663 | 3.945 | 2.154 | 1.287 |
| Troyer citrange | 1.005 | 0.515 | 0.183 | 1.352 | 0.778 | 0.352 | 2.022 | 1.543 | 0.918 |
| Rangpur lime | 1.328 | 0.676 | 0.241 | 1.713 | 1.011 | 0.455 | 2.560 | 2.026 | 1.213 |
| Cleopatra mandarin | 0.567 | 0.306 | 0.118 | 0.843 | 0.462 | 0.246 | 1.462 | 0.924 | 0.554 |
| L.S.D. at 5% | 0.240 | 0.002 | 0.005 | 0.011 | 0.005 | 0.018 | 0.265 | 0.079 | 0.009 |
| | **2004** | | | | | | | | |
| Sour orange | 1.214 | 0.578 | 0.199 | 1.517 | 0.781 | 0.382 | 2.254 | 1.525 | 0.930 |
| Volkamer lemon | 2.097 | 0.758 | 0.259 | 2.529 | 1.095 | 0.659 | 3.941 | 2.159 | 1.290 |
| Troyer citrange | 1.015 | 0.556 | 0.185 | 1.355 | 0.818 | 0.347 | 2.00 | 1.545 | 0.920 |
| Rangpur lime | 1.389 | 0.689 | 0.251 | 1.720 | 1.019 | 0.451 | 2.561 | 2.019 | 1.215 |
| Cleopatra mandarin | 0.688 | 0.416 | 0.129 | 0.855 | 0.486 | 0.256 | 1.845 | 0.925 | 0.555 |
| L.S.D. at 5% | 0.140 | 0.053 | 0.024 | 0.283 | 0.071 | 0.035 | 0.430 | 0.085 | 0.208 |

**Auger = 2356 $cm^3$**

The differences were significant between them in both seasons. The lowest dry weight of fibrous roots, was found for Cleopatra mandarin. On the other hand, Sour orange and Troyer citrange had intermediate values in this respect. These results agree with those reported by Saad-Alla *et al.* (1985) who found that Troyer citrange had the smallest amount of feeder roots as compared to Rough lemon and Sour orange.

It is clear that dry weight of the fibrous roots increased at 100 and 150 cm distances from tree trunk with depths 30, 60 and 90 cm. Also fibrous roots were concentrated on the soil surface, but decreased in the deeper

layers, this result was true for all rootstocks. These findings agree with those reported by Dawood *et al.* (2002) and Ennab (2003). They reported that Volkamer lemon and Rangpur lime had the greatest root density and distribution, while Cleopatra mandarin had the lowest values in this respect.

**C. Yield and fruit quality:**

Data presented in Table (6) showed that fruit yield as kg/tree of Volkamer lemon and Rangpur lime was significantly heavier than that on the other tested rootstocks. Moreover, Sour orange and Troyer citrange gave intermediate value of fruit weight as yield per tee whereas, Cleopatra mandarin had the lowest value with significant differences between this rootstock and all tested ones.

As for fruit quality, the results in Table (6) showed that fruits of Volkamer lemon were larger as fruit length and diameter followed by Sour orange and Troyer citrange was moderate, while fruits of Rangpur lime and Cleopatra mandarin were small. Fruit volume and weight values were greatest for Sour orange followed by Volkamer lemon. Throyer citrange had intermediate values, but the lowest values of both parameters measured for Rangpur lime and Cleopatra mandarin. The differences were significant in both seasons. Number of seeds per fruit was highest in Rangpur lime ranged from 29 to 34.3 seeds in both seasons, while it was moderate in Sour orange, Volkamer lemon and Troyer citrange. The least number was in Cleopatra mandarin. Also, data in Table (6) showed that, the highest values of seed germination percentage (81.6%) was calculated for Sour orange followed by Cleopatra mandarin (71.0%) while the lowest value recorded for Troyer citrange rootstock (49.6%). Volkamer lemon and Rangpur lime rootstocks recoded moderate values (69.2 and 64.0%) respectively. The differences were significant in all cases in both seasons.

**Table (6):Yield, physical and chemical fruit characters and germination (%) of five citrus rootstocks during 2003 and 2004 seasons.**

| Rootstock | Fruit length (cm) | Fruit diameter (cm) | Fruit volume ($cm^3$) | Fruit weight (g) | Number of seeds/fruit | Germin-ation (%) | SSL (%) | Acidity (%) | Yield as kg/tree |
|---|---|---|---|---|---|---|---|---|---|
| | **2003** | | | | | | | | |
| Sour orange | 5.56 | 5.00 | 154.80 | 145.98 | 24.00 | 81.6 | 9.24 | 5.46 | 63.5 |
| Volkamer lemon | 6.80 | 6.46 | 126.88 | 116.88 | 22.40 | 69.2 | 8.60 | 4.68 | 91.8 |
| Troyer citrange | 4.92 | 4.46 | 114.00 | 99.06 | 21.00 | 49.6 | 11.62 | 5.76 | 59.3 |
| Rangpur lime | 3.72 | 4.46 | 82.40 | 81.10 | 29.00 | 64.0 | 7.90 | 6.16 | 89.5 |
| Cleopatra mandarin | 3.56 | 3.20 | 81.10 | 75.26 | 14.80 | 71.0 | 10.92 | 3.98 | 37.4 |
| L.S.D. at 5% | 0.31 | 0.46 | 7.78 | 7.32 | 2.85 | 12.33 | 0.46 | 0.27 | 4.4 |
| | **2004** | | | | | | | | |
| Sour orange | 5.72 | 4.56 | 154.80 | 141.56 | 22.30 | 83.8 | 9.13 | 5.33 | 63.4 |
| Volkamer lemon | 6.84 | 6.59 | 127.13 | 116.53 | 20.30 | 69.4 | 8.30 | 4.86 | 93.0 |
| Troyer citrange | 5.08 | 4.54 | 115.56 | 95.83 | 19.20 | 54.6 | 11.26 | 5.60 | 58.7 |
| Rangpur lime | 3.99 | 2.90 | 84.00 | 82.50 | 34.30 | 65.2 | 7.90 | 6.00 | 90.8 |
| Cleopatra mandarin | 3.77 | 3.26 | 83.50 | 76.03 | 16.10 | 72.4 | 10.90 | 3.96 | 38.6 |
| L.S.D. at 5% | 0.96 | 1.06 | 2.07 | 1.85 | 1.92 | 13.85 | 0.26 | 0.18 | 38.6 |

The highest SSL was found in Troyer citrange juice, Cleopatra mandarin and Sour orange, but the lowest value was in Rangpur lime and Volkamer lemon. Acidity was low in Cleopatra mandarin, while it was highest in Rangpur lime followed by Troyer citrange and Sour orange. On the other side, Volkamer lemon gave intermediate values in this respect. The differences were

significant among all tested rootstocks in both seasons. The obtained results agree with those reported by El-Barkouky *et al.* (1987a) and (1987b).

**D. Root and leaf mineral content:**

As for root mineral content, data in Table (7) revealed that N and K in roots were highest for Sour orange and Volkamer lemon, while Troyer citrange had intermediate values. The lowest values found in Rangpur lime and Cleopatra mandarin.

**Table (7): Concentrations of macro and micro-nutrients in the roots of five citrus rootstocks during 2003 and 2004 seasons.**

| Rootstock | N % | P % | K % | Ca % | Mg % | Na % | Cl % | Fe ppm | Mn ppm | Zn ppm | Cu ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2003** | | | | | | | | | | |
| Sour orange | 1.45 | 0.19 | 0.91 | 1.45 | 0.274 | 0.240 | 0.178 | 184.6 | 91.8 | 87.8 | 17.0 |
| Volkamer lemon | 1.34 | 0.18 | 0.88 | 1.49 | 0.242 | 0.224 | 0.162 | 224.8 | 70.8 | 68.0 | 11.4 |
| Troyer citrange | 1.20 | 0.17 | 0.75 | 1.40 | 0.266 | 0.294 | 0.136 | 240.8 | 91.0 | 77.6 | 14.0 |
| Rangpur lime | 1.10 | 0.14 | 0.77 | 1.56 | 0.250 | 0.232 | 0.176 | 234.2 | 123.4 | 60.8 | 11.6 |
| Cleopatra mandarin | 1.09 | 0.24 | 0.66 | 1.35 | 0.258 | 0.198 | 0.140 | 215.8 | 93.2 | 79.4 | 13.2 |
| L.S.D. at 5% | 0.24 | 0.02 | 0.03 | 0.06 | N.S. | 0.040 | 0.020 | N.S. | 5.8 | 3.9 | 2.5 |
| | **2004** | | | | | | | | | | |
| Sour orange | 1.44 | 0.20 | 0.46 | 1.46 | 0.264 | 0.239 | 0.179 | 185.5 | 92.7 | 88.5 | 18.6 |
| Volkamer lemon | 1.35 | 0.18 | 0.86 | 1.48 | 0.241 | 0.222 | 0.163 | 225.7 | 71.5 | 69.0 | 11.5 |
| Troyer citrange | 1.25 | 0.17 | 0.53 | 1.41 | 0.0258 | 0.290 | 0.137 | 240.5 | 92.1 | 78.6 | 15.6 |
| Rangpur lime | 1.15 | 0.15 | 0.79 | 1.56 | 0.249 | 0.233 | 0.177 | 235.3 | 122.6 | 61.9 | 12.5 |
| Cleopatra mandarin | 1.10 | 0.25 | 0.77 | 1.38 | 0.251 | 0.192 | 0.141 | 215.9 | 94.5 | 80.6 | 13.9 |
| L.S.D. at 5% | 0.07 | N.S | 0.13 | N.S. | 0.009 | 0.010 | 0.015 | N.S | 5.5 | N.S | 1.7 |

The differences were significant among all tested rootstocks in both seasons. Meanwhile, the other macro and micro-nutrients in roots of all tested rootstocks were not consistent in their trend, but each of them revealed higher values in some rootstocks and lower for others. Sour orange revealed high levels of P, Mg, Cl, Zn and Cu but lower in Fe content. Besides, Volkamer lemon recorded higher values of Ca and P but lower in Mg, Na, Cl, Mn and Cu. Rangpur lime was higher in Ca, Fe and Mn but lower in P, Mg, Na, Cl, Zn and Cu. Troyer citrange was higher in Mg, Na, Fe and Cu but lower in P, Ca, Cl and Mn Cleopatra mandarin showed higher P, Mn and Zn contents but lower in Ca, Na, Cl and Fe. These results were true in both seasons. Similar results were obtained by Azab (1995), Dawood (1996) and Ennab (2003).

Concerning leaf mineral content, data in Table (8) showed that Volkamer lemon and Rangpur lime had higher levels of N, P, K, Ca, Mg, Fe, Mn and Cu but lower in Na, Cl and Za as compared with all tested rootstocks. The other rootstocks i.e. Sour orange, Troyer citrange and Cleopatra mandarin were not consistent in their trend of macro and micro-nutrients of the leaves. Sour orange revealed high levels of N, Mn and Cu but lower P, Ca, Mg, Na, Fe and Zn content. Also, Troyer citrange was higher in P, K, Na, Fe and Zn but lower in N, Mn, Zn and Cu. Cleopatra mandarin showed higher Mg and Na contents but lower in N, PI, K, Ca, Cl, Fe, Zn and Cu. These results agree with those reported by Abou-Rawash *et al.* (1995) who found that leaf N, P, K contents of Rangpur lime were highest, whereas Volkamer lemon exhibited the greatest value of Mg, Fe and Mn in leaves. On the other

hand, Sour orange surpassed all other rootstocks in their leaf Na and Cl contents.

**Table (8):Concentrations of macro and micro-nutrients in the leaf of five citrus rootstocks during 2003 and 2004 seasons.**

| Rootstock | N % | P % | K % | Ca % | Mg % | Na % | Cl % | Fe ppm | Mn ppm | Zn ppm | Cu ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2003** | | | | | | | | | | |
| Sour orange | 2.56 | 0.194 | 1.37 | 3.526 | 0.48 | 0.152 | 0.206 | 125.1 | 44.6 | 45.0 | 13.0 |
| Volkamer lemon | 2.47 | 0.202 | 1.33 | 3.562 | 0.57 | 0.166 | 0.200 | 134.8 | 34.5 | 55.4 | 12.8 |
| Troyer citrange | 2.23 | 0.210 | 1.47 | 3.540 | 0.49 | 0.190 | 0.208 | 148.8 | 37.2 | 56.2 | 11.2 |
| Rangpur lime | 2.30 | 0.196 | 1.44 | 3.616 | 0.39 | 0.158 | 0.195 | 135.4 | 45.3 | 57.8 | 7.8 |
| Cleopatra mandarin | 2.02 | 0.186 | 1.21 | 3.310 | 0.59 | 0.240 | 0.172 | 126.1 | 37.3 | 47.6 | 9.6 |
| L.S.D. at 5% | 0.16 | 0.021 | 0.18 | 0.039 | N.S | 0.041 | 0.029 | 10.3 | N.S | 6.9 | 1.9 |
| | **2004** | | | | | | | | | | |
| Sour orange | 2.51 | 0.196 | 1.32 | 3.524 | 0.56 | 0.152 | 0.204 | 123 | 45.5 | 45.6 | 13.5 |
| Volkamer lemon | 2.42 | 0.213 | 1.36 | 3.558 | 0.65 | 0.162 | 0.217 | 132 | 35.8 | 56.8 | 12.9 |
| Troyer citrange | 2.11 | 0.214 | 1.52 | 3.537 | 0.59 | 0.187 | 0.206 | 146 | 38.6 | 56.7 | 10.8 |
| Rangpur lime | 2.28 | 0.193 | 1.48 | 3.611 | 0.45 | 0.156 | 0.208 | 133 | 46.7 | 58.4 | 7.6 |
| Cleopatra mandarin | 2.09 | 0.188 | 1.27 | 3.300 | 0.69 | 0.239 | 0.172 | 124 | 38.4 | 48.3 | 10.0 |
| L.S.D. at 5% | 0.11 | 0.005 | 0.12 | 0.027 | 0.07 | 0.001 | 0.002 | 6.03 | N.S | N.S | 2.33 |

Data in Table (9) show the final evaluation of the five tested rootstocks, this evaluation may help plant breeders to design breeding program for improving rootstock characters.

**Table (9):Final evaluation of the five rootstocks.**

| | Characters | SO | VL | TC | RL | CM |
|---|---|---|---|---|---|---|
| | **I. Vegetative growth** | | | | | |
| 1 | Tree high | 2 | 3 | 3 | 2 | 1 |
| 2 | Canopy volume $(m)^2$ | 2 | 3 | 2 | 3 | 1 |
| 3 | Av. area per leaf $(cm^2)$ | 3 | 3 | 1 | 3 | 2 |
| 4 | Av. leaf area per shoot $(cm^2)$ | 3 | 3 | 1 | 2 | 1 |
| 5 | Av. No. % leaves per shoot | 2 | 3 | 3 | 2 | 1 |
| 6 | Shoot length (cm) | 2 | 3 | 3 | 1 | 1 |
| | **II. Fruit and seed** | | | | | |
| 7 | Fruit length (cm) | 2 | 3 | 2 | 2 | 1 |
| 8 | Fruit diameter (cm) | 3 | 3 | 2 | 2 | 1 |
| 9 | Fruit volume $(cm^3)$ | 3 | 2 | 2 | 2 | 1 |
| 10 | Fruit weight (g) | 3 | 2 | 2 | 1 | 1 |
| 11 | Number of seeds/fruit | 2 | 2 | 2 | 3 | 1 |
| 12 | Germination % | 3 | 2 | 1 | 2 | 3 |
| 13 | SSL % | 2 | 2 | 3 | 1 | 3 |
| 14 | Acidity % | 2 | 2 | 3 | 3 | 1 |
| 15 | Yield kg/tree | 2 | 3 | 2 | 3 | 1 |
| | **III. Leaf mineral contents** | | | | | |
| 16 | N % | 3 | 3 | 2 | 2 | 1 |
| 17 | P % | 2 | 3 | 3 | 2 | 1 |
| 18 | K % | 2 | 2 | 3 | 3 | 1 |
| 19 | Ca% | 2 | 2 | 2 | 3 | 1 |
| 20 | Na % | 1 | 1 | 2 | 1 | 3 |
| 21 | Cl % | 3 | 2 | 3 | 1 | 1 |
| 22 | Fe ppm | 1 | 2 | 3 | 2 | 1 |
| 23 | Zn ppm | 2 | 3 | 3 | 3 | 2 |
| 24 | Cu ppm | 3 | 3 | 3 | 1 | 2 |

**SO = Sour orange VL = Volkamer lemon TC = Troyer citrange**
**RL = Rangpur lime CM = Cleopatra mandarin 1 = Weak or low 2 = Medium**
**3 = vigorous or high**

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## النمو والمحصول وجودة الثمار والتركيب المعدنى لخمسة أصول موالح

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أجرى هذا البحث لدراسة أهم الصفات الخضرية والثمرية والمحصول والتركيب المعدنى للجذور والأوراق فى بعض أصول الموالح وذلك خلال موسمى ٢٠٠٣م ، ٢٠٠٤م ، وقد شملت الدراسة أصول النارنج والفولكاماريانا وليمون الرانجبور والترويز سترانج واليوسفى كليوباترا. وقد اتضح من الدراسة لأهم الصفات الخضرية أن أصول الفولكاماريانا وليمون الرانجبور تعتبر قوية النمو ، بينما النارنج يعتبر متوسط النمو ، فى حين أن أ صول الترويز سترانج واليوسفى كليوباترا أعطت أقل نمو تحت ظروف هذه الدراسة.

بينت الدراسة أن أصول الفولكاماريانا وليمون الرانجبور ذات مجموع جذرى متعمق وأكثر انتشارا وذلك عند المقارنة بباقى الأصول.

كما ثبت أن ثمار الفولكاماريانا والنارنج كبيرة الحجم وثمار الترويز سترانج متوسطة الحجم بينما ثمار ليمون الرانجبور واليوسفى كليوباترا صغيرة الحجم ، ومن حيث عدد البذور بكل ثمرة فإن أكبر عدد من البذور وجد فى ثمار ليمون الرانجبور أما أقل عدد فقد وجد فى ثمار اليوسفى كليوباترا أيضا أثبتت الدراسة أن أعلى نسبة إنبات للبذور كانت فى بذور النارنج وأقل نسبة إنبات كانت فى بذور الترويز سترانج ، أما ليمون الرانجبور و الفولكاماريانا واليوسفى كليوباترا فكانت نسبة إنبات بذورها متوسطة بالمقارنة بأصل النارنج.

احتوت أوراق أصول الفولكاماريانا وليمون الرانجبور على أعلى مستوى من النيتروجين ـ الفوسفور ـ البوتاسيوم ـ الكالسيوم ـ الماغنيسيوم ـ الحديد ـ المنجنيز ـ النحاس وأقل مستوى من الصوديوم والكلور فى حين أن محتوى الجذور من العناصر الغذائية سواء الكبرى أو الصغرى لم يأخذ اتجاه ثابت فى كلا الموسمين.