the time before this condition develops. An example of undesireable root development is the thin mat of roots which formed at the base of the plastic bag used in Expt 3 (Table 1). These roots were not removed or disturbed during transplanting. When the trees were examined later, this mat was still intact (Fig. 6). Some roots grew from the mat, but new growth often came from adventitious roots which emerged along the trunk above the root ball. Removal of the mat at planting would probably enhance root system development.

The new containers seem to encourage fibrous root growth rather than woody roots (Fig. 7) as compared with field-grown trees which have the typical root system described earlier. The fibrous to woody root ratio may change with plant age while in the nursery and differ according to the scion/rootstock combination and other factors. In the containerized nursery, if plant age and container volume affect the "type" of nursery tree root system, then this might help to explain some of the variation reported in the behaviour of container-grown trees in commercial orchards.

The successful establishment and subsequent field growth of citrus nursery trees, regardless of production method, requires root system expansion and development. From the limited observations reported herein, tree growth would generally be regarded as satisfactory except under extreme circumstances of root system mishandling because of poor planting or the failure to treat a container-bound condition.

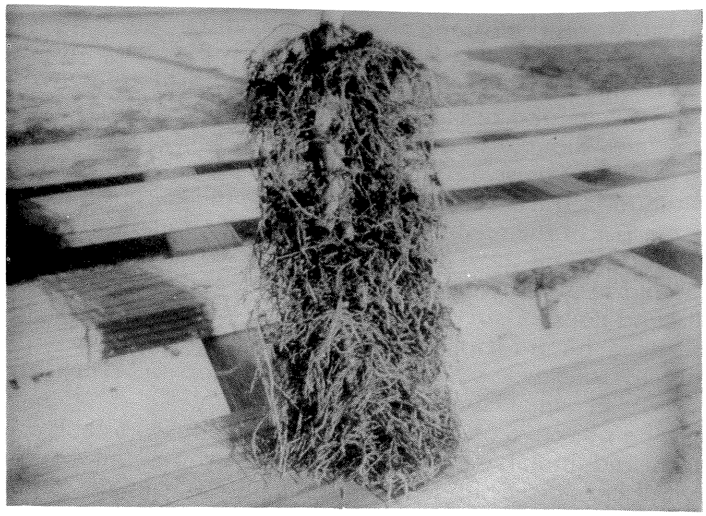

Fig. 7. Typical root system development of a citrus nursery tree grown in a 0.5 gal plastic bag using a medium with 50% peat.

Literature Cited

1. Bevington, K. B. and W. S. Castle. 1982. Development of the root system of young 'Valencia' orange trees on rough lemon and Carrizo citrange rootstocks. Proc. Fla. State Hort. Soc. 95:33-37.
2. Castle, W. S. 1978. Citrus root systems: Their structure, function and relationship to tree performance. Proc. Intern. Soc. Citriculture 1:62-69.
3. Castle, W. S. and C. O. Youtsey. 1977. Root system characteristics of citrus nursery trees. Proc. Fla. State Hort. Soc. 90:39-44.
4. Castle, W. S. and J. J. Ferguson. 1982. Current status of greenhouse and container production of citrus nursery trees in Florida. Proc. Fla. State Hort. Soc. 95:42-46.
5. Castle, W. S., W. G. Adams, and R. L. Dilley. 1979. An indoor, container system for producing citrus nursery trees in one year from seed. Proc. Fla. State Hort. Soc. 92:3-7.
6. Wheaton, T. A., W. S. Castle, D. P. H. Tucker, and J. D. Whitney. 1978. Higher density plantings for Florida citrus-concepts. Proc. Fla. State Hort. Soc. 91:27-33.

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GROWTH OF BARE-ROOTED AND CONTAINER-GROWN 'HAMLIN' ORANGE TREES IN THE FIELD

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Additional index words. Citrus sinensis, nursery.

Abstract. **Bare-rooted and container-grown 'Hamlin' orange trees [*Citrus sinensis* (L.) Osb.] on sour orange rootstock (*C. aurantium* L.) were planted in double-row beds to compare growth for the first 2 years under the same edaphic, cultural and environmental conditions. In experiment one, standard nursery trees were used, with bare-rooted trees being larger than container-grown trees at planting time. In a second experiment, trees of more uniform size were used. In a third experiment, container-grown trees were planted after removing all, 1/2, or no medium prior to planting to study the effect of media removal on growth over one season. Bare-rooted trees were significantly larger than container-grown trees 8 and 20 months after planting in experiment one. When trees of more uniform size were used, bare-rooted trees were significantly larger than container-grown trees 8 months after planting. After 18 months, trunk cross sectional area of bare-rooted trees remained significantly larger, but canopy volume was similar. Removal of medium from container-grown trees improved growth the first season, especially root growth, suggesting that it is important to select large nursery trees with healthy root systems and to break up the root ball prior to planting to achieve optimum growth for container-grown trees.**

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Florida nurserymen have been producing bare-rooted citrus trees in field nurseries for many years. Recently, however, citrus trees have also been produced in various types of containers in the greenhouse (2). Advantages of greenhouse systems include greater control over the production system, shorter growing cycles, and reduced transplant shock (1, 9, 11, 12). Much controversy exists, however, concerning growth and survival rates of container-grown compared to bare-rooted trees. Some growers feel that bare-rooted trees grow-off faster because of their spreading, extensive root system, while others believe that containerized trees are superior due to the water-holding properties of the medium surrounding the roots. Unfortunately, many of these observations have arisen from unreplicated tests with variable soil, cultural, and environmental conditions. A survey of growers in 1983-84 suggested the need for information on this subject ranked second only to rootstock selection (Larry K. Jackson, Univ. of Florida, personal communication).

The objective of this study was to compare establishment and initial growth of container-grown and bare-rooted citrus trees under the same cultural, climatic, and edaphic conditions. In addition, the effect of the media on growth of containerized trees was studied.

Materials and Methods

Three field experiments were conducted at the Horticultural Unit located NW of Gainesville using 'Hamlin' orange trees on sour orange rootstock. Beds 55 ft wide and 2 to 2.5 ft high were constructed in March, 1985. Soil type was Kanapaha sand (loamy, siliceous, hyperthermic, Grossarenic, Paleaquult) underlain by an impervious hardpan. Two tree rows 25 ft apart were used on each bed with trees set 11 ft apart. Irrigation was applied by 90 degree, 10 gallon-per-hour microsprinklers located ca. 3.25 ft NW of tree trunks. Available soil moisture was maintained at optimum conditions (20% soil moisture depletion, T. E. Marler, Univ. of Florida, unpublished).

Experiment one. Greenhouse-grown trees in 4 X 4 X 14 inch plastic containers (Citripots) and field-grown, bare-rooted trees were obtained from commercial nurseries in May, 1985 and planted as part of a study comparing tree types and fertilizer sources (8). Typical nursery trees were obtained, with bare-rooted trees being larger than containerized trees. Trunk diameter averaged 0.47 and 0.30 inches for bare-rooted and containerized trees, respectively. Twelve single tree replications per treatment combination (three fertilizer types X two tree types) were used, resulting in 36 trees per tree type.

A mark was painted on each tree ca. 2 inches above the bud union. Trunk diameter at this mark and canopy height and width were measured on 16 May 1985, 10 Dec. 1985, and 7 Dec. 1986. Trunk cross-sectional area was calculated from diameter and canopy volume was calculated as $(4/3)(3.14)(1/2H)(1/2W)^2$, where H = height and W = width (16). This formula assumes the canopy to approximate the shape of a prolate spheroid.

Six trees for each tree type were carefully excavated by hand in December, 1985 for growth measurements and root examination. Total plant fresh and dry weight, new root growth, total shoot length, and leaf area were measured after 8 months in the field. Roots of bare-rooted trees were stained with Safranin-0 dye prior to planting, which allowed roots that developed in the field to be distinguished from those present at planting time. Roots extending out of the media in containerized trees were considered to have developed in the field. Leaf areas were calculated from the regression of leaf fresh weight on leaf area $Y = -5.61 + 20.22X$, $r^2 = 0.94$, where Y = calculated leaf area (ft^2) and X = leaf fresh weight (lb.), using data obtained from eight sample trees (data not shown).

Data were subjected to analysis of variance. Due to lack of interactions among treatments, only data comparing nursery tree type are presented here. Comparisons of fertilizer sources are made in an accompanying paper (8).

Experiment two. A similar study was begun in May, 1986 using trees from commercial nurseries different from those used in experiment one. Trees of more uniform size than those used in experiment one were selected, with trunk diameter averaging 0.40 and 0.32 inches for bare-rooted and containerized, respectively. The same fertilizer sources were compared (8) and six single tree replications were used per treatment combination (three fertilizer sources X two tree types), resulting in 18 trees per tree type. Trunk cross sectional area and canopy volume were determined on 6 May 1986, 7 Dec. 1986, and 7 Oct. 1987. Six trees per tree type were excavated in December, 1986 and measurements similar to those of 1985 were made on these 8-month-old trees.

Experiment three. Poor root growth was observed on some containerized trees in experiment one, therefore a third experiment was designed to compare the effect of removing different amounts of container media on subsequent growth. Greenhouse-grown trees produced in 4-inch citripots and averaging 0.31 inches in diameter were treated by using water from a garden hose to rinse away all, the bottom 1/2, or no media prior to planting in May, 1986. Standard fertilizer was applied using recommended rates (6). Treatments were replicated nine times in a randomized complete block. All trees were excavated in Dec. 1986 for root examination and growth measurements. Plant fresh and dry weight, dry weight of new roots, canopy volume, and trunk cross sectional area were measured.

Results and Discussin

Tree size, expressed as trunk cross sectional area, canopy volume, plant fresh and dry weights, total shoot length, calculated leaf area, and dry weight of new roots, was significantly less for container-grown than bare-rooted trees after 8 months of growth in experiment one (Fig. 1, Table 1). Canopy volume was affected most, as container-grown trees were 25% the size of bare-rooted trees (Fig. 1). Size of bare-rooted trees, measured as trunk cross sectional area and canopy volume, remained significantly greater than that of container-grown trees 20 months after planting (Fig. 1). Container-grown trunk cross sectional area averaged 51% and canopy volume 37% of the size of bare-rooted trees.

Bare-rooted trees in experiment two also were significantly larger than container-grown trees after 8 months in the field, as determined by trunk cross sectional area, canopy volume, plant fresh and dry weight, dry weight of new roots, and leaf area (Fig. 2, Table 1). Total shoot length of the tree types was not significantly different, however. Averaged over all measurements, container-grown trees were 68% as large as bare-rooted trees. After 18 months in the field, container-grown trees averaged 86% the size of bare-rooted trees based on trunk cross sectional area and canopy volume.

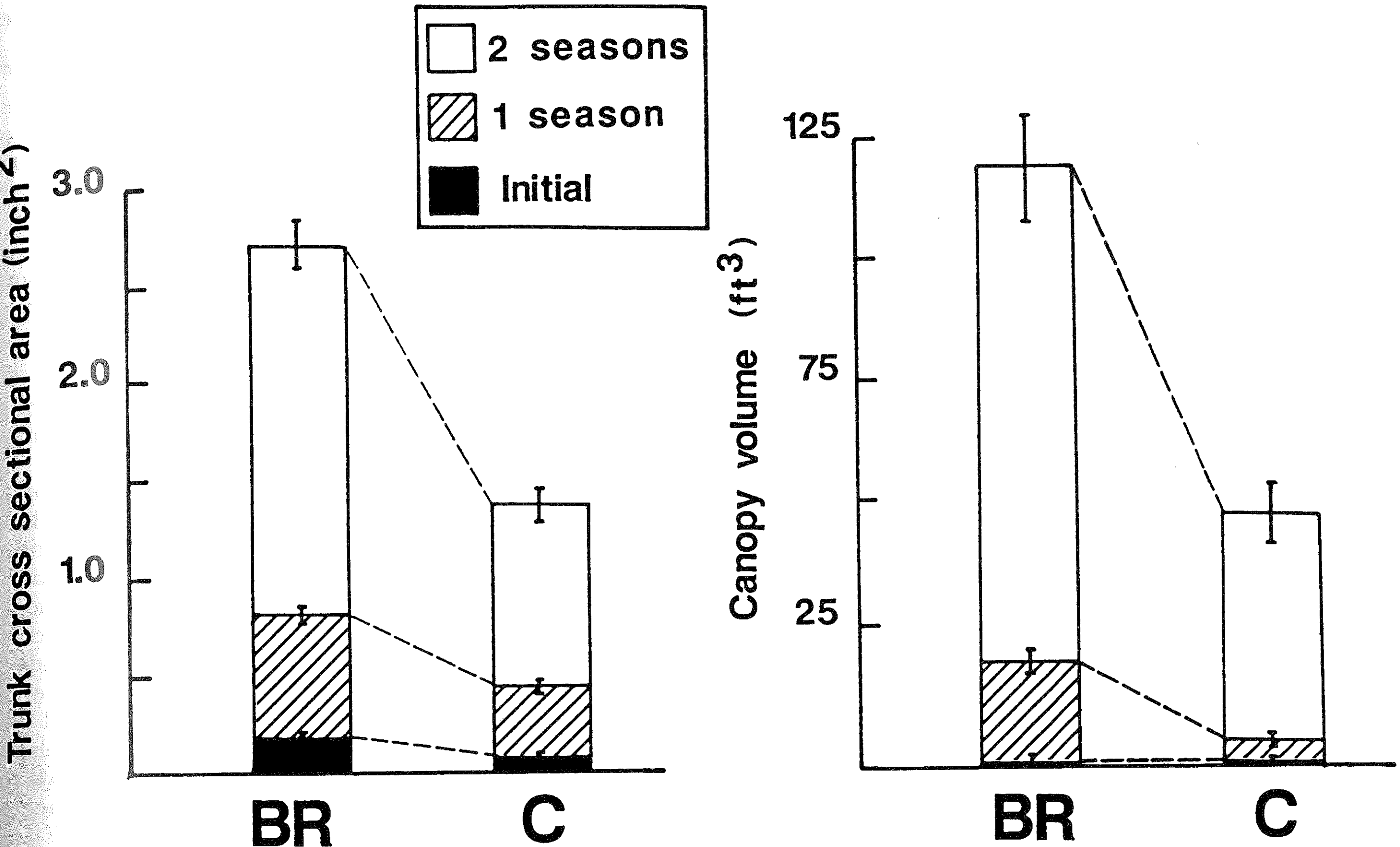

Fig. 1. Effect of 'Hamlin' orange nursery tree type on increase in trunk cross sectional area and canopy volume from May 1985 to Dec. 1986. Bars represent standard errors of means, n = 36. BR = bare-rooted, C = container-grown.

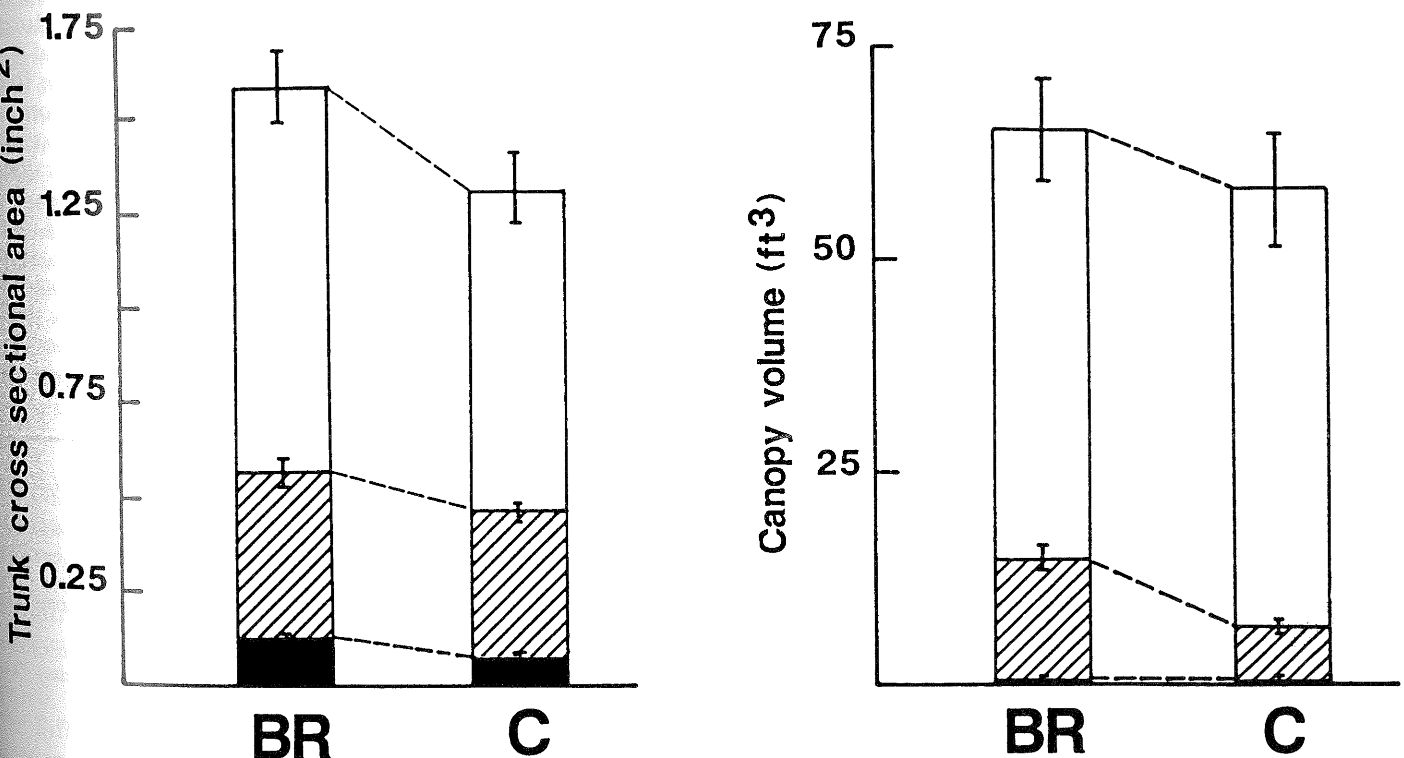

Fig. 2. Effect of 'Hamlin' orange nursery tree type on increase in trunk cross sectional area and canopy volume from May 1986 to Oct. 1987. Bars represent standard errors of means, n = 18. BR = bare-rooted, C = container-grown. Refer to Fig. 1 for legend.

Table 1. Effect of nursery tree type on growth of 'Hamlin' orange trees after 8 months in the field.

Tree type	Fresh wt (lb.)	Dry wt (lb.)	Dry wt new roots (lb.)	Total shoot length (inch)	Leaf area (ft^2)
Expt one (May-Dec. 1985)					
Bare-rooted	4.81	1.68	0.32	415.9	14.95
Container	1.90	0.69	0.12	173.2	1.49
	**	**	**	**	**
Expt two (May-Dec. 1986)					
Bare-rooted	3.41	1.07	0.25	311.8	10.98
Container	2.59	0.80	0.13	241.7	5.87
	*	*	**	ns	*

*, **, ns significant at the 5% and 1% levels or not significant, respectively, by F test. Mean of six trees/treatment.

Table 2. Effect of removing media prior to planting on growth of containerized 'Hamlin' orange plants from May to December 1986.

Amount of container media removed	Fresh wt (lb.)	Dry wt (lb.)	Dry wt new roots (lb.)	Canopy volume (ft^3)	TCA^z (inch^2)
All	3.22	1.04	0.26	13.37	0.48
1/2	3.09	1.00	0.20	8.44	0.49
Control	2.59	0.80	0.13	5.84	0.43
SE^y	0.29	0.09	0.03	2.09	0.03

^{z}Trunk cross sectional area.
^{y}SE = standard error, n = 9.

Webber (15) found that after roguing off-type rootstocks, initial 'Washington' navel orange tree size was not correlated with tree size after 8 years. Similarly, Gardner and Horanic (4) found no relationship between initial and ultimate tree size with 17-year-old 'Parson Brown' and 'Valencia' orange trees. Unfortunately, neither of these reports discuss the influence of initial tree size on precosity and size during the early years of bearing. The data presented here indicate that nursery tree size strongly influences growth of citrus trees during the first 20 months in the field.

Initial size difference may not have been the only factor determining the large difference in growth of bare-rooted and container-grown trees in experiment one. Roots of many container-grown trees after 8 months in the field were limited to a small volume of soil surrounding the media. Container-grown trees in experiment two, however, did not respond similarly in that all excavated trees had root growth greater than two feet beyond the container media. This is not reflected in root dry weight (Table 1), which indicates that initial root extension into field soil may be as important as total root growth. These observations also indicate that initial root growth from newly-planted containerized trees is highly variable from year-to-year or nursery-to-nursery.

Medium removal prior to planting container-grown trees significantly improved tree growth, measured as plant fresh and dry weight, new root dry weight, canopy volume, and trunk cross sectional area (Table 2). Differences between the control and treatment with all medium removed were two-fold or greater for root growth and canopy volume. Studies from California suggest that water movement from field soil to organic media around the roots may be slow (12). This is particularly true as the medium dries and its hydraulic conductivity decreases. In fact, one advantage of a California mix was that it was easily shaken loose prior to planting (11). Drying of container medium after planting due to evapotranspiration, drainage (8), and difficulty in rewetting could lead to increased plant stress and decreased growth. Death of containerized landscape plants has been attributed to these phenomena (3). Survival of container-grown and bare-rooted citrus trees was similar in this study, but slow initial growth occurred for containerized trees and has been observed in other plantings on the same site. Reduced root growth accompanying slow canopy growth may result from maturation of root tips in the dried container media, as has been shown with pine seedlings in dry soils (5).

A second possible explanation for poor initial growth of containerized greenhouse-grown citrus trees is lack of acclimation to field growing conditions prior to planting. Optimum conditions for growth in the greenhouse, combined with little concern for acclimation to field conditions, resulted in poor survival rates for containerized forestry seedlings (14). Potted plants transferred from a shaded, humid environment to full sun typically suffer stress even with optimum soil moisture conditions in the field (7). Moreover, vigor of container-grown ornamental plants frequently declines rapidly following removal from a high liquid N fertilization program (T. H. Yeager, Univ. of Florida, personal communication). The problem is lessened by lowering N rates near the end of the production cycle or by utilizing controlled-release fertilizers instead of a liquid fertilizer program. Acclimation is also promoted by reduced irrigation frequency in the nursery, which lessens water stress and increases root growth after transplanting (13).

Many container-grown citrus trees are being produced and planted throughout Florida with a high degree of success. However, most of these trees are initially smaller than bare-rooted trees and have distinctively different rooting and branching patterns. Moreover, our data suggest that bare-rooted trees will initially grow faster than container-grown trees if compared under the same cultural, edaphic, and environmental conditions. However, differences in initial growth can be minimized by shaking loose some medium from around roots of containerized trees prior to planting. It is also important to choose the largest, healthiest trees initially, whether bare-rooted or containerized, to improve growth for the first two years after planting.

Literature Cited

1. Anonymous. 1972. Potted plants: a plan for tomorrow. Calif. Citrograph 57:435-436.
2. Castle, W. S., W. G. Adams, and R. L. Dilley. 1979. An indoor container system for producing citrus nursery trees in one year from seed. Proc. Fla. Stat Hort. Soc. 92:3-7.
3. Costello, L. and J. L. Paul. 1975. Moisture relations in transplanted container plants. HortScience 10:371-372.
4. Gardner, F. E. and G. E. Horanic. 1959. Relation of citrus nursery tree size from 1/2 to 7/8 inches to ultimate size and production. Proc. Fla. State Hort. Soc. 72:102-105.
5. Kaufmann, M. R. 1968. Water relations of pine seedlings in relation to root and shoot growth. Plant Physiol. 43:281-288.
6. Koo, R. C. J., C. A. Anderson, I. Stewart, D. P. H. Tucker, D. V. Calvert, and H. K. Wutscher. 1984. Recommended fertilizers and nutritional sprays for citrus. Fla. Agr. Expt. Sta. Bul. 536D.

7. Kramer, P. J. and T. T. Kozlowski. 1979. Physiology of woody plants. Academic Press, New York.
8. Marler, T. E., J. J. Ferguson, and F. S. Davies. 1987. Growth of young 'Hamlin' orange trees using standard and controlled-release fertilizers. Proc. Fla. State Hort. Soc. 100:61-64.
9. Moore, P. W. 1966. Propagation and growing citrus nursery trees in containers. Proc. Int. Plant Prop. Soc. 16:54-62.
10. Nelms, L. R. and L. A. Spomer. 1983. Water retention of container soils transplanted into ground beds. HortScience 18:863-866.
11. Platt, R. G. and K. W. Opitz. 1973. Propagation of citrus. p. 1-47. In: W. Reuther (ed.) The citrus industry, Vol. 3. Univ. Calif., Riverside.
12. Richards, S. J., M. K. Harjung, J. E. Warnecke, and W. H. Hillis. 1967. Unique procedures employed in growing lemon trees. Calif. Citrograph 48:96-99.
13. Rook, D. A. 1973. Conditioning radiata pine seedlings to transplanting by restricting watering. N.Z.J. For. Sci. 3:54-59.
14. Tinus, R. W. and P. W. Owston. 1984. Physiology research made forestation with container-grown seedlings successful. p. 143-155. In: M. L. Duryea and G. N. Brown (eds.) Seedling physiology and reforestation success. Martinus Nijhoff, Dordrecht, Netherlands.
15. Webber, H. J. 1932. Variations in citrus seedlings and their relation to rootstock selection. Hilgardia 7(1):1-79.
16. Westwood, M. N. 1978. Temperate zone pomology. W. H. Freeman & Co., New York.

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CITRUS SURVEY AND CITRUS MAPPING MICROCOMPUTER PROGRAMS

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Additional index words. citrus inventory, grove counts, data collection .

Abstract. **Citrus Survey and Citrus Mapping Microcomputer programs are examples of software designed for field use.**

Citrus Survey is a microcomputer program designed to collect tree data in the field and store this information as a computer file. A user can gather any information, including varieties, rootstocks, tree size or tree condition using the laptop microcomputer, TRS-80, Model 100. The field information is printed in two parts: statistical report of the grove and a map of the trees using a companion program, Citrus Mapping.

The Citrus Mapping Program has several options when printing a grove map. First, the map can be printed in the same direction as mapped in the field or the map can be rotated with North at the top of the page. Second, the user may select all of the information used to describe the trees in a grove to be printed or the user may arbitrarily select only portions of the information to be printed. Third, the user can select maps to be printed on 8½ inch or 14 inch paper.

Citrus Survey is written in TRS-80, Model 100 Basic. Citrus Mapping is a microcomputer program written using DOS 3.3 for Apple and MS-DOS for IBM computers or equipment compatible with either of the above.

The techniques of grove mapping and the advantages associated with an up-to-date tree inventory have been described in detail (1, 4). The traditional method was to record tree data on graph paper or a suitable substitute. With the introduction of aerial color infrared photography Blazquez et al. (3) recorded tree data in the field on a clear acetate placed over a photographic enlargement of a grove. Thet mapped random sections of a grove and used the information to verify aerial photo-interpreted maps. Barros et al. further developed this technique by recording tree data in the field with a BASIC program written for a Times/Sinclair 1000 microcomputer (2).

The effort to develop software for grove mapping evolved from a critique by a group of citrus managers of an aerial color infrared (ACIR) photography project of 1000 acres in north-central Polk County. The group consisted of Robert Kerr, Vice President, Grove Care, Harvesting, and Fruit Procurement, Holly Hill Fruit Products, Inc.; Bill Manual, formerly Director of Operations, Haines City Citrus Growers Association; Erroll Fielding, Grove Manager, Orange-Co, Inc.; and John Husted, Production Manager, Waverly Growers Association. They agreed that the ACIR photography project was successful in providing accurate information on tree condition and stress. The group wanted to expand the project to include mapping of trees by variety. An accurate tree count by variety was important to all four organizations because of their fresh fruit markets. To schedule harvesting crews, an estimate of available fruit depended upon an accurate tree count by variety.

In 1983, the author agreed to develop software to collect tree data in the field and the group of four fresh fruit organizations agreed to share the cost of the portable computer and accessories.

Materials and Methods

Grove data was collected in a ground survey with a TRS-80 Model 100 portable computer containing 32 kilo bytes of random access memory (RAM). Other accessories included a Radio Shack computer cassette recorder, computer cassette tapes, a recorder-to-computer cable and RS-232 cable.

The data was transferred to both an Apple II series computer and an IBM compatible Zenith using a RS-232 cable connected to a serial interface card. ASCII Express telecommunications software was used to transfer the data. IBM or IBM compatible computers were equipped with a null connector attached to the RS-232 cable in addition to telecommunications software, such as ASCII Express, Tandy's Desk-mate or Procomm.

The software was written in BASIC and divided into two parts. The data collection or Citrus Survey Program was stored on cassette tape and the data presentation or