All clones reported in this paper will be field tested before being officially recommended for planting in Florida citrus groves.

LITERATURE CITED

1. Cooper, W. C. 1959. Personal communication.
2. Feder, W. A., H. W. Ford, J. Feldmesser, F. E. Gardner, R. S. Suit, A. Pieringer, and P. C. Hutchins. 1958. Citrus varieties, species, and relatives susceptible to attack and damage by the burrowing nematode, **Radopholus similis**. U. S. Dept. Agr. Plant Dis. Reptr. **38**: 794-795.
3. Feder, W. and H. W. Ford. 1958. Susceptibility of certain citrus varieties, species and relatives to the burrowing nematode. Proc. Fla. State Hort. Soc. **70**: 60-63.
4. Ford, H. W. 1953. The effect of spreading decline disease on the distribution of feeder roots of orange and grapefruit trees on rough lemon rootstock. Proc. Amer. Soc. Hort. Sci **61**: 68-72.
5. Ford, H. W. 1956. Citrus rootstock selections tolerant to the burrowing nematode. Proc. Fla. State Hort. Soc. **69**: 44-51.
6. Ford, H. W. and W. A. Feder. 1958. Procedures used for rapid evaluation of citrus for resistance to certain endoparasitic nematodes. Proc. Amer. Soc. Hort. Sci. **71**: 278-284.

RELATION OF CITRUS NURSERY TREE SIZE FROM ½ TO ⅞ INCHES TO ULTIMATE SIZE AND PRODUCTION

F. E. GARDNER AND G. E. HORANIC

Crops Research Division

U.S.D.A. Agricultural Research Service

Orlando

Most citrus growers and nurserymen hold a rather definite opinion about the relative future growth and fruitfulness of large and small nursery trees on a given rootstock. It is generally believed that large nursery trees will maintain their relative size advantage. Certainly the price graduation upward for trees of increased caliper supports the idea that the larger trees must be superior in some respect.

There is considerable published work on deciduous fruit trees to support the belief that large nursery trees continue to be large trees in the orchard and that small ones continue to be small. Deciduous fruits, however, present a quite different situation from that of citrus because they are budded on zygotic seedlings, each genetically different from the other, whereas because of nucellar embryony, most seedlings of a given variety of citrus are genetically alike. Many varieties of citrus produce both nucellar and zygotic seedlings, and the percentage of each varies with the variety.

The most extensive work with citrus on the problem under consideration was reported by Webber. A first experiment, published in 1920 (2), involved the selection from a large number of nursery trees on sweet orange stocks of 18 small, 18 medium, and 18 large trees with Washington navel orange, Valencia orange, and Marsh grapefruit scion varieties. Their trunk diameters were measured when they were planted and again after about 2 years of growth. As might be expected, the three sizes maintained their relative positions during the period. Unfortunately, these results of only 2 years' growth were published and led Webber to some premature speculations. A report in 1932 (3) considered these same trees after 11 years of growth. While the Washington navel oranges and Marsh grapefruit still maintained their relative size positions, which were also reflected in the total amount of fruit produced, the Valencia oranges did not follow the pattern. In fact, the smallest trees at the start were intermediate in size after 11 years and produced the most fruit.

Apparently Webber felt that the tendency of large trees to remain large and small trees to remain small might be due to the presence of off-type seedlings (genetic variations) among the rootstock seedlings. Accordingly, he initiated another experiment, carefully devised and ingeniously prosecuted, to investigate this possibility (3). Washington navel orange buds from a single parent tree were budded on sour orange seedlings of a wide range of sizes. When the seedling tops were removed to force the buds, those seedlings which appeared to be variants were budded as scion varieties on sour orange and on Rough lemon and planted in a separate block for subsequent observation as to their variance from type. The whole population of trees budded with Washington navel orange, including those on variant stocks, were field-planted and their growth performance and fruit production were measured. Webber found a high positive relation between the size of the seedlings at budding time and the size of the resulting 1-year-old budlings and also a significant posi-

tive correlation between seedling size and size of the orchard tree 8 years later. But when measurements on all variant rootstock trees were removed from the calculations this correlation disappeared entirely. The size correlation between the budlings and the orchard trees 7 years later was also positive when the whole population was considered, but shrank to insignificance when the rootstock variants were discarded.

Mendel (1) budded large and small seedlings of Palestine sweet lime with Shamouti sweet orange and found that the size effect of the seedling stocks, as well as of the budlings, appreciable at the outset, became minor by 4 years after the budded trees were set in the orchard. While the Palestine sweet lime is highly nucellar, Mendel pointed out the importance of eliminating the few off-type seedlings before budding.

Materials and Methods

The present study of the relationship of original size of nursery tree to the ultimate size of orchard tree and yield of fruit is derived from a rootstock test planting on Lakeland fine sand at Tavares, Florida, now 17 years old. The planting consists of 2 scion varieties, Parson Brown and Valencia, on 7 rootstocks and of Parson Brown unbudded seedling trees. Each scion variety on each stock is planted in groups of 3 trees within a block with 13 replications of Valencia and 11 of Parson Brown used in this study.

The rootstocks include: 1. Sour orange 3 (from a selected tree at Eustis); 2. Sour orange A (from commercial seed); 3. Rough lemon (from commercial seed); 4. Bowen grapefruit (from a selected tree at Eustis); 5. Cleopatra mandarin (from a selected tree at Orlando); 6. Rusk citrange (from trees at Glen St. Mary, now lost); 7. Sweet orange (variety Parson Brown, Carney strain). In addition to the above listed rootstocks, unbudded seedlings of Parson Brown were included in the planting.

The trunk circumference of the young trees was measured in centimeters at planting time in the orchard in 1942 and at frequent intervals up to and including 1959. The yield record in boxes per tree (total for the last 4 years) is used in this report to correlate with the 1942 and the 1959 tree sizes. A 4-year

Table 1. Initial and final trunk circumferences and yield of Parson Brown and Valencia orange trees on various rootstocks, with coefficients of variability

Scion variety and rootstock	No. of trees	Circumference 1942 cm.	Circumference 1942 coeff. var.	Circumference 1959 cm.	Circumference 1959 coeff. var.	4-year total yield boxes/tree	4-year total yield coeff.var.
Parson Brown:							
Sour 3	32	5.4	12.1	56.5	9.27	14.9	19.73
Sour A	32	5.4	14.7	55.8	9.34	16.2	17.96
Rough lemon	32	5.9	11.0	63.0	8.03	23.0	18.13
Grapefruit	29	6.2	13.8	70.4	12.95	20.4	31.91
Cleopatra mand.	31	5.6	13.5	69.3	9.26	22.5	13.60
Rusk citrange	33	6.0	10.3	46.0	10.93	13.4	21.42
Sweet orange	31	6.4	13.7	62.7	7.81	20.6	23.98
Unbudded sdgls.	31	7.7	16.7	93.4	10.73	30.7	17.49
Valencia:							
Sour 3	37	6.0	9.6	61.4	10.62	10.5	22.00
Sour A	39	5.9	15.5	57.5	10.54	10.8	22.78
Rough lemon	35	6.1	15.5	70.7	7.69	21.3	18.64
Grapefruit	37	5.7	16.7	70.9	9.79	16.1	22.17
Cleopatra mand.	37	5.3	12.4	70.3	7.87	16.8	13.75
Rusk citrange	39	6.0	10.1	43.8	9.70	6.5	31.54
Sweet orange	38	6.0	10.4	69.6	8.16	16.3	19.82

L.S.D. for final size:
Parson Brown
@ .05 = 4.01
@ .01 = 5.30
Valencia
@ .05 = 3.14
@ .01 = 4.16

L.S.D. for yield:
Parson Brown
@ .05 = 3.53
@ .01 = 4.56
Valencia
@ .05 = 1.60
@ .01 = 2.11

record was used rather than the last year, to obviate any unusual yield situation with a particular stock and also to compensate for any alternate bearing effect.

The budwood used in the propagation of the trees in this experiment was taken from several young trees of each variety rather than from single tree sources. All trees in the mother tree block of Parson Browns were allegedly of the Carney strain and the Valencias of the Chase strain. Almost nothing is known of the virus complement of the parent trees, but from general experience with old-line clones in Florida, one could reasonably assume that the trees are carrying the now well-known viruses. It is not known whether, or to what extent, virus effects may have influenced the results reported.

Results

The initial tree size, the final tree size, and the total yield in boxes of fruit for a 4-year period for each variety on each of the rootstocks is presented in table 1. The coefficients of variability are also shown for each of these measurements. The marked influence of rootstock on tree size and yield is evident but will not be further commented on in this report. We are concerned primarily with relationship of nursery tree size to orchard performance.

It would be of interest to know, both from a scientific and a practical point of view, whether some rootstocks result in orchard trees of greater uniformity in size and production. The variability within rootstocks as expressed by the coefficients of variability shown in table 1 do not indicate that the various rootstocks differ appreciably from one another in their influence on the size variability of the 17-year -old orchard trees. It is of interest, however, that in most instances the variability of the final size is smaller than that of the initial size. In all cases variability in yields is much greater than variability in tree size. Cleopatra rootstock with Parson Brown and also with Valencia tops appears to be less variable in yield than the other stocks.

The relation between initial tree size, final tree size, and yield within each rootstock expressed as coefficients of correlation, is shown in table 2. For Parson Brown variety none of the 7 rootstocks nor the unbudded seedlings of Parson Brown show significant correlations between initial tree size and final tree size or between initial tree size and yield of the last 4 years. This is also true for the Valencia variety except for rootstocks 1 and 5, for which the correlation is significant at the 5% level between initial size and yield. As might be expected, there is a positive correlation, significant in most instances, between final tree size and yield. This varies considerably between rootstocks, but this variation is not consistent between the two scion varieties.

The relation of final tree size and yield of the two scion varieties to initial tree size arranged by class-size intervals is shown in table 3. In this case all 7 rootstocks are combined. The class size intervals are selected

Table 2. Correlation coefficient between initial size, final size, and yield of Parson Brown and Valencia orange trees on the various rootstocks

Scion variety and measurements correlated	r for indicated rootstock (see footnote)							
	1	2	3	4	5	6	7	8
Parson Brown:								
Initial size and final size	-.216	-.086	-.194	-.176	-.251	+.158	-.070	+.168
Initial size and yield	-.382	-.111	-.372	-.367	-.164	-.001	+.012	+.015
Final size and yield	+.724**	+.827**	+.324	+.396	+.708**	+.496*	+.601**	+.389
Valencia:								
Initial size and final size	+.229	+.022	+.304	-.005	-.049	-.021	-.256	
Initial size and yield	+.443*	+.011	+.284	-.190	+.440*	+.145	+.284	
Final size and yield	+.546**	+.543**	+.821**	+.415*	+.216	+.456*	+.418*	

*Significant at odds of 19 to 1.
** " " " " 99 to 1.

Footnote: No. 1. Sour orange 3
2. Sour orange A
3. Rough lemon
4. Grapefruit (Bowen)
5. Cleopatra mandarin
6. Rusk citrange
7. Sweet orange (Parson Brown)
8. Unbudded seedlings

Table 3. Final tree size and yield of Parson Brown and Valencia orange trees in relation to initial tree size when all rootstocks were combined

Initial trunk size Cir. (cm.)	Diam. (in.)	No. of trees	Final trunk size Cir. (cm.)	Total 4-year yield (boxes)
		Parson Brown Variety		
3.6-4.5*	1/2	11	62.46	19.14
4.6-5.5	5/8	69	60.93	19.38
5.6-6.5	3/4	102	60.76	18.93
6.6-7.5	7/8	32	58.12	16.73
		Valencia variety		
3.6-4.5*	1/2	16	68.22	15.90
4.6-5.5	5/8	74	62.37	13.39
5.6-6.5	3/4	123	64.11	15.59
6.6-7.5	7/8	46	62.53	14.37

*Not all stocks are represented in this class.

to coincide with caliper intervals of size familiar to both nurserymen and growers. For example, the 5/8-inch size falls midway in the trunk-circumference class of 4.6 to 5.5 cm. It is evident that the smaller nursery trees produced as large orchard trees after 17 years as did the larger nursery trees. For Parson Brown variety table 3 appears to show negative relationships between initial size, final size, and yield, i.e., the smaller trees resulting in large orchard trees and higher yields. That these differences are not statistically significant is supported by the correlation coefficients of table 2.

Discussion

The results of this study indicating no pronounced relation between initial size of nursery tree and ultimate size in the orchard is in general agreement with the results of Mendel (1) and also Webber's experiment (3) in which he removed the effect of variant seedling stocks. The present study, being incidental to a long-term rootstock trial, covers an appreciably longer period than the others cited and includes a wide range of rootstocks and 2 scion varieties in a thoroughly replicated statistical design. The results suggest that a rather good job was done in rogueing out the seedling variants before they were budded. Without such rogueing strong positive correlations between initial and final tree sizes might have resulted, as in Webber's data with these variants included.

The writers cannot refrain from pointing out the practical aspects of this and similar studies. First, the studies indicate that large nursery trees have no intrinsic superiority over medium-sized ones insofar as the ultimate size and yield of the orchard trees are concerned, provided that the nurseryman has done a thorough job of discarding all off-type rootstock seedlings prior to budding. If the nurseryman has been negligent in this regard, the grower might expect that purchase of small trees would work to his ultimate disadvantage. The discarding of all off-type seedlings and runts among which the greatest proportion of variants occur is advantageous to the nurseryman besides being part of his responsibility to the citrus grower.

Although this report discredits the commonly-held belief that the larger nursery trees will maintain their superiority throughout the life of the orchard, it is recognized that there are practical reasons which justify a price differential for the larger sizes. Smaller nursery trees are somewhat less costly to the nurseryman to dig and deliver. Moreover, the mortality of smaller trees upon planting in the orchard is apt to be greater than that of the larger ones.

Summary and Conclusion

A 17-year-old rootstock test block of two varieties on seven rootstocks with thoroughly replicated design provided an opportunity to determine the influence of initial tree size at time of planting on the ultimate tree size and yield. Although the tree size and yield were profoundly influenced by the rootstock variety, statistical studies of the data available indicate no pronounced correlation between the initial sizes studied and ultimate size or between initial size and yield within the various rootstocks. A positive relationship is shown between final tree size and yield, as might be expected.

LITERATURE CITED

1. Mendel, K. Seedling size as a criterion for the selection of sweet lime stocks. Hadar 13(2): 44-48. 1940.
2. Webber, H. J. Selection of stocks in citrus propagation. Calif. Agr. Exp. Station Bull. 317. 1920.
3. Webber, H. J. Variations in citrus seedlings and their relation to rootstock selection. Hilgardia 7(1): 1-79. 1932.

Acknowledgment:

The authors gratefully acknowledge the assistance of E. James Koch of the Biometrical Services Division, Beltsville, Maryland, with the statistical analyses in this report.