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Effect of Citrus Rootstocks on Root Distribution and Leaf Mineral Content of 'Orlando' Tangelo Trees[1]

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Abstract. The effect of rootstock on tree size, root distribution and leaf mineral content of 'Orlando' tangelos on 11 rootstocks was studied. Pronounced differences in depth of rooting, weight of feeder roots and tree height were detected. Depth of rooting was correlated to tree height, (r = .58, 1970; r = .83, 1971) i.e., the tallest trees had the deepest root systems. Feeder root wt and tree height were not related. The level of leaf N, K, Ca and Mg but not P was related to rootstock, suggesting a differential absorption of mineral nutrients by rootstock. The level of N appeared to be influenced by root distribution. Trees with deep extensive root systems or with a large number of feeder roots near the surface had high leaf N. Leaf K was significantly correlated with depth of rooting, (r = .96, 1970; r = .84, 1971). The results suggested the maximum performance of all rootstocks was not attained under the uniform cultural conditions of this experiment and therefore the need to examine each rootstock under conditions optimum for it.

Citrus rootstocks can influence the cold hardiness, growth, leaf mineral content and fruit size and quality of the scion cultivar. The rootstock, in turn, can be influenced by the scion and the soil environment.

Some have suggested that physical characteristics of root systems, such as differences in the distribution and concentration of feeder roots, could account for rootstock effects (15). Differences of this nature have been demonstrated in FL (4, 11) and elsewhere (1, 7, 10); however, many root studies have often been hindered by 1 or more short-comings which include lack of adequate quantitative data, failure to make statistical comparisons, or restriction of the study to a limited zone of the total rooting area.

This research was undertaken to examine the depth and lateral extent of rooting and root density of several citrus rootstocks and their effects on the leaf mineral contents of the scion.

Materials and Methods

In 1970, 5 trees on each of 10 rootstocks were selected (from the 2 rows of the planting containing the most vigorous trees) to determine their feeder root wt, rooting depth, tree height and leaf mineral content. Rooting depths and feeder root wt were obtained from multiple borings made on each tree at the drip line, 90 cm out from the drip line and then at 60 cm intervals until the row middle was reached. A hand-operated well drilling auger was used to obtain cores of soil in 4120 cc (20.3 cm in diam by 12.7 cm in depth) increments (4). The cores were sifted and feeder roots 2 mm or less in diam were separated, dried and weighed. Height of trees was measured to the nearest 3.0 cm. Depth to the clay layer underlying the planting, soil texture (3) and pH were also determined on samples collected from 8 points along row middles.

Thirty leaves were collected on 3 occasions from previously tagged nonfruiting shoots on individual trees to determine leaf mineral content. Samples were oven-dried and analyzed for N, P, K, Mg, and Ca by standard procedures (2). All measurements were repeated in 1971, except those regarding depth to clay, soil texture and pH. The

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desired precision for rooting depth and feeder root wt was not obtained in 1970. Thus, data were taken from 100 trees or 10 replicates in 1971, instead of the 50 trees or 5 replications used in 1970 and sampling was limited to borings at the drip line. The increased number of trees used in 1971 prevented pooling the data for the 2 years so the results from each year were considered independently.

Results

Depth to the clay layer in the experimental planting ranged from 200 to 254 cm (80–100 inches). Soil above this layer contained little or no clay and was classed as a sand. The pH of the soil ranged from 6.7 at the surface to 4.6 in the clay. Clay content of the subsoil layer varied between 10 and 38%. The soil changed abruptly with depth from a sand into a sandy clay loam or sandy clay in some areas. In other areas the change was more gradual. The clay content of the subsoil layer eventually increased to 30% or more in all areas and seemed to restrict root growth of all rootstocks as has been noted previously (4).

The marked influence of rootstock on mean height of 'Orlando' tangelo trees and differences in rooting depth and total feeder root weight was clearly evident (Table 1). Rootstocks fell into 3 well-defined groups in both years in their effect on tree height. The tallest trees were those on rough lemon, 'Palestine' sweet lime and 'Cleopatra' mandarin, all about 4.0 m (13 ft) high. The shortest trees were those on 'Rusk' citrange and the trifoliate orange selections, about 2.5 m (8 ft) high. Trees on 'Carrizo' and 'Troyer' citrange, sour orange and sweet orange were intermediate, about 3.3 m (11 ft) high.

Mean depth of rooting at the drip line ranged from 4.6 m (183 inches) for trees on rough lemon to 2.8 m (109 inches) for those on 'Rubideaux' trifoliate orange in 1970 and from 3.7 m (144 inches) for trees on rough lemon to 2.1 m (81 inches) for those on 'Rusk' citrange in 1971. Significant correlation coefficients of $r = 0.577$ in 1970 and $r = 0.826$ in 1971 were found between mean tree height and depth of rooting.

The slightly shallower mean rooting depth and the slightly lower tree height in 1971, as compared with 1970 data, was due to the increased number of trees sampled in 1971. The larger number of trees sampled in 1971 resulted in greater precision and large differences between rootstocks that were not significant in 1970 were significant in 1971.

Rootstock had a pronounced effect on mean total feeder root weight; however, the larger root wt were not consistently associated with the most vigorous and deep rooted trees. Both tall and short trees, e.g. those on rough lemon and the trifoliate orange selections, had mean total feeder root wt over 100.0 g. in 1970, when samples from 2 borings (drip line and drip line plus 90 cm) were combined. Trees on 'Rusk' citrange had the smallest mean weight, 74.9 g, in 1970 as well as in 1971 when samples were taken from borings at the drip line only. Correlation coefficients between mean tree height and total feeder root weight were not significant either year.

Lateral spread of the roots could not be determined precisely for all rootstocks. Roots of most of the larger trees had already grown past the row middle and extended into the rooting zone of adjacent trees. Lateral roots of 'Troyer' and 'Carrizo' citrange had nearly reached the row middle and those of 'Rusk' citrange, the trifoliate orange selections and sweet orange had extended approximately 3.7 m (12 ft).

The percentages of feeder roots at various depths are shown in Fig. 1. The deep-rooted trees on rough lemon and sweet lime had more than 50% of their feeder roots below 76 cm (30 inches) in the soil. The trees intermediate in rooting depth tended to have an equal amount of feeder roots above and below 76 cm. Exceptions were the trees on 'Cleopatra' mandarin, 'Rusk' citrange and 'Rubideaux' trifoliate orange which had over 60% of their roots above 76 cm. Rough lemon was the only rootstock which had any roots deeper than 460 cm (180 inches).

Effects of rootstock on leaf mineral content are shown in Table 2. There were several changes in the relative position of the rootstocks for all nutrients between 1970 and 1971, however, most could be accounted for on the basis of year to year variation.

The highest mean leaf N content was from trees on sweet lime, 2.45%, in 1970, and 'English Small' trifoliate orange, 2.53%, in 1971. The lowest mean leaf N content was from trees on 'Cleopatra'

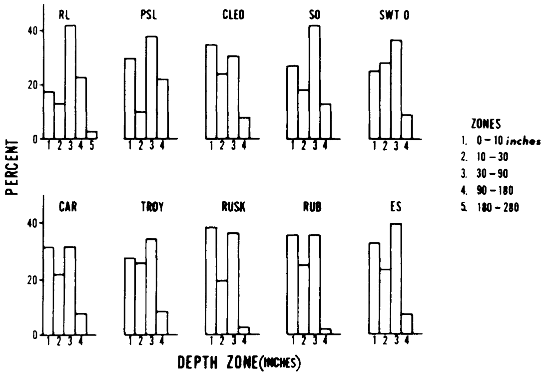

Fig. 1. The influence of rootstock on the percentages of feeder roots at different depths (average of 5 borings made at the dripline in 1970 and of 10 borings in 1971).

Table 1. A comparison of rootstock influence on mean value for tree height and root distribution of 'Orlando' tangelo trees.[z]

Rootstock	Tree height		Depth of rooting[y]		Total feeder root wt[x]	
	1970 (m) (ft)	1971 (m) (ft)	1970 (m) (inches)	1971 (m) (inches)	1970 (g)	1971 (g)
Rough Lemon	4.0 (13.2)e	3.9 (12.7)c	4.7 (183)c	3.7 (144)c	136.7c	83.2h
Palestine Sweet Lime	4.0 (13.0)de	3.9 (12.8)c	4.0 (159)bc	3.5 (138)c	101.3abc	64.0e
Cleopatra Mandarin	3.9 (12.7)cde	3.8 (12.4)c	3.4 (133)ab	2.8 (110)b	89.8ab	46.3a
Sour Orange	3.6 (11.7)bcd	3.5 (11.5)b	3.5 (136)ab	2.8 (110)b	97.9ab	54.6c
Sweet Orange	3.4 (11.1)b	3.4 (11.2)b	3.5 (138)ab	2.4 (95)ab	93.8ab	52.3b
Citrange						
Carrizo	3.6 (11.7)bcd	3.4 (11.2)b	3.3 (130)ab	2.6 (103)b	119.8bc	69.6f
Troyer	3.5 (11.4)bc	3.5 (11.5)b	3.3 (129)ab	2.5 (97)ab	96.7ab	58.4d
Rusk	2.5 (8.3)a	2.6 (8.4)a	3.0 (117)ab	2.1 (81)a	74.9a	51.3b
Trifoliate Orange						
Rubideaux	2.6 (8.4)a	2.8 (9.3)a	2.8 (109)a	2.3 (90)ab	103.6abc	71.0f
English Small	2.5 (8.1)a	2.8 (9.2)a	2.9 (115)ab	2.4 (95)ab	123.2bc	78.3g

[z] Means not sharing the same letter within columns are significantly different at the 5% level. The 1970 data were collected from 5 replicates and the 1971 data from 10 replicates.

[y] Dept of rooting at the dripline.

[x] Total feeder root wt in an entire column of soil 30.5 cm (1 foot) square for borings at dripline. Data from 1970 also includes the wt of feeder roots collected from the boring 90 cm (3') from the dripline.

Table 2. The effect of rootstock on mean values of macronutrients in 'Orlando' tangelo leaves.[z]

Rootstock[x]	Element in leaf dry matter (%)[y]									
	N		P		K		Mg		Ca	
	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
PSL	2.45e**	2.44ef*	.116ns	.907ns	2.08d**	1.38ef*	.52a	.64a*	3.14a*	3.43cd*
RL	2.29bcd	2.39de	.114	.097	2.11d	1.48f	.52a	.65a	3.51b	3.48cde
SO	2.19abc	2.24abc	.116	.093	1.68bc	1.13cd	.77c	.76bc	3.71bcd	3.66e
CLEO	2.07a	2.34bcde	.115	.095	1.69bc	1.29de	.61b	.65a	4.03d	3.57de
SWT O	2.09a	2.15a	.127	.094	1.74bc	1.29de	.64b	.62a	3.99cd	3.35c
CAR	2.28bcd	2.29bcd	.116	.094	1.74bc	1.24de	.81c	.81cd	3.56b	3.15b
TROY	2.24bc	2.35cde	.116	.099	1.65bc	1.19d	.80c	.82d	3.66bcd	3.53cde
RUB	2.33cde	2.37de	.109	.094	1.43a	0.94ab	.75c	.79bcd	3.58bc	3.08b
ES	2.41de	2.53f	.113	.101	1.43a	1.00bc	.76c	.67a	3.69bcd	2.79a

[z] Leaf age—5½ months.

[y] Means not sharing the same letter within columns are significantly different at the level indicated:
* 5%
** 10%

[x] See Table 1 for explanation of rootstock symbols.

mandarin and sweet orange, 2.07% in 1970 and 2.15% in 1971, respectively.

There were no statistical differences between the mean P content of leaves from the different rootstocks for either year.

The differences in leaf K content clearly separated the rootstocks into 3 groups in 1970, but less so in 1971. The trees with the highest leaf K content were those on rough lemon and sweet lime. Those on the trifoliate orange selections and 'Rusk' citrange formed the group with the lowest K levels. Trees on the remaining rootstocks were intermediate.

Leaf Mg content was generally highest in trees on 'Carrizo' and 'Troyer' citrange, 0.81%, and ranged to the lowest values of 0.52 and 0.64% from trees on sweet lime in 1970 and 1971, respectively.

Rootstock influenced leaf Ca content more than any other nutrient studied. Trees on 'Cleopatra' mandarin, sweet orange, sour orange, and 'Troyer' citrange had among the highest leaf Ca levels both years. Trees on the trifoliate orange selections were also among the highest in 1970 but declined in 1971.

Discussion

Data from root distribution studies in the field have rarely been analyzed statistically. The root data (Table 1) were subjected to statistical analysis. In 1970, large differences such as 75 cm in depth of rooting ('Rubideaux'-sweet orange) or 29 g in wt of feeder roots ('Rusk'-'Rubideaux'), were not significant, suggesting inadequate precision. Therefore, twice as many trees of each rootstock were sampled in 1971. This increase in sample size resulted in significant differences in depth of rooting and feeder root wt between rootstocks that did not differ significantly in 1970.

There were 2 general types of root systems, intensive and extensive, that were related to the volume of soil penetrated by the roots. Rough lemon exemplified the extensive type, having a root system characterized by extensive lateral and vertical development. This stock is well known for its excellent adaptation to sandy soils in FL. Sweet lime was also of this type, however, vertical distribution of its feeder roots was somewhat different (Fig. 1). The root characteristics of both rootstocks generally agree with those observed by others (4, 10). The trifoliate orange selections and 'Rusk' represent the intensive type, having the majority of feeder roots located in the top 76 cm of soil. The root systems of the remaining rootstocks were intermediate but in most cases they had some characteristics more similar to 1 or the other extreme. For example, the distribution of sour orange roots was similar to that of sweet lime yet 'Cleopatra' mandarin, which had a rooting depth identical to sour orange, was similar to the intensive type.

Tree height was greatly influenced by rootstock (Table 1) verifying a relationship consistently found in other research (5, 6, 8, 9), however, the manner in which rootstock affects tree size has not been determined. Reports relating tree size to size of the root system are particularly sparse, even though it is commonly accepted that "size of root system is always in the same relative proportion to size of trunk and top (16)." The term 'size' generally implies soil volume penetrated but disregards the significant differences that can occur in root concentration and distribution between root systems occupying equal soil volumes. The term does not take into account those environments where the growth of tree root systems have become restricted in depth due to a physical barrier such as an impermeable clay layer or a water table. Under circumstances such as these, root concentration, and physiological differences may assume more prominent roles. For example, differences in tree size due to rootstock occur in the Indian River Area of FL where rooting depth is limited to less than 1 m by a high water table (6).

The importance of depth of rooting in this study was evident in the significant correlation (r = .958, 1970; r = .837, 1971) between this factor and tree height. This has not been reported previously but appears reasonable because deeper rooted plants should have access to a greater volume of soil, assuming equal lateral root development. However, increases in depth of rooting between rootstocks were not associated with concomittant increases in feeder root quantity. Some large trees, although deep rooted, did not have large feeder root weights while the small trees on trifoliate orange rootstock had shallow, but dense root systems. This explains in part why the quantity of feeder roots, as measured by their wt, was not related to tree height.

Nevertheless, the fact that the statistical correlation between these factors was not significant does not necessarily imply that they are not related. Root wt alone does not provide any indication as to the effectiveness of the root system in absorbing water and nutrients.

The leaf mineral content of 'Orlando' was influenced by rootstock. These differences were assumed to be due primarily to the differential ability of the rootstock to absorb water and nutrients and to physical differences between the root system.

A possible relationship between the physical features of the root systems and leaf N and K was established. Nitrogen and K are the 2 elements reportedly having the greatest effect on tree growth (13). Therefore, it appears meaningful that trees on sweet lime and rough lemon, the rootstocks with the most extensive root systems and which produced the largest trees, also had among the higher leaf N contents. Trees on the shallow rooted trifoliate orange selections also had high leaf N content (Table 2); however, the denseness of their root systems near the surface and the reported ability of citrus roots to absorb N rapidly (12) could explain the high leaf N in this case. The small tree size on the trifoliate selections, despite their high leaf N content, was probably due to a moisture limitation on the deep, coarse, sandy soil.

Trees on trifoliate orange are much larger on soils more retentive of moisture (14). Trees on the remaining rootstocks had root systems neither as extensive as those of rough lemon nor with as many feeder roots near the surface as the trifoliate oranges.

Leaf K content was influenced by rootstock. The differences appeared to be related to depth of rooting as suggested by the highly significant correlation (r = .958, 1970; r = .837, 1971) of this factor and leaf K. This relationship is reasonable because the sandy soil in the experimental planting has a low C.E.C. and K is readily leached. Also, K is a cation, so some would be absorbed by the clay micelles of the subsoil layer. These ions would be available to those rootstocks, such as rough lemon and sweet lime, which had a considerable number of feeder roots in the clay. It is difficult to explain, however, why the distribution of feeder roots was not as strongly related to K as to N uptake. Leaf K is often reduced by heavy cropping (12) but previous reports of work with the same trees used in this study (8, 9) showed that the deepest rooted trees, those on sweet lime and rough lemon, also had by far the largest crops. Also, trees on 'Cleopatra' and sweet orange, which were unfruitful, had high leaf K. Thus, differences in K were not related to fruiting.

We conclude from the data presented that real and measurable differences existed between the root systems of several citrus rootstocks and they were related to differences in tree size and in some cases to leaf mineral content. The significance of these results, however, must be interpreted with caution, recognizing that they were obtained within the confines of a rather definite environment and subjected to a uniform cultural program, as has been the case with most rootstock trials.

Differences obtained under these circumstances are more likely to reflect the adaptation of a plant to a given environment rather than its true potential under more favorable cultural conditions. Thus, a second generation of rootstock research is needed to establish the performance of a given rootstock under optimum conditions.

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Exogenous Gibberellic Acid and the Cytokinin Isopentenyladenine Retardants of Senescence in Romaine Lettuce[1]

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Abstract. A single preharvest spray of gibberellic acid (GA$_3$), alone or with the cytokinin, isopentenyladenine (IPA), retarded leaf yellowing, and, to a lesser extent, leaf rot of romaine lettuce (*Lactuca sativa* L. 'Hazera Yellow'). The most effective spray was 10 ppm GA$_3$ plus 0.1 ppm IPA. Effects of 1 ppm GA$_3$ together with 0.1 ppm IPA were similar to those of 25 ppm GA$_3$ and were always superior to the controls (water-sprayed). Lettuce sprayed by the hormones and packed in polyethylene (PE) liners remained green and sound longer than that either sprayed or packaged.

Following the finding of Richmond and Lang (13) that kinetin retarded senescence of detached xanthium leaves, successful attempts were made (4, 6, 11, 14) to retard deterioration of lettuce by pre- and postharvest treatments with substances having cytokinin activity: 6-benzylaminopurine (benzyladenine) and 6-furfurylaminopurine (kinetin). However, so far none of these materials have been approved for commercial use. We, therefore, tested the effect of gibberellic acid (GA$_3$) and of the cytokinin IPA 6 (γ, γ, dimethylallyl) amino purine on deterioration of romaine lettuce. These senescence-retarding hormones (2, 3, 4, 5, 7, 8, 9) seemed particularly suitable for eventual commercial application, because they are endogenous in plants (5, 7, 10).

Materials and Methods

Experiments were conducted in January through April from 1970 to 1972. A motorized-backpack sprayer delivering 20–25 l/dunam

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