ROOTSTOCK EFFECTS ON ROOT DISTRIBUTION AND LEAF MINERAL CONTENT OF 'ORLANDO' TANGELO TREES

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Abstract. **Depth of rooting, weight of feeder roots and tree height of 'Orlando' tangelos varied pronouncedly with rootstock. Depth of rooting and tree height were statistically correlated, r = 0.58 in 1970 and r = 0.83 in 1971; i.e., the tallest trees had the deepest root systems. Levels of leaf N, K, Ca and Mg respectively, but not P, were related to rootstock. Trees with deep extensive root systems or with a large number of feeder roots near the surface had the highest leaf N contents. Leaf K was significantly correlated with depths of rooting, r = 0.96 in 1970 and r = 0.84 in 1971. The results suggested the need to examine rootstock responses under several cultural regimes.**

There are many reports describing the influence of citrus rootstocks on such factors as yield, fruit quality, vigor of growth, hardiness to cold, resistance to drought, and leaf mineral content. Some have suggested that rootstock effects may be partially due to differences in the distribution and quantity of feeder roots (8). There are several reports on root distribution of rootstocks in Florida but only a few rootstocks were studied and the data were not related to tree performance (2, 3, 4, 6). This research was undertaken to relate the distribution and quantity of feeder roots of 11 different rootstocks to tree height and leaf mineral content.

Materials and Methods

Trees used in this study are part of an experimental planting of 'Orlando' [*Citrus paradisi* (L) Macf. X *C. reticulata* Blanco] tangelos on 11 different rootstocks planted in 1961 as part of a commercial grove on well-drained Astatula (formerly Lakeland) fine sand in Lake County. The experimental design, details of which have been previously reported (5), consisted of 15 single tree replicates of each rootstock.

Root distribution and density (weight) of feeder roots were determined according to the method described by Ford (3), in which cores of soil are obtained with an auger and the roots contained, screened from the soil. The feeder, 2 mm diameter and smaller, roots are then separated out and weighed. The root systems were examined in this study in 1970 and in 1971. In 1970, 5 trees on each of 10 rootstocks (Fig. 1) were selected for study, the size of the experiment being limited by the large amount of work required to obtain the root samples. Even so, over 2,000 cores of soil

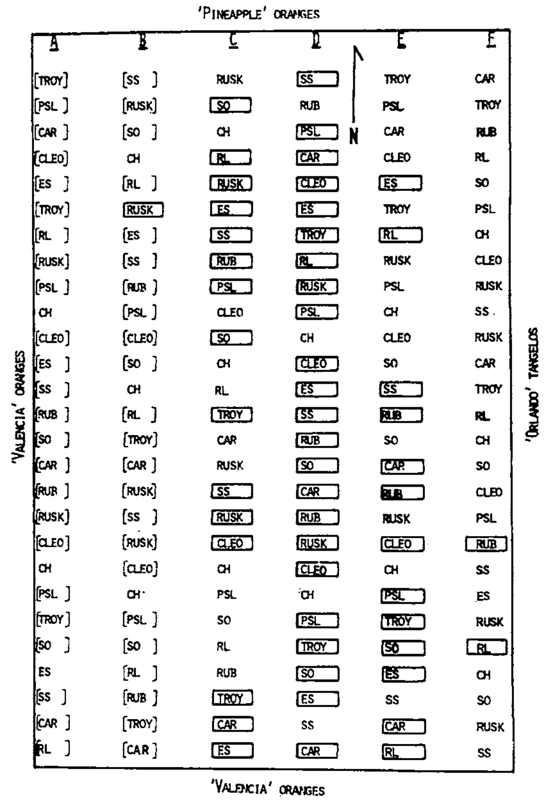

Fig. 1. Planting plan showing trees used in 1970 ([ ]) and 1971 ( ) and also indicating border plantings.

Key to Rootstock Symbols:

RL —**rough lemon**
PLS —**Palestine sweet lime**
SO —**sour orange**
SS —**sweet orange**
CLEO —**Cleopatra mandarin**
CAR —**Carrizo citrange**
TROY —**Troyer citrange**
RUSK —**Rusk citrange**
CH —**Christian trifoliate orange**
RUB —**Rubideaux trifoliate orange**
ES —**English Small trifoliate orange**

were obtained each year. Multiple borings were made on the east side of each tree, at the canopy drip-line, 90cm (3 ft.) outside the drip-line, and at 60cm (2 ft.) intervals until the row middle was reached, in 1970. The sampling procedure was modified in 1971 because the 1970 data on depth and density of rooting at the canopy drip-line lacked the desired precision. Also, the root system of adjacent trees on several rootstocks were intermingled in the row middles, thereby preventing accurate determinations of lateral root limits. Thus, samples were taken only at the drip-line and the number of trees on each rootstock was increased from 5 to 10. The 1971 borings were made on the west instead of the east side of the trees to ensure sampling from undisturbed root areas.

Tree height was measured with a surveyor's rod marked in .1 ft. (3.0 cm) units. Depth to the subsoil clay layer, soil texture and pH were determined from samples taken from 4 locations in each of the 2 row middles. Thirty leaves were collected on 3 dates in both years from previously tagged non-fruiting shoots. Samples were analyzed for N, P, K, Mg and Ca by standard procedures (1) and data were subjected to appropriate statistical analyses.

Results and Discussion

Data obtained in 1970 (Table 1) showed clearly that mean tree height, rooting depth and total feeder root weight varied greatly with rootstock. Rootstocks fell into 3 well-defined groups based on tree height. The tallest trees were those on rough lemon, 'Palestine' sweet lime and 'Cleopatra' mandarin. All were about 4.0 m (13 ft.) high. The shortest trees were those on 'Rusk' citrange and the trifoliate orange selections, which were about 2.5 m (8 ft.) high. Trees on 'Carrizo' and 'Troyer' citranges, sour orange and sweet orange were intermediate, about 3.3 m (11 ft.) high.

Mean root depth at the drip-line ranged from 4.6 m (183 in) for trees on rough lemon to 2.8 m (109 in) for those on 'Rubideaux' trifoliate orange. A significant correlation coefficient or $r = 0.577$ between mean tree height and depth of rooting was obtained.

The 1971 data confirmed results obtained in

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

Rootstock	Tree height				Depth of rooting[y]				Total feeder root weight[z]	
	1970		1971		1970		1971		1970	1971
	(m)	(ft.)	(m)	(ft.)	(m)	(in.)	(m)	(in.)	(g)	(g)
RL	4.0	(13.2)e	3.9	(12.7)c	4.7	(183)c	3.7	(144)c	136.7c	83.2h
PSL	4.0	(13.0)de	3.9	(12.8)c	4.0	(159)bc	3.5	(138)c	101.3abc	64.0e
CLEO	3.9	(12.7)cde	3.8	(12.4)c	3.4	(133)ab	2.8	(110)b	97.9ab	54.6c
SO	3.6	(11.7)bcd	3.5	(11.5)b	3.5	(136)ab	2.8	(110)b	97.9ab	54.6c
SWT O	3.4	(11.1)b	3.4	(11.2)b	3.5	(138)ab	2.4	(95)ab	93.8ab	52.3b
CAR	3.6	(11.7)bcd	3.4	(11.2)b	3.3	(130)ab	2.6	(103)b	119.8bc	69.6f
TROY	3.5	(11.4)bc	3.5	(11.5)b	3.3	(129)ab	2.5	(97)ab	96.7ab	48.4d
RUSK	2.5	(8.3)a	2.6	(8.4)a	3.0	(117)ab	2.1	(81)a	74.9a	51.3b
RUB	2.6	(8.4)a	2.8	(9.3)a	2.8	(109)a	2.3	(90)ab	103.6abc	71.0f
ES	2.5	(8.1)a	2.8	(9.2)a	2.9	(115)ab	2.4	(95)ab	123.2bc	78.3g

[x]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]Depth of rooting at the dripline.

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

1970. Greater statistical precision was obtained, however, through the use of a larger number of trees and changes in sampling procedures already described. Mean depth of rooting was slightly less in 1971 than in 1970 because the same trees were not measured in both years (Fig. 1).

Mean total feeder root weight varied with the rootstock. Large root weights, however, were not consistently associated with the largest and deepest rooted trees. Both tall and short trees, e.g. those on rough lemon and trifoliate orange respectively, had mean total feeder root weights over 100.0 g 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. Mean tree height and total weight of feeder roots were not statistically correlated.

Lateral spread of roots could not be determined precisely for all rootstocks because roots of the group containing the tallest trees had already intermingled in the row middles. Roots of 'Troyer' and 'Carrizo' citranges had nearly met in the row middles and those of 'Rusk' citrange, the trifoliate orange selections and sweet orange had extended only 3.7 m (12 ft.) laterally.

Percentages of feeder roots at various depths for 1970 and 1971 combined, are presented in Fig. 2. Deep-rooted trees on rough lemon and sweet lime had more than 50% of their feeder roots below 76 cm (30 in.). 'Cleopatra' mandarin however, was an exception with over 60% of its roots at less than 76 cm deep. Trees intermediate in rooting depth tended to have an equal amount of feeder roots above and below 76 cm. Shallower rooted trees, 'Rusk' citrange and the trifoliate orange selections, had over 60% of their roots above 76 cm. Rough lemon was the only rootstock which had a mean maximum root depth greater than 460 cm (180 in.); however, a few trees of sweet lime extended that deep.

Texture of the subsoil appeared to have an influence on the depth of rooting. The soil contained little or no clay above 200 to 254 cm (80-100 in.) and was classed as sand. The soil changed abruptly

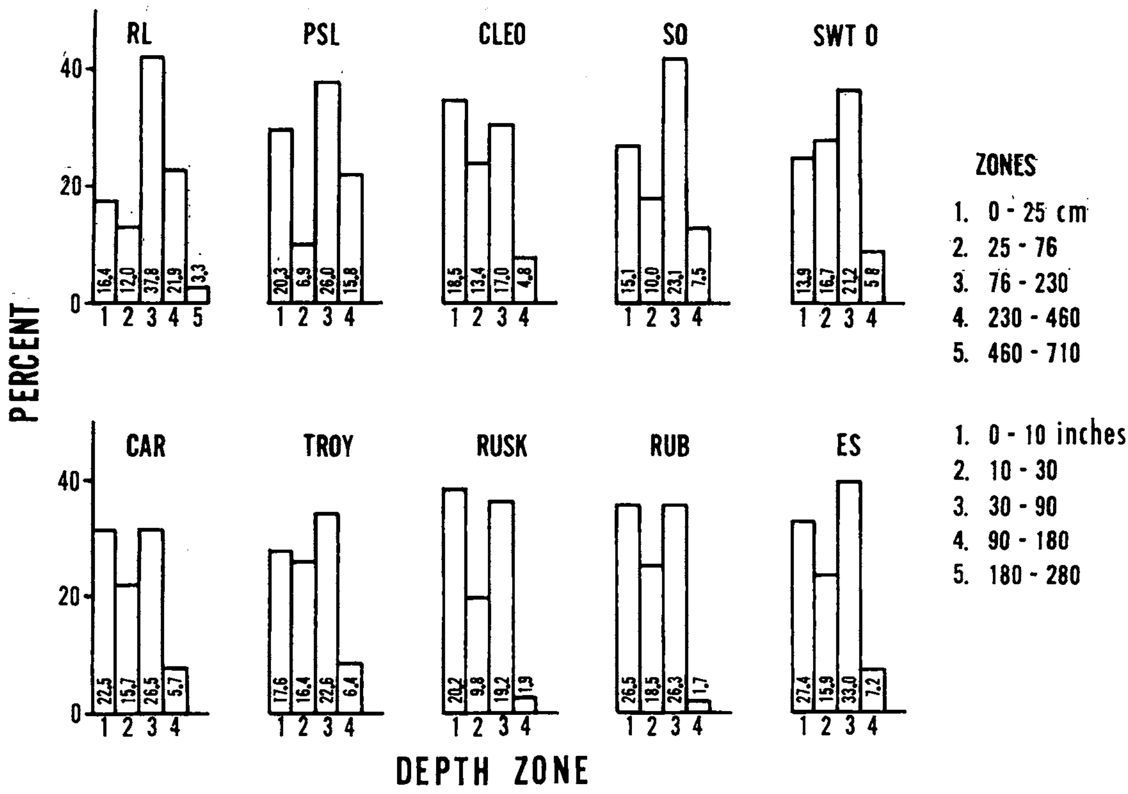

Fig. 2. The mean influence of rootstock on the percentages of feeder roots at different depths for borings made in 1970 and 1971. Each histogram also contains the weight of feeder roots found in each zone.

with depth from sand to a sandy clay loam or sandy clay in some areas but more gradually in others. Clay content of the subsoil clay layer varied between 10 and 38%. Root growth of all rootstocks appeared to be restricted when the clay content increased to 30% or more, which agrees with Ford's work (3).

The leaf contents of several mineral elements were influenced by rootstocks, 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 simply on the basis of year to year variation.

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

Differences in leaf K content clearly separated the rootstocks in 3 groups in 1970, but less so in 1971. 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 percentages. 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 0.69 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 contents over the 2 year period. Trees on the trifoliate orange selections were also among the highest in 1970 but declined in 1971.

There are several conclusions to be drawn and applications to be made from these results.

1. Depth and quantity of rooting can be not only quantitatively described but statistically tested for differences with a reasonable number of samples. Heretofore, root systems have been described quantitatively but not subjected to statistical examination (2, 3, 4), thereby sometimes leaving the meaning of the results in *question.*

2. Height of tree and depth of rooting were statistically correlated, with the largest trees having the deepest root system. This, along with the fact that over 50% of the root system of the largest trees was deeper than 76 cm, suggests that depth of rooting is important. No effort was made to determine the reasons deep-rooted trees were largest but increased moisture supply available in

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

Rootstock[z]	N 1970	N 1971	P 1970	P 1971	K 1970	K 1971	Mg 1970	Mg 1971	Ca 1970	Ca 1971
	Element in leaf dry matter (%)									
PSL	2.45e**	2.44ef*	.116ns	.097ns	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	1.29d3	.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	1.24d3	.81c	.81cd	3.56b	3.15b
TROY	2.24bc	2.35cde	.116	.099	1.65bc	1.19d	.80c	.82d	3.66bcd	3.53cde
RUSK	2.15ab	2.21ab	.121	.101	1.44ab	0.86a	.76c	.82d	3.46ab	3.60ce
RUB	2.33cde	2.37de	.109	.094	1.43a	0.94ab	.75c	.79bcd	3.58bc	3.08b
ES	2.41ae	2.53f	.113	.101	1.43a	1.00bc	.76c	.67a	3.69bcd	2.79a

[x]Leaf age - 5 1/2 months.

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

[z]See Fig. 1 for explanation of rootstock symbols

the larger soil volume occupied by the roots appeared to be a logical explanation.

3. Leaf mineral content varied with the rootstock species or cultivar, indicating a differential ability of rootstocks to obtain mineral elements from the soil.

4. Vigorous growth of trees is normally associated with high N levels yet small trees on trifoliate selections had leaf N contents as high or higher than the large trees on rough lemon, Table 2. Most of the leaf mineral contents fell within the optimum range thus the data suggest that either the moisture level or some unknown factor inherent in the rootstock-scion combination resulted in the small tree size. Exocortis virus could also be a factor. Tests of budwood from the trees show them free of exocortis, however, and sweet oranges on trifoliate orange rootstock reportedly may be as large as those on 'Troyer' citrange (7) when grown on soils more retentive of moisture. Thus, the small size of trees on trifoliate orange is probably attributable to a lack of moisture resulting from the shallower root systems.

5. Both the differential ability of rootstocks to obtain mineral elements from the soil and their differential ability to obtain moisture, as suggested by differences in the depth and density of rooting, indicates that optimum performance can not be obtained for a wide range of rootstocks under a single set of cultural practices. For example, the size of trees on trifoliate orange and 'Rusk' citrange, with added irrigation might well be much nearer to that of the largest trees, such as those on sweet lime and rough lemon. Trees on 'Cleopatra' are noted for low yields and small fruit sizes during their first 15 to 20 years of age. Their relatively shallower root systems as compared with trees of similar size, suggests additional irrigation could overcome the tendency to low yields. Small fruit sizes might be attributed in part both to a limited moisture supply and a lower leaf K. Addition of water through irrigation and of K through use of higher rates of K fertilizer might overcome, at least partially, yield and fruit size problems associated with this rootstock.

Literature Cited

1. Anderson, C. A. et al. 1968. Methods of analysis. Fla. Agr. Exp. Sta. Project 1398. Lake Alfred, Florida.

2. Ford, H. W. 1952. The distribution of feeder roots of orange and grapefruit trees on rough lemon rootstock. Citrus Magazine. 14 (11): 22,23.

3. ————. 1954. The influence of rootstock and tree age on root distribution of citrus. Proc. Amer. Soc. Hort. Sci. 63:137-142.

4. ————. 1964. The effect of rootstock, soil type and soil pH on citrus root growth on soils subject to flooding. Proc. Fla. State Hort. Soc. 77:41-45.

5. Krezdorn, A. H. and W. J. Phillips. 1968. The influence of rootstock on the size of tree, yield and quality of fruit of young 'Orlando' tangelo trees. Proc. Amer. Soc. Hort. Sci. Trop. Reg. 11:73-81.

6. Savage, E. M., W. C. Cooper, and R. B. Piper. 1945. Root systems of various citrus rootstocks. Proc. Fla. State Hort. Soc. 58:44-48.

7. Straus, G. R. 1962. Trifoliate proves excellent rootstock for Ivanhoe planting. Calif. Citrog. 47:373-376.

8. Wallace, A. et al. 1952. The rootstock-scion influence on the inorganic composition of citrus. Proc. Amer. Soc. Hort. Sci. 59:133-142.

DEVELOPMENT OF SCION CULTIVARS OF CITRUS IN FLORIDA

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Abstract. **There is a need for new tangerine, tangelo, orange, and grapefruit cultivars that resist diseases, insects, and cold and produce fruit with high quality and good taste. Early and late-maturing tangerines and tangelos would fill a market demand. Early maturing orange and grapefruit cultivars would permit better use of harvesting labor, packinghouses, and processing equipment. The hazard of freeze injury to fruit would be reduced, because the fruit could be harvested before onset of cold weather. Several promising tangerine and tangelo selections are established in advanced tests to determine whether they are worthy of release to the industry.**

The U. S. Department of Agriculture began citrus hybridization in Florida in 1893. Cooper et al. (1) reviewed the objectives and progress from 1893 through 1962. During the late 1890's, the primary objective was the development of cold-hardy selections. Many of the early hybrids produced inedible fruit. There was renewed interest in the program in 1942, when the emphasis was to produce early maturing tangerine (*Citrus reticulata*) hybrids.

Five hybrids from the 1942 crosses have been released in Florida. 'Robinson', 'Osceola', 'Lee',