

## Growth Performance and Plant Water Relations of Seven Citrus Rootstocks Under the Arid Environment of Qatar

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**ABSTRACT.** Growth and plant water relations of seven citrus rootstocks were tested under the arid environment of Qatar. Rootstocks used were Rangpur lime, Volkamer lemon, *Citrus macrophylla* (Alemow), Yuma Citrange, *Citrus amblicarpa*, Sacaton Citrumelo and Cleopatra mandarin. Transplants were raised in the greenhouse and when six months old, they were transplanted in the open field and monitored to age of 32 months.

While in the greenhouse, all seven rootstocks showed similar and irregular pattern of increased absolute growth rate (AGR) with age as based on shoot height. The highest values of AGR in the greenhouse ranged between 3.9 mm/day in Sacaton citrumelo to 5.1 mm/day in Yuma citrange. The AGR was significantly reduced during the first year of transplantation, while increased rates were resumed during the second year after transplantation with highest values ranged from 1.6 mm/day in *Citrus amblicarpa* to 9.3 mm/day in Rangpur lime. Generally, the three rootstocks namely Rangpur lime, Volkamer lemon and *Citrus macrophylla* exhibited after transplantation an overall better AGR, survival, stem diameter, leaf area, dry matter production and shoot branching than the other four rootstocks.

All tested rootstocks showed limited fluctuations in their water content and water saturation deficit during the day time. The Rangpur lime, Volkamer lemon and *Citrus macrophylla* have significantly lower number of stomata on their leaves than the other rootstocks – an important asset for plants to reduce water loss and delay, onset of water stress and maximize the period of growth.

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It is recommended that raising of transplants in the greenhouse ensures their successful establishment and growth after transplantation in the open field. The two rootstocks Rangpur lime and Volkamer lemon are recommended to be used in Qatar.

Rootstocks are of vital importance in the quality and quantity of production, and survival of citrus plants. Although many citrus varieties are used successfully as rootstocks under different environmental conditions of the mediterranean and temperate regions, some are better suited to specific conditions than are others as they vary considerably in their response to different environments (Rodney and Harris 1973, Ortiz *et al.* 1986, Castle 1987, Monteverde *et al.* 1988, Nieves *et al.* 1991). In arid regions of the Arabian Gulf, there have been no comprehensive studies on growth performance of the newly introduced citrus rootstocks. The study of growth performance and establishment of these new rootstocks under the arid conditions of the Gulf region has become necessary to meet the rapid agricultural developments in the region.

Plant water relations of the different rootstocks may exert some control over their growth and survival under arid environments. The water content and water saturation deficit are common indices which reflect the ability of plants to cope with the prevailing environments (Larcher 1980, Kramer 1983). The question then arises as to what extent the local success of citrus rootstocks can be linked with their water relations characteristics? However, previous studies on the investigated rootstocks did not evaluate their growth performance in accordance with plant water relations under arid environments.

Environmental interactions with a genetically different rootstock combination mandates that different combinations be evaluated under regional and local conditions of the Arabian Gulf. The purpose of this study was to evaluate and compare the growth performance and plant water relations of seven citrus rootstocks under the environmental conditions in State of Qatar. This evaluation enables us to select potential rootstocks for the arid region of Arabian Gulf.

### Materials and Methods

Seven rootstocks namely Rangpur lime (*Citrus limonia* Osbeck), Volkamer lemon (*Citrus volkameriana* Ten & Pasq.), Alemow (*Citrus macrophylla* Wester), Yuma Citrange (*Citrus sinensis* (L.) Osbeck x *Poncirus trifoliata* (L.) Raf.), *Citrus amblicarpa*, Sacaton Citrumelo (*Citrus paradisi* Macf. x *Poncirus trifoliata* (L.) Raf.), and Cleopatra mandarin (*Citrus reshni* Hort. ex. Tan) were investigated in this

study. The experimental research site is located in Rodat Al Faras, north of Qatar. Transplants of the investigated rootstocks were raised from seeds in the greenhouse. Seeds were obtained from Willits and Newcomb Inc., Arvin, California, U.S.A. During the two growing seasons of 1992/1993 the seeds were potted in black plastic bags (25 x 30 cm) with soil taken from the experimental site. When six months old, the transplants of uniform appearance were selected and transplanted 50 cm apart in the open field site. Plants were watered at regular intervals every 7 days.

Growth characteristics were monitored one month after seedling emergence while in the greenhouse and continued after transplantation in the open field. The absolute growth rate based on plant height was estimated every week by mathematical growth analysis (Hegazy and Ismail 1992). The absolute growth rate (AGR) measured as  $AGR = (H_2 - H_1) / (t_2 - t_1)$ , where  $H_1$  is the initial height and  $H_2$  is the height after growth interval between times  $t_1$  and  $t_2$ . The percentage of living plants, stem diameter, number of branches, total leaf area, and shoot and root dry weights were estimated at the end of the experiment.

To investigate the plant water relations, the water content of the leaves was determined. Fresh weight and oven dry weight after drying for 48 hours at 80°C, allowed calculation of water content (percentage fresh weight) by the following formula:

$$\text{Water content} = [( \text{Fresh weight} - \text{dry weight} ) / \text{Fresh weight}] \times 100$$

Water saturation deficit is the amount of water which the plant requires to reach full saturation. After its fresh weight determination, leaves were placed in covered Petri dish filled with water and kept in the dark at laboratory temperature for 24 hours. This period was found to be sufficient to saturate the leaves. Saturated weight and oven dry weight were determined. The water saturation deficit (WSD) was calculated by the following formula :

$$\text{WSD} = [(\text{Saturated weight} - \text{Initial fresh weight}) / (\text{Saturated weight} - \text{Dry weight})] \times 100$$

For stomatal investigation, mature fresh leaves were collected from similar orders on every rootstock. The leaf area was determined and then used for stomatal studies. Stomatal density was expressed as the number of stomata per square millimeter. Removal of the epidermis for stomatal studies was accomplished by incubation of 2mm pieces from fresh leaves in a macerating fluid of glacial acetic acid-hydrogen peroxide and distilled water (40:40:20) at 45°C for about 30 hours following a technique modified by Boulos and Beakbane (1971).

The epidermis was then peeled off and examined under the light microscope. Stomatal measurements were made on 5 leaves of every rootstock and in 10 randomly chosen microscopic fields of each leaf peeling. Each figure in the text is thus a mean based on 50 microscopic fields.

Results obtained for growth and water relations were generally the means of 16 replicates. The two way analysis of variance which tests the row and the column effects were analysed according to Dixon and Massey (1969). The LSD has been used for individual comparison. Soil analysis was carried out according to Allen *et al.* (1974) and Jackson (1962).

## Results

### *Environment*

The physical analysis of the soil in the experimental site indicated that it consists of 24.6% sand, 22.0% silt and 53.4% clay. The chemical analysis (Table 1) shows that the soil is calcareous and alkaline in reaction. The electric conductivity ranged between 3.0 and 6.6. mmhos/cm at 25°C. Chemical analysis of the irrigation water in the experimental farm indicated pH 8.3 electric conductivity 2.14 mm/cm, and total soluble salts 1600 ppm.

The average monthly air temperature and relative humidity during the experimental time are shown in Fig. 1. At the time of raising the transplants, air temperature in the open field was higher than that in the greenhouse, while the relative humidity in the greenhouse was higher than that in the open field (Fig. 1a). The seasonal variation of air temperature and relative humidity in the open field during the two experimental periods after transplantation attained similar fluctuation pattern with hot dry summers and relatively wet warm winters (Fig. 1b and c).

### *Growth performance*

During the nursery period in the greenhouse, the seven tested rootstocks showed irregular pattern of increased absolute growth rate (AGR) with age (Fig. 2a-g). The highest values of AGR in the greenhouse ranged between 3.9 mm/day in Sacaton citrumelo to 5.1 mm/day in Yuma citrange. The AGR of all seven rootstocks was significantly reduced during the first year after transplantation, *i.e.*, from age 7 to 18 months (Fig. 2a-g). Irregular pattern of increased rates of AGR were resumed during the second year after transplantation, *i.e.*, from age 20 to 32 months, with highest values ranged from 1.6 mm/day in *Citrus amblicarpa* to 9.3 mm/day in *Citrus macrophylla*. The three rootstocks namely Rangpur lime, Volkamer lemon and Cleopatra mandarine exhibited an overall better AGR than the other four rootstocks.

**Table 1.** Soil chemical analysis in the experimental study site

Depth (cm)	pH	E.C.	Anions (meq/L)			Cations (meq/L)				S.A.R.	CaCO <sub>3</sub> %	Macro-nutrients (ppm)			Micro-nutrients (ppm)			
			HCO <sub>3</sub>	Cl	SO <sub>4</sub>	Ca	Mg	Na	K			N	P	K	Fe	Zn	Mn	Cu
0-15	7.4	6.6	2.08	20.8	57.7	35.4	17.7	26	1.6	5.1	11.2	400	35.5	360	2.7	0.90	7.0	1.1
15-30	7.5	5.6	2.08	19.9	46.4	27.9	14.5	25	1.0	5.4	11.6	300	29.5	230	3.0	2.1	7.1	1.0
30-60	7.7	3.0	1.76	11.3	18.0	9.1	4.3	17	0.6	6.6	11.5	200	25.5	184	2.4	1.5	8.0	1.9

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

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

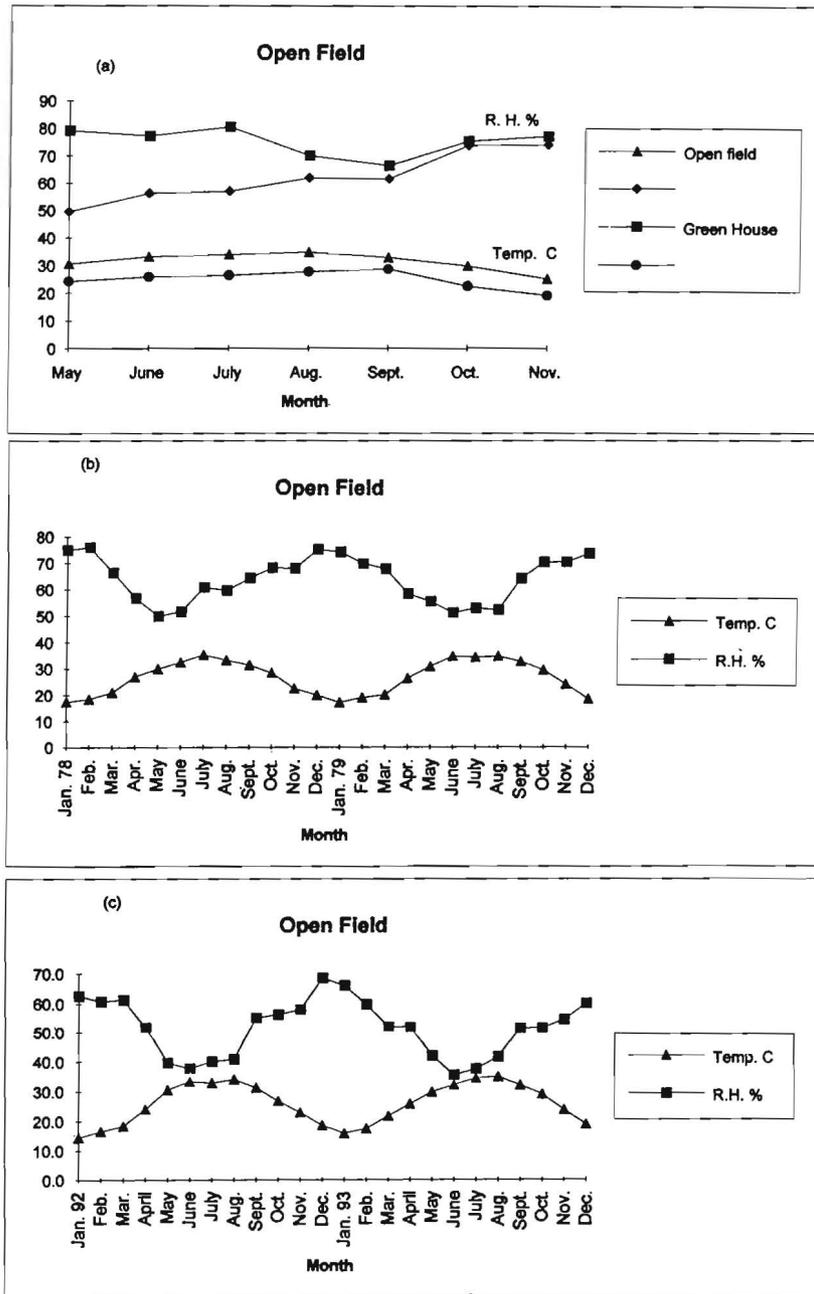


Fig. 1. Average monthly air temperature and relative humidity during the experimental time in the open field and green house.

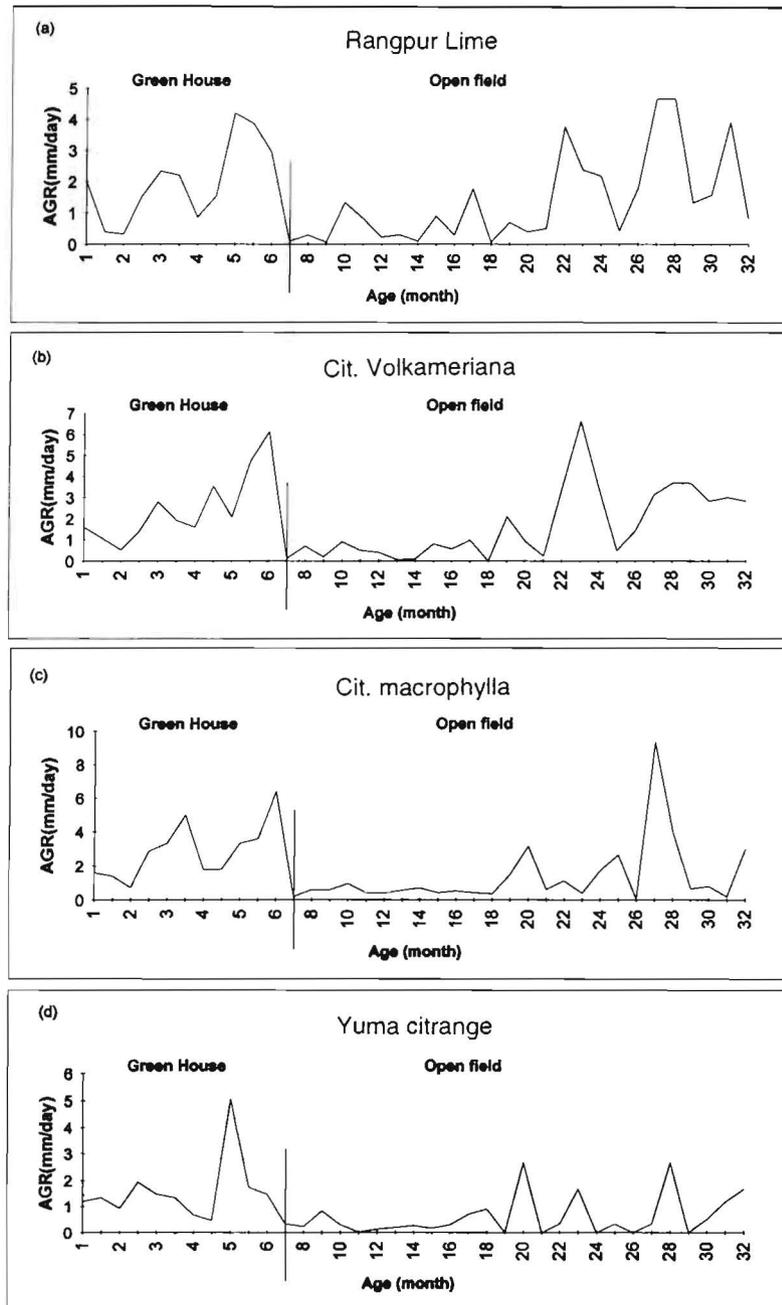


Figure (2)

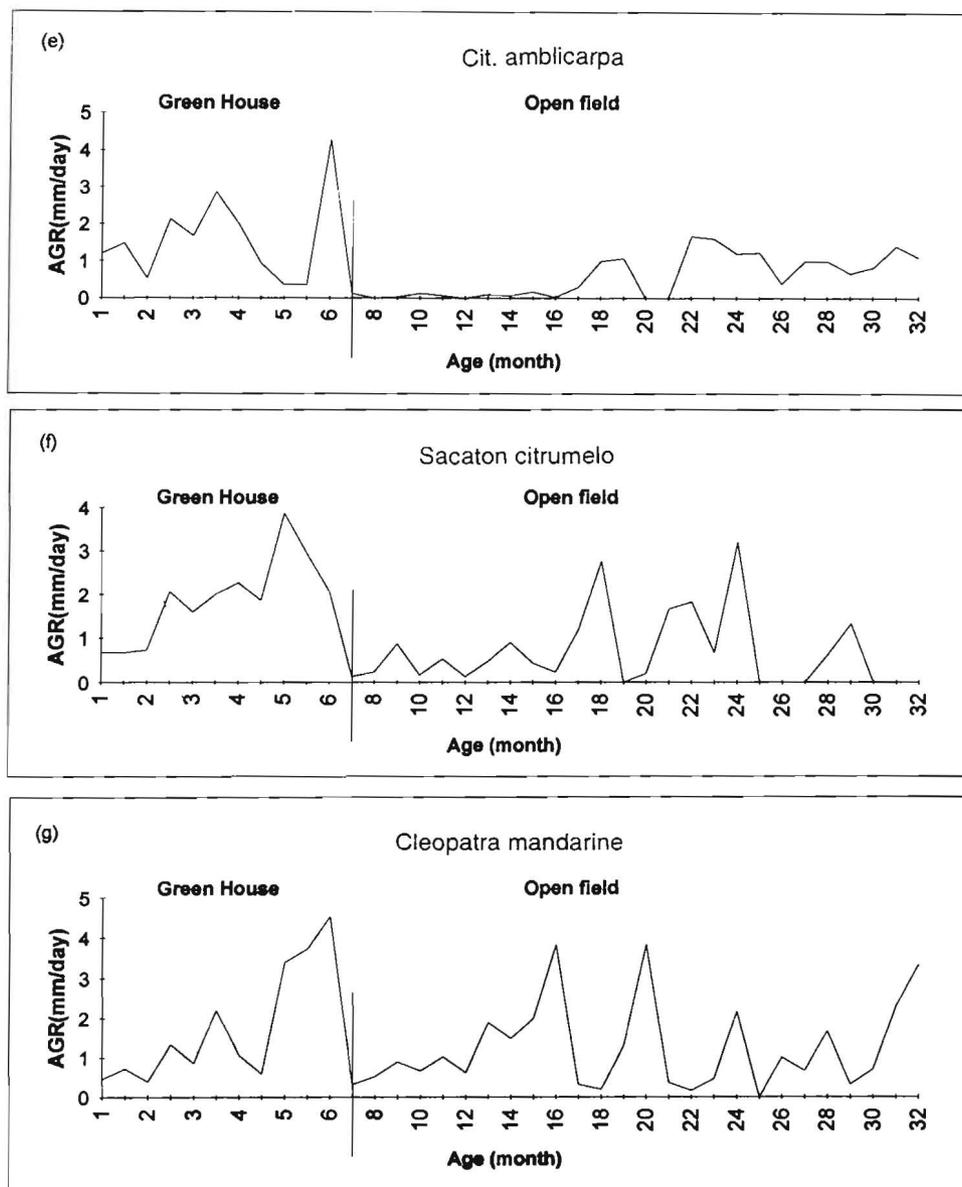


Fig. 2. Age-specific absolute growth rate (AGR, mm/day) of the seven investigated rootstocks. Vertical line marking the seventh month on the graph represents the termination of the experiment in the green house and its beginning in the open field.

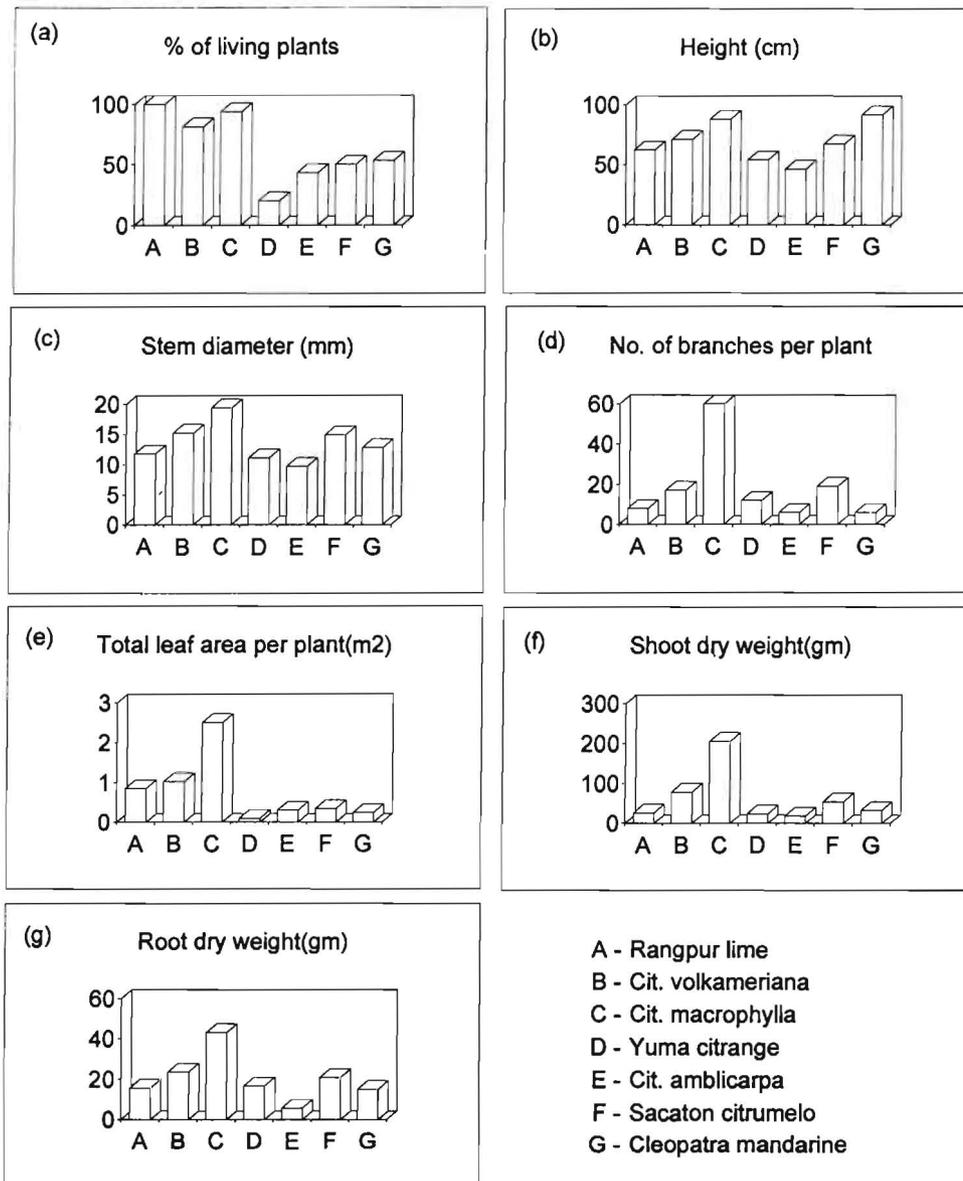


Fig. 3. Growth characteristics as measured at the end of the experiment in the open field. Plants were at age of 32 months.

The growth characteristics shown in Fig. 3a-g demonstrate the similarities and also variations among the different rootstocks. After transplantation the three rootstocks Rangpur lime, Volkamer lemon and *Citrus macrophylla* exhibited better survival, greater stem diameter, more shoot branching, leaf area and dry matter production than the remaining rootstocks (Fig. 3a-g). The growth results of this study indicate that *Citrus macrophylla* is characterized by vigorous and easy growth in the greenhouse and in the open field.

#### *Plant water relations*

All tested seven rootstocks were found to have limited fluctuations in their daily water content and water saturation deficit (Fig. 4a-g). When the average water content is taken as a measure, the following sequence from highest to lowest values was observed for the seven rootstocks: Yuma citrange  $\approx$  Sacaton citrumelo  $>$  *Citrus amblicarpa*  $\approx$  *Citrus macrophylla*  $>$  Volkamer lemon  $>$  Rangpur lime  $\approx$  Cleopatra mandarine. The water saturation deficits for all rootstocks were low at high water contents and increased with decreasing water content.

The number of stomata per unit leaf area varied considerably in different rootstocks. In Volkamer lemon, Yuma citrange and *Citrus amblicarpa*, stomata occur on both surfaces of leaves, but were found only on the lower surface of leaves of the remaining four rootstocks (Table 2). The Rangpur lime, Volkamer lemon and *Citrus macrophylla* have significantly lower number of stomata on their leaves than the other rootstocks.

### **Discussion**

For the successful establishment and survival of citrus rootstocks under arid environments, it is important that during the first year after transplantation, all available assimilates are translocated to the safe underground organs than to risk a complete loss in aboveground shoots that are subject to different stresses. This way, the chances for success in next year's growth are increased. An ecological advantage of this behaviour is the ability to replenish the water lost through transpiration, particularly during the hot season. These findings are supported by the improved growth performance during the second year after transplantation where the absolute growth rate amounted two or three times the rate during the first year. This is proved true for the investigated rootstocks which attained high absolute growth rate after transplantation but suffered reduced growth and survival in the following year.

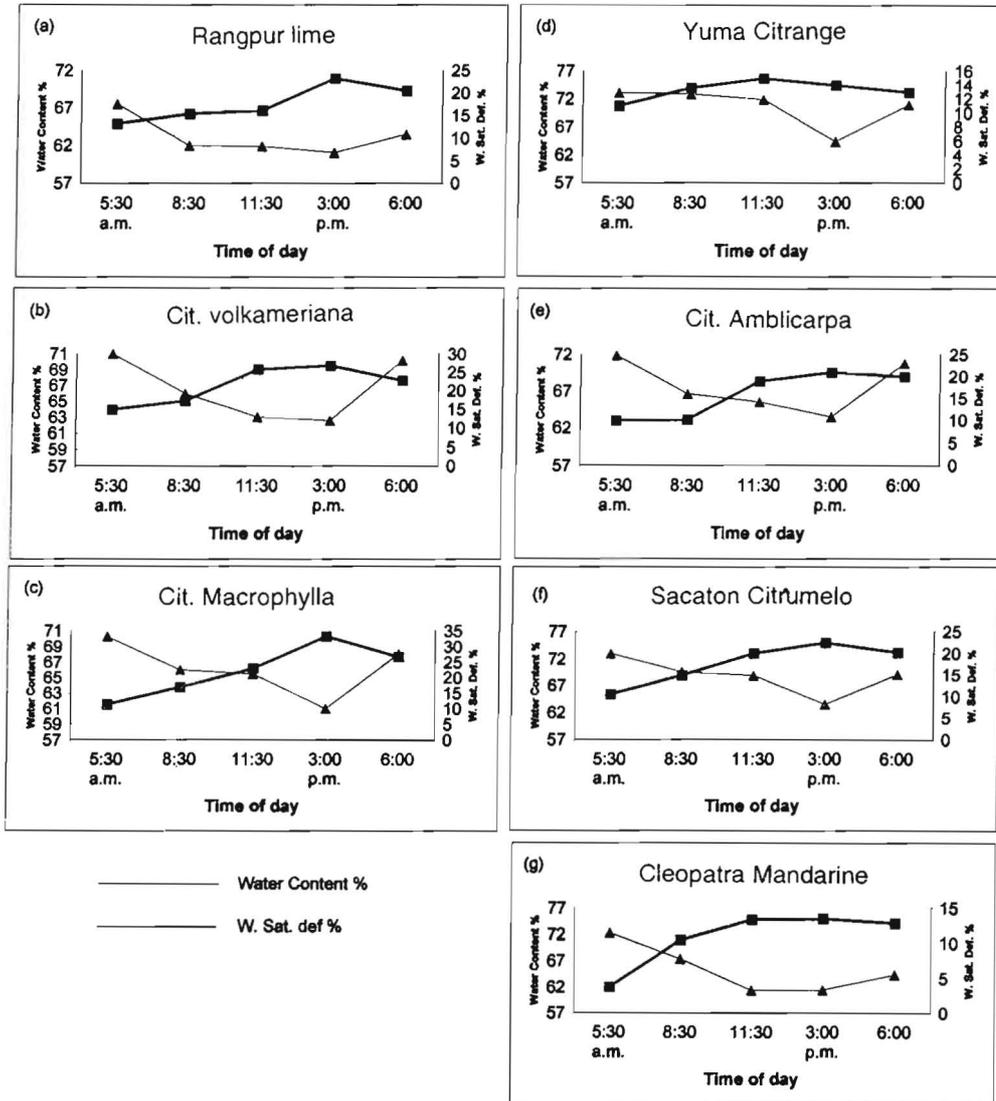


Fig. 4. Daily variation of leaf water content and water saturation deficit in the seven investigated rootstocks.

**Table 2.** Leaf area and average number of stomata per mm<sup>2</sup> on the upper and lower leaf surface in the different citrus rootstocks

Rootstocks	Single leaf area (cm <sup>2</sup> )	Number of stomata	
		Upper surface	Lower surface
Rangpur lime	17.00 a	0.00 c	57.80 b
Cit. volkameriana	16.60 a	8.33 ab	54.83 b
Cit. macrophylla	17.80 a	0.00 c	54.75 b
Yuma citrange	7.10 ab	6.79 b	84.87 a
Cit. amblicarpa	5.90 b	15.40 a	69.25 ab
Sacaton citrumelo	6.50 ab	0.00 c	79.81 a
Cleopatra mandarine	13.40 a	0.00 c	69.16 ab

Differences between means in any column having the same letter are insignificant at 0.05 level.

The measurements of leaf water content and water saturation deficit revealed that investigated rootstocks are capable of maintaining relatively high water content and low water saturation deficit with limited daily fluctuations. This behaviour can be achieved only if the plants are able to extract water from soil rapidly enough to compensate for water loss. The three rootstocks, Rangpur lime, Volkamer lemon and *Citrus macrophylla* seem to have a relatively stable plant water relations as they have significantly lower number of stomata on their leaves than the other rootstocks. This enables the plants to have better control on water loss and delay the onset of water stress, an important behaviour to maximize the period of growth.

In comparing the overall performance of the investigated rootstocks, it is apparent that Rangpur lime, Volkamer lemon and *Citrus macrophylla* have better growth under arid environment of the Gulf region than the other four rootstocks. Other studies (Ferguson *et al.* 1990, Fallahi and Rodney 1992) showed that, these three rootstocks can be successful under the arid climate of Arizona and California. However, *Citrus macrophylla* was found to be sensitive to tristeza virus disease

(Burns *et al.* 1986, Ashkenazy and Amit 1988). Meanwhile, there are no local rootstocks that could be used for comparison against the investigated rootstocks. For these reasons, the two rootstocks, Rangpur lime and Volkamer lemon are recommended to be used in the arid region of the Arabian Gulf. This agrees with Ashkenazy (1992).

A number of considerations follow from the results of this study. First, raising of rootstock transplants in the greenhouse is useful for successful establishment and growth after transplantation in the open field. Second, the reduced shoot growth after transplantation of nursery plants is advantageous in allowing plants for adaptation and to develop good root system and stump. Third, the reduced vegetative growth after transplantation increases the juvenility period, that may ensure better development of the stump - an important character for grafting.

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## النمو والعلاقات المائية في سبعة أصول حمضية تحت ظروف البيئة الجافة بدولة قطر

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أجريت هذه الدراسة على سبعة أصول من الحمضيات تحت ظروف البيئة القطرية . وقد تم الحصول على بذور هذه الأصول من مؤسسة وليتس ونيو كومب ، كاليفورنيا ، الولايات المتحدة الأمريكية ، ويهدف هذا البحث إلى دراسة النمو والعلاقات المائية تحت ظروف البيوت المحمية والظروف الطبيعية . وقد تمت دراسة معدل النمو ، سمك الساق ، مساحة الأوراق ، تفرع المجموع الخضري ، إنتاج المادة الجافة ، المحتوى المائي ، النقص في التشبع المائي وعدد الثغور على الأوراق .

زرعت بذور الأصول السبعة في بيت محمي لمدة ستة شهور ثم نقلت الشتلات إلى الظروف الطبيعية وتم رصدها حتى وصلت إلى عمر ٣٢ شهراً . أظهرت النتائج أنه لا يوجد فروق معنوية في نمو الأصول السبعة داخل البيت المحمي ، ويتميز النمو في هذه المرحلة بتذبذب الزيادة والنقصان على مدار الستة شهور في البيت المحمي . وبعد نقل الشتلات إلى الظروف الطبيعية ، كان هناك انخفاض في معدل النمو خلال العام الأول ، بينما كانت هناك زيادة معنوية في النمو خلال العام الثاني ، أما بالنسبة للعلاقات المائية فقد بينت النتائج تذبذب طفيف في المحتوى المائي ودرجة النقص في التشبع المائي على مدار اليوم .

وتوصي الدراسة بإمكانية إستخدام النوعان المسميان Rangpur Lime and Volkamer Lemon كأصول حمضية في دولة قطر وذلك لما تحتويه من صفات تؤهلها لتحمل الجفاف والظروف البيئية السائدة في منطقة الخليج العربي .