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Leaf and Root Chemical Constituents of Seven Citrus Rootstocks Under the Arid Environment of Qatar

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Abstract. Certain leaf and root chemical constituents of seven citrus rootstock seedlings were determined to study and compare the nutritional status among these rootstocks. The rootstocks used were Macrophylla, Volkameriana, Rangpur lime, Cleopatra mandarin, *Citrus amblycarpa,* Sacaton citrumelo and Yuma citrange. Seedlings were grown in calcareous soil and irrigated with moderatly saline water under the arid environment of Qatar State, Arabian Gulf. Results showed that leaves of Macrophylla, Volkameriana and Rangpur lime contained significantly higher protein, ash, N, P, K, Fe, Mn and Cu and lower carbohydrates and Na contents than that of the other four studied rootstocks. However, the chemical constituents of roots did not show remarkable differences.

Selection of rootstock to suit a given soil type, environmental conditions and scion variety is a major factor for success of citrus industry. However, it is difficult to find a single rootstock resistant to all diseases, tolerant to poor-drained soil, drought and salinity and consistently produces abundant crops of good fruit quality with all scion combinations. Thus, each cultivar should be fitted to a particular stock to perform best under specific conditions and purposes (Reuther 1973). Rootstocks influence not only growth vigour, yield and fruit quality, but also resistance to diseases, tolerance to high levels of certain mineral elements in the soil and to agro-climatic conditions (Sinclair 1984, Gallasch and Dalton 1989 and Ferguson *et al.* 1990). Moreover, the differences among rootstocks in their capacity to absorb the mineral nutrients are well known (Bukovac *et al.* 1959 and Jones 1971).

The aim of the present study was to determine and compare certain leaf and root chemical compositions of seven citrus rootstocks; Macrophylla, Volkameriana, Rangpur lime, Cleopatra mandarin, *Citrus amblycarpa,* Sacaton citrumelo and Yuma citrange grown under the arid environment of Qatar State and to find a reasonable explanation of the differences between the studied citrus rootstocks.

Materials and Methods

This study was carried out on seven citrus rootstocks namely Alemow (*Citrus macrophylla* Wester); Volkamer lemon (*Citrus volkameriana,* Ten. and Pasq.); Rangpur lime (*Citrus limonia,* Osbeck); Cleopatra mandarin (*Citrus reshni,* Hort. ex. Tan.); *Citrus amblycarpa* Hassk., Ochse.; Sacaton citrumelo [*Citrus paradisi* Macf. X *Poncirus trifoliata* (L.) Raf.] and Yuma citrange [*Citrus sinensis* (L.) Osbeck X] *Poncirus trifoliata* (L.) Raf.]. Seedlings were grown in the Government Experimental Farm at Rodat AL-Faras, North of Qatar State, Arabian Gulf. The seeds were obtained from Willits and Newcomb Inc., Arvin, California, USA and potted in plastic bags (25 x 30 cm) filled with soil taken from the experimental site. The bags were kept under the greenhouse conditions for six months from 1st July 1991 up to 1st January, 1992 and from June 15th, 1992 up to December 15, 1992 in the two successive seasons of study, respectively. Thereafter, apparently uniform seedlings were selected and transplanted at 50 cm apart in the open field. Each rootstock variety was represented by 16 seedlings and each seedling was considered as a replicate. The soil chemical analysis (Table 1) revealed that the soil was calcareous with average 11.43% $CaCO_3$, pH 7.5 and SAR = 5.7. Meanwhile, Na concentration in the layer of rootzone distribution (0-30 cm) was 25-26 meq./L. The irrigation water was moderately saline with E.C. 2.15 mmhos/cm and T.D.S. 1600 ppm.

During this time the seedlings were in pots; not transplanted yet. On mid-October of 1992 and 1993 seasons samples of fully expanded mature leaves (the third one from the base of the previously tagged non-flushing shoots) were collected. Also, root samples were taken at the same time for the chemical analysis. Total carbohydrates were determined by using the phenolsulphoric acid reaction (Smith *et al.* 1956). Nitrogen was determined by Micro-Kjeldahle method (Pregl 1945), protein (N x 6.25) and ash by the standered methods of A.O.A.C. (1980), Na and K by flame photometer, P by spectrophotometry, Fe, Mn and Cu were assayed with Atomic Absorption Spectorphotometer (Unicam SP 1900) according to Chapman and Pratt (1961).

Table 1. Soil chemical analysis in the experimental site.

Depth	S.P	pH	E.C	Meq. / L							S.A.R.	$CaCO_3$	Nutrient status						
				Anions			Cations												
(cm)				HCO_3	Cl	SO_4	Ca	Mg	Na	K		%	N %	P ppm	K ppm	Fe ppm	Zn ppm	Mn ppm	Cu ppm
0-15	52.1	7.4	6.6	2.08	20.8	57.7	35.4	17.7	26	1.6	5.1	11.2	0.04	35.5	360	2.7	0.90	7.0	1.1
15-30	54.6	7.5	5.6	2.08	19.9	46.4	27.9	14.5	25	1.0	5.4	11.6	0.03	29.5	230	3.0	2.1	7.1	1.0
30-60	56.1	7.7	3.0	1.76	11.3	18.0	9.1	4.3	17	0.6	6.6	11.5	0.02	25.5	184	2.4	1.5	8.0	1.9

S.P. = Saturation Percentage.

E.C. = Electric Conductivity mmhos / cm at 25 °C.

S.A.R = Sodium Adsorption Ratio = $Na / \sqrt{(Ca + Mg)/2}$.

The complete randomized design, with 16 replicates for each rootstock, was followed throughout the whole work. The obtained data were subjected to analysis of variance using SAS computer program (Duncan's method) according to Waller and Duncan (1969).

Results and Discussion

1- Leaf chemical constituents:

Data concerning leaf chemical constituents of seven studied citrus rootstocks during 1992 and 1993 seasons are shown in Tables (2 and 3).

1-1. Carbohydrate, Protein and Ash contents:

In both seasons of study, it is clear that the rootstocks: Macrophylla (M), Volkamerina (V) and Rangpur lime (RL) indicated higher foliar protein and ash contents in comparison with the other tested rootstocks [Cleopatra mandarin (CM), *Citrus amblycarpa* (CA), Sacaton citrumelo (SC) and Yuma citrange (YC)]. On the other hand, the former rootstocks group (M, V and RL) showed lower foliar carbohydrate content as compared with the latter ones (CM, CA, SC and YC). Such traits encouraged their growth vigor.

Many researchers reported that, Macrophylla, Volkamer lemon and Rangpur lime are suitable citrus rootstocks for most citrus scion cvs. under arid climate for their early and vigorous growth, salt and drought tolerance and high productivity (Blondel *et al.* 1986, Jalikop *et al.* 1986, Koller 1986, Foguet *et al.* 1987, Rao *et al.* 1987, Amir *et al.* 1988, Continella *et al.* 1988, Holtzhausen *et al.* 1988, Monteverde *et al.* 1988, Vardi *et al.* 1988, Wutscher and Bistline 1988, Fallahi *et al.* 1989, Jimenez *et al.* 1989, Nauer and Carson 1989, Nieves *et al.* 1991, Ashkenazy 1992 and Fallahi 1992). However, Ashkenazy and Amit (1988) excluded Macrophylla for its sensitivity to tristeza virus disease. In addition, data reported by Azab and Hegazy (1995) clarified that the three rootstocks (RL, V and M) exhibited - after transplantation - better survival percentage, thicker stem, higher number of shoots, larger leaf area and higher dry matter production than CM, CA, SC and YC rootstocks.

1.2. Nutrient elements (N, P, K and Na):

Regarding leaf N content, the data revealed that higher N levels were detected in the leaves of M, V and RL rootstocks in comparison with other tested rootstocks (CM, CA, SC and YC). This finding was true in both experimental seasons.

Table 2. Leaf chemical constituents of seven citrus rootstocks (1992).

Rootstock	Total carbo-hydrate (%)	Protein (%)	Ash (%)	Element concentration in dried leaves N (%)	P (%)	K (%)	Na (%)	Fe ppm	Mn ppm	Cu ppm
Macrophylla (M)	72.9 c	15.0 a	12.0 ab	2.40 a	0.20 ab	2.12 a	0.18 b	45.7 ab	45.9 a	8.7 ab
Volkameriana (V)	72.8 c	14.4 a	12.8 a	2.30 a	0.22 a	1.43 b	0.19 b	49.0 a	35.4 ab	11.4 a
Rangpur lime (RL)	74.1 c	14.0 a	11.7 ab	2.24 a	0.20 ab	1.42 b	0.18 b	44.6 ab	36.7 ab	6.8 b
Cleopatra mandarin (CM)	75.3 bc	13.6 ab	11.0 bc	2.18 ab	0.17 c	1.03 d	0.34 a	39.5 bc	27.6 b	7.8 ab
Citrus amblycarpa (CA)	77.1 ab	13.1 bc	10.6 c	2.09 ab	0.16 c	1.06 d	0.26 ab	36.6 bc	29.0 b	5.6 b
Sacaton citrumelo (SC)	79.2 a	12.1 cd	8.7 d	1.94 bc	0.18 bc	1.30 c	0.27 a	38.1 bc	25.0 b	5.8 b
Yuma citrange (YC)	80.0 a	11.0 d	9.8 cd	1.76 c	0.17 c	1.30 c	0.31 a	34.0 c	6.1 c	1.3 c

Means followed by the same letter(s) within each column are not significantly different at 5% level.

Table 3. Leaf chemical constituents of seven citrus rootstocks (1993).

Rootstock	Total carbo-hydrate (%)	Protein (%)	Ash (%)	Element concentration in dried leaves						
				N (%)	P (%)	K (%)	Na (%)	Fe ppm	Mn ppm	Cu ppm
Macrophylla (M)	70.1 c	14.4 a	14.0 a	2.3 a	0.19 ab	1.95 a	0.13 b	50.2 b	50.0 a	10.1 ab
Volkameriana (V)	71.2 c	15.0 a	14.4 a	2.4 a	0.20 a	1.25 b	0.15 b	57.8 a	40.1 b	12.3 a
Rangpur lime (RL)	70.2 c	14.4 a	13.6 a	2.3 a	0.21 a	1.40 b	0.14 b	55.6 a	42.5 b	8.0 bc
Cleopatra mandarin (CM)	74.5 b	11.3 b	10.3 b	1.8 b	0.17 bc	0.91 c	0.29 a	41.0 c	25.2 d	6.3 bc
Citrus amblycarpa (CA)	80.0 a	11.9 b	9.6 b	1.9 b	0.16 c	0.95 bc	0.23 a	39.0 c	31.0 c	4.5 cd
Sacaton citrumelo (SC)	81.2 a	10.0 bc	9.2 bc	1.6 b	0.17 bc	1.10 b	0.25 a	42.0 c	22.4 d	5.2 cd
Yuma citrange (YC)	79.0 a	9.4 c	8.5 c	1.5 b	0.15 c	1.16 b	0.26 a	30.0 d	11.5 e	2.4 d

Means followed by the same letter(s) within each column are not significantly different at 5% level.

Anyhow, in the first season, leaf N level for (M, V and RL) rootstocks ranged from 2.24 to 2.40 % against 1.76 to 2.18 % for the other tested rootstocks. The same trend was noticed in the second season. It is clear that, leaf N content of (M, V and RL) rootstocks were within the optimum range of citrus leaves, but those of the other ones were low (Embleton *et al.* 1983).

Similarly, in both seasons the same three rootstocks (M, V and RL) showed higher leaf P levels in comparison with the others. For instance, in the first season, P percentage of (M, V and RL) rootstocks ranged from 0.20 to 0.22 % against 0.16 - 0.18 % for the other rootstocks. In the second season, the corresponding values were 0.19-0.21 % and 0.15-0.17 % respectively. These values indicate that P levels in (M, V and RL) rootstocks were higher than the optimum range of citrus trees, while values of other tested rootstocks were within the normal range. The higher P levels in leaves of (M, V and RL) rootstocks might be due to the greater number of P absorption sites on their roots and to their pronounced growth resulting in a greater demand for P (Keshava Murthy and Iyengar 1990).

Also, in both seasons, leaf K levels in (M, V and Rl) rootstocks were higher than in the other ones. In the first season, folair K percentage of (M, V and RL) stock plants ranged from 1.42 to 2.12 % against 1.03 to 1.30 % for the other tested rootstocks. In the second season, the corresponding values were 1.4-1.95 % and 0.91-1.16%, respectively. The above-mentioned K levels were, generally, within the optimum range of citrus plants, except for Macrophylla which gave higher values (Embleton *et al.* 1983). The obtained data concerning leaf NPK content are in line with those reported by Zekri (1993) on citrus rootstocks.

Contrary to NPK, foliar Na levels were obviously lower in (M, V and RL) stock plants in comparison with the others. In the first season, Na percentage ranged from 0.18 to 0.19 % for (M, V and RL) leaves against from 0.26 to 0.34% for the other rootstocks. In the second season, the corresponding values were 0.13-0.15% and 0.23-0.29%, respectively. Na percentage in leaves of (M, V and RL) stock plants were always within the nonhazardous levels. The obtained results are in line with previous reports, Nieves *et al.* (1991) and Zekri (1993) reported that citrus scions are generally salt sensitive and their response to salinity depends on rootstock potentiality to absorb sodium ions. Rhoades *et al.* (1992) suggested that excessive salinity reduces plant growth primarily because it increases the energy that must be expended to acquire water from the soil of the root zone and to make the biochemical adjustments necessary to survive under stress. This energy is diverted from the processes which lead to growth. In the same direction, the study of Azab and Hegazy (1995) cleared that survival percentages of (M, V and RL) rootstock seedlings were much higher than those of other tested stocks cvs. It seems that, these had the ability to reduce Na absorption by roots leading to less Na accumulation in leaves (Alva 1991).

1-3. Trace elements (Fe, Mn and Cu):

The data indicated that Fe, Mn and Cu levels in leaves of (M, V and RL) stock plants were always significantly higher than the corresponding levels of the other tested rootstocks. For example, in the first season, Fe levels ranged from 44.6 to 49.0 ppm for (M, V and RL) stock plants and from 34.0 to 39.5 ppm for the other rootstocks. Similarly, Mn levels ranged from 35.4 to 45.9 ppm for (M, V and RL) rootstocks and from 6.1 to 29.0 ppm for the others. Also, Cu levels ranged from 6.8 to 11.4 ppm for (M, V and RL) and from 1.3 to 7.8 ppm for the other rootstocks. The same trend could be confirmed in the second season. In addition, the recorded Fe levels were-generally-lower than the optimum range for citrus plants. The Mn and Cu levels were within their optimum ranges, except in Yuma citrange (YC), which contained lower values. Similar findings on Cu levels were reported by Misra *et al.* (1989).

The present study indicated that leaves of (M, V and RL) stock plants contained higher Mn levels than other tested rootstocks. This finding was associated with higher protein and lower carbohydrate content of the same stock plants (M, V and RL) which may be due to the important role of Mn in protein metabolism. High protein levels usually encourage forming new vegetative growth, causing depletion of carbohydrates (Maatouk *et al.* 1988, Gallasch and Dalton 1989).

2- Root chemical constituents:

Data concerning root chemical constituents of the tested citrus rootstocks are given in Tables (4 and 5).

Comparing the chemical constituents of leaves (Tables 2 and 3) and roots (Tables 4 and 5), it is clear that leaves had higher levels of protein, N, P and K while roots had higher levels of Fe, Mn and Cu. Meanwhile, no consistent trend could be detected concerning carbohydrates and Na contents. The higher levels of micro-nutrients Fe, Mn and Cu in roots may be due to higher P levels in plant tissues which affects micro-nutrients translocation from roots to leaves (Keshava Murthy and Iyengar 1990).

However, contrary to leaves, the chemical constituents of roots did not obviously reflect the nutritional status differences between stock cvs. As such, each of the tested cvs. revealed higher levels for some nutrients and lower levels for

Table 4. Root chemical constituents of seven citrus rootstocks (1992).

Rootstock	Total carbo-hydrate	Protein	Ash	Element concentration in dried leaves						
	(%)	(%)	(%)	N (%)	P (%)	K (%)	Na (%)	Fe ppm	Mn ppm	Cu ppm
Macrophylla (M)	79.5 a	8.3 a	11.8 b	1.33 a	0.30 a	0.91 a	0.15 b	84.5 b	62.9 b	15.2 a
Volkameriana (V)	80.3 a	6.1 bc	14.1 b	0.98 b	0.18 bc	0.85 a	0.20 b	99.7 b	75.6 b	9.0 b
Rangpur lime (RL)	74.5 b	5.8 bc	19.5 a	0.92 b	0.14 c	0.79 ab	0.19 b	146.9 a	124.2 a	12.4 ab
Cleopatra mandarin (CM)	79.7 a	6.6 b	13.7 b	1.05 b	0.25 ab	0.80 a	0.19 b	101.1 b	99.0 a	10.2 b
Citrus amblycarpa (CA)	78.5 a	5.2 c	15.1 b	0.83 b	0.09 c	0.68 b	0.25 a	85.0 b	22.0 c	10.4 b
Sacaton citrumelo (SC)	71.7 c	6.5 b	19.4 a	1.02 b	0.13 c	0.94 a	0.28 a	151.0 a	120.7 a	14.3 a
Yuma citrange (YC)	80.9 a	6.2 bc	13.0 b	0.99 b	0.10 c	0.66 b	0.30 a	98.3 b	73.2 b	10.4 b

Means followed by the same letter(s) within each column are not significantly different at 5% level.

Table 5. Root chemical constituents of seven citrus rootstocks (1993).

Rootstock	Total carbo-hydrate	Protein	Ash	Element concentration in dried leaves						
	(%)	(%)	(%)	N (%)	P (%)	K (%)	Na (%)	Fe ppm	Mn ppm	Cu ppm
Macrophylla (M)	80.5 a	7.5 a	12.5 b	1.20 a	0.26 a	0.89 a	0.14 c	79.0 b	75.0 b	16.0 a
Volkameriana (V)	78.5 ab	5.1 bc	13.5 b	0.81 bc	0.16 bc	0.91 a	0.19 bc	89.6 b	66.8 bc	8.2 b
Rangpur lime (RL)	71.0 c	4.7 c	18.7 a	0.75 bc	0.15 b	0.85 a	0.21 b	135.0 a	130.0 a	10.2 ab
Cleopatra mandarin (CM)	78.0 ab	6.1 b	12.9 b	0.98 ab	0.21 a	0.77 a	0.15 c	110.0 ab	88.9 b	11.4 ab
Citrus amblycarpa (CA)	76.5 b	4.5 c	16.4 ab	0.72 c	0.19 b	0.61 b	0.24 ab	91.5 b	40.9 c	11.6 ab
Sacaton citrumelo (SC)	67.4 d	5.8 bc	18.2 a	0.93 bc	0.10 b	0.99 a	0.30 a	142.0 a	111.0 ab	15.2 a
Yuma citrange (YC)	82.1 a	5.6 bc	12.4 b	0.89 bc	0.08 b	0.58 b	0.27 ab	87.5 b	55.5 bc	13.5 ab

Means followed by the same letter(s) within each column are not significantly different at 5% level.

others. For example, in both seasons Macrophylla revealed high levels of carbohydrates, protein, N, P, K and Cu levels while Volkameriana revealed higher values of carbohydrates only. On the other hand, Rangpur lime was higher in ash, Fe, Mn and Cu and Cleopatra mandarin contained highest levels of carbohydrates and P. *Citrus amblyearpa* yielded higher Na values and Sacaton citrumelo gave higher values for ash, K, Na, Fe, Mn and Cu. Yuma citrange was leading in Na levels only. These results were true in both seasons. Excepts for the higher Na levels, no consistent trend could be traced, in roots of (CA, SC and YC) rootstocks which was in harmony with leaf analysis results (Tables 2 and 3) and with results of survival and growth vigour reported by Azab and Hegazy (1995).

3. K/Na ratio in leaves and roots:

As shown in Fig. (1) K/Na ratio in either leaves or roots took the same trend. It is clear that leaves of Macrophylla, Volkameriana and Rangpur lime had higher K/Na ratio as compared with the other rootstocks. However, the higher K/Na ratio in roots included the same three stock cvs. in addition to Cleopatra mandarin. The high K/Na ratio may explain the salt tolerance of M,V and RL rootstocks, which may be attributed to "a genetic control" of absorption and transport mechanisms. Clarkson and Ulrich Luttge (1991) reported that the genetic information for the ability to discriminate between Na^+ and K^+ resides on the long arm of chromosome 4D -in citrus and other relatives - can affect transport from roots to shoots, its how lower Na^+ and higher K^+ levels when the long arm is present.

4. C/N ratio in leaves:

Data in Fig. (1) revealed that the good grown stock cvs; M, V and RL had lower C/N ratio as compared with other poorly grown ones. This may be related to a high rate of carbohydrate depletion during the more active vegetative growth period of these cvs. as shown by Azab and Hegazy (1995).

Consequently, good growth of stock plants was comported the high K/Na ratio in their leaves or roots and the low C/N ratio in the leaves.

Accordingly, it can be concluded that under arid climate, Macrophylla, Volkameiana and Rangpur lime rootstocks could be grown in calcareous soil and irrigated with moderately saline water; taken into consideration the sensitivity of Macrophylla to tristeza virus disease.

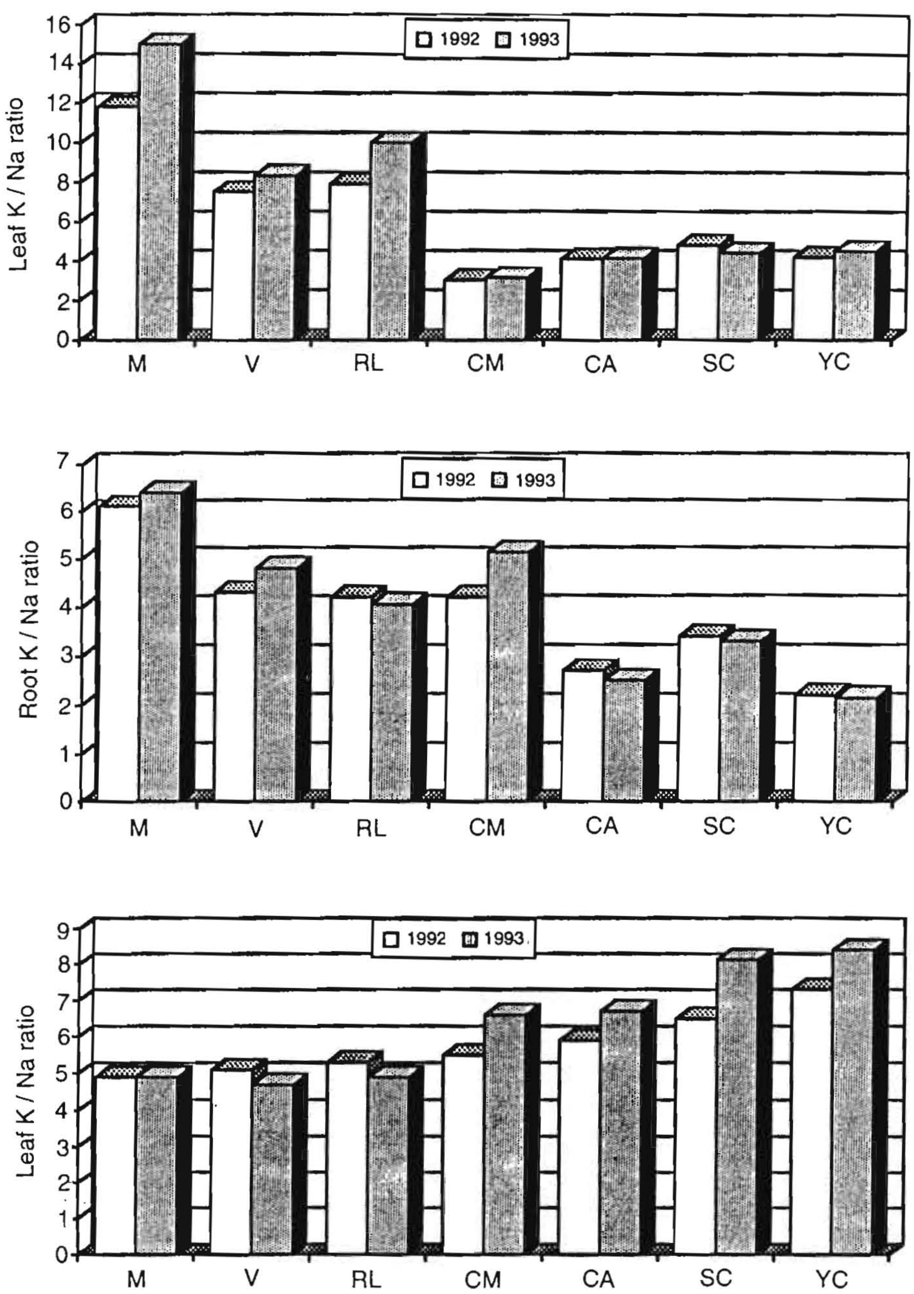

Fig. 1. K/Na and C/N ratios in leaves and roots of studied citrus rootstocks (1992 and 1993).

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المكونات الكيماوية للأوراق والجذور في سبعة أصول للحمضيات تحت ظروف البيئة الجافة بدولة قطر

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تم تقدير بعض المكونات الكيماوية لأوراق وجذور شتلات سبعة أصول للحمضيات وذلك لدراسة ومقارنة الاختلافات في المحتويات الكيماوية للأصول التالية :

Macrophylla , Volkameriana , Rangpur lime , Cleopatra mandarin , *Citrus amblycarpa* , Sacaton citrumelo and Yuma citrange . وهذه الشتلات منزرعة في تربة جيرية وتروى بمياه متوسطة الملوحة تحت ظروف البيئة الجافة بدولة قطر .

أوضحت النتائج احتواء أوراق الأصول, Macrophylla ,Volkameriana Rangpur lime, على مستوى عال من البروتين والرماد والنيتروجين والفوسفور والبوتاسيوم علاوة على الحديد والمنجنيز والنحاس ومستوى منخفض من الكربوهيدرات والصوديوم بالمقارنة بالأصول الأربعة الأخرى ، في حين لم تظهر تقديرات المحتويات الكيماوية في الجذور أية اتجاهات محددة للتباين في النمو بين الأصول المختلفة .