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TREE SPACING AFFECTS CITRUS FRUIT DISTRIBUTION AND YIELD[1,2]

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Additional index words. tree density, tree size, harvesting.

Abstract. **Fruit distribution within the canopy and yield per acre were affected by spacing of 'Pineapple' orange [Citrus sinensis (L.) Osb.] trees during 5 seasons. Trees were 18 yr old at the beginning of the study and involved spacings of 20 x 25 ft, 15 x 20 ft, and 10 x 15 ft. Fruit distribution was determined by harvesting individually 4 ft zones vertically through the tree and by harvesting inside and outside fruit separately. A greater percentage of fruit was found in the upper parts of the tree at closer spacings. More inside fruit occurred on trees at wider spacings. Higher yields were obtained from trees at closer spacings in this experiment.**

Tree spacing has become a very important consideration in citrus plantings. Generally, closer planted trees result in earlier net returns, but at the expense of earlier developing management problems. Growers want early net returns on their investment and maximum returns over the productive life of the planting. Selection of tree spacing to achieve these ends is complex and many of the considerations have been discussed elsewhere (1, 2, 3, 4, 5, 6, 7, 8).

Fruit distribution on the tree is important from the harvesting standpoint. For a given fruit density, fruit within 7 to 8 ft of the ground can be harvested without a ladder and can be harvested faster and easier than fruit more than 8 ft from the ground. Fruit within arm's reach of the outer tree canopy can usually be harvested at an easier and faster rate (fruit/hr) than fruit further inside the canopy because outer fruit is easier to reach and the fruit density (number of fruit per unit volume of canopy space) is generally higher.

The objective of this paper is to report on the effect of 3 different tree spacings on fruit distribution and yield.

Materials and Methods

'Pineapple' orange trees on rough lemon (*Citrus jambhiri* Lush.) rootstock were planted in 1960 at spacings of 20 x 25 ft, 15 x 20 ft, and 10 x 15 ft at the Citrus Research and Education Center grove at Barnum City in Central Florida. These spacings are equivalent to 87, 145, and 290 trees per acre, respectively. The trees were frozen back to the soil banks in 1962, and the first season of recorded fruit production was 1967-68. Annual hedging was started in 1966 in the 10 x 15 ft spacing and 1971 in the 15 x 20 ft spacing. The hedging width between tree rows was a nominal 7 ft near ground level and increased approximately 1 ft per 4 ft of height. Little foliage has been removed from the trees in the 20 x 25 ft spacing. In the 10 x 15 ft spacing, every fifth tree was removed in the row (10 ft spacing) in 1975 to form 4-tree units, resulting in 232 trees per acre. Cultural practices including overhead irrigation were performed uniformly in all tree spacings (3).

Fruit distribution and yields were determined on the 3 tree spacings during five seasons, 1978-79 through 1982-83. These were the 12th through 16th seasons of fruit production. When the fruit was harvested, it was separated by height zones on the tree: 0 to 4 ft, 4 to 8 ft, 8 to 12 ft, and greater than 12 ft above ground. Further, within each height zone, fruit harvested beyond an arm's reach (approximately 3 ft) of the outside canopy was designated as inside fruit.

Four trees (4 replications) each were harvested each season at the 20 x 25 ft and 15 x 20 ft spacings. In the 10 x 15 ft spacings, 4 replications of the 4-tree units were harvested. Within each 4-tree unit, fruit records from the 2 center trees (hedgerow) were kept separate from the 2 end trees adjacent to the space resulting from the tree removal in 1975. It was assumed for this paper that the 2 center trees represented solid hedgerow trees (290 trees per acre); the 2 end trees represented a 10 x 15 ft planting with every third tree in the row removed resulting in 194 trees per acre.

Fruit yields were determined by weighing. Tree canopy height and width measurements were made in 1978-79, 1981-82, and 1982-83. Canopy width measurements were made approximately 4 ft above ground on the east-west (across row) and north-south (in row) directions.

Results and Discussion

In the 20 x 25 ft spacing, the tree height averaged 14.8 ft high and the canopy diameter averaged 17.5 ft in both north-south and east-west directions. Fruit distribution in the first 3 seasons was fairly uniform at 25% to 35% in each of the 3 bottom zones (Fig. 1). In the last 2 seasons, fruit in the 8 to 12 ft zone had increased to 39% and 44%, respectively. Fruit above 12 ft high had increased to 27% of the total by the last season. Inside fruit fluctuated from 19% the first season to 26% the fourth season, then down to 7% the last season. Over the 5 seasons, outside fruit averaged 86% of the total.

Trees in the 15 x 20 ft spacing averaged 14.5 ft in height and the canopy width dimensions averaged 15 ft in the north-south and 14.3 ft in the east-west directions. Vertical fruit distribution was more variable than in the 20 x 25 ft spacing (Fig. 2). One possible reason for this was that hedging removed more tree canopy in the 15 x 20 ft spacing. During the 5 seasons, outside fruit averaged 87% of the total, with a range from 79% to 93%. There was no apparent reason for the high percentage (55%) of fruit in the 0 to 4 ft zone in 1982-83.

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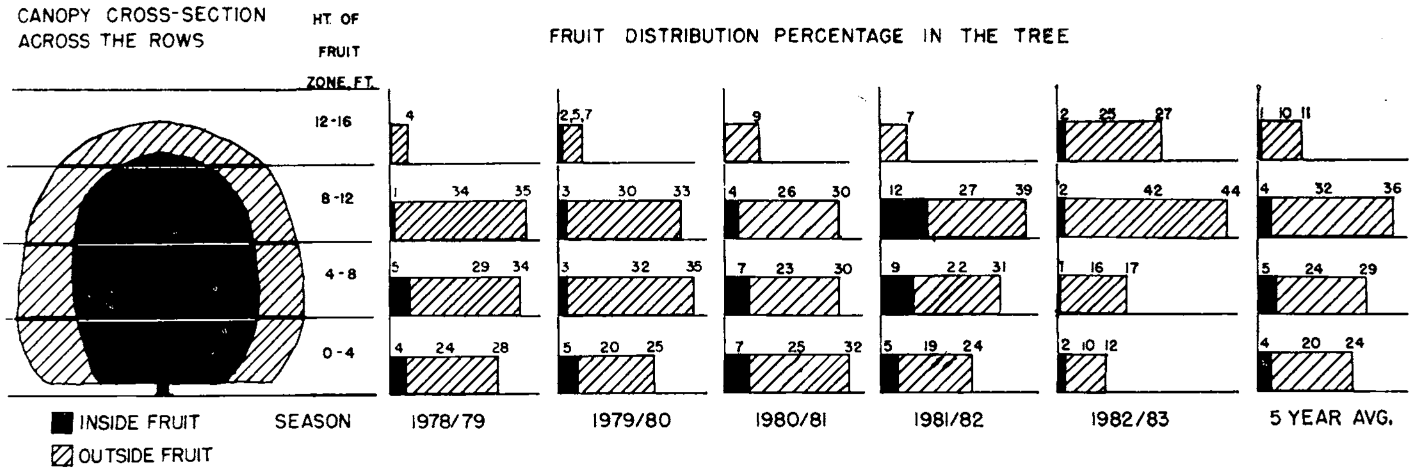

Fig. 1. Fruit distribution of 'Pineapple' orange trees on 20 x 25 ft spacing. Numbers above each bar are, left to right, percentage fruit inside, outside, total, in each height zone.

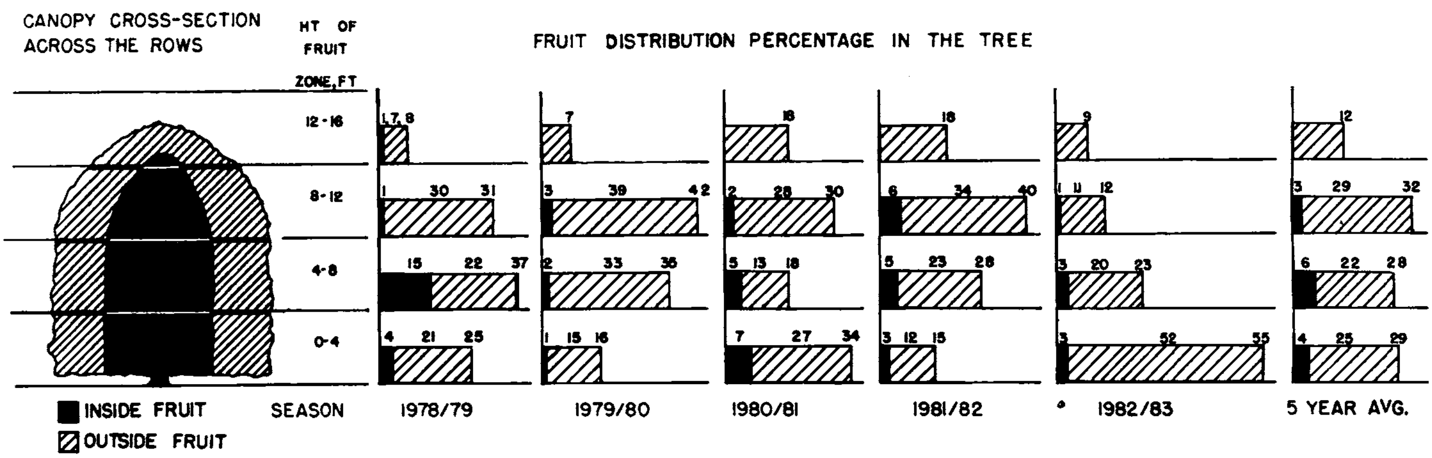

Fig. 2. Fruit distribution of 'Pineapple' orange trees on 15 x 20 ft spacing. Numbers above each bar are, left to right, percentage fruit inside, outside, total, in each height zone.

In the 10 x 15 ft spacing, all fruit was designated as outside fruit (Fig. 3) because little or no fruit existed inside the canopy beyond arm's reach. These trees were considerably wider at lower heights than at the upper heights because of the hedging angle. A small percentage of the fruit was harvested at the lower heights (greater tree canopy widths); conversely, a high percentage of fruit was harvested at the upper heights (smaller tree canopy widths) where essentially all of the fruit was within arm's reach.

Trees in the 10 x 15 ft spacing averaged about 16 ft high. By 1978-79, tree canopies in the hedgerow had achieved their maximum widths, being confined by crowding at 10 ft in the north-south direction and by hedging at 9 ft in the east-west direction. The 2 bottom zones consistently had similar amounts of fruit, but less than the 2 top zones. Four of 5 seasons, the top zone had the most fruit. Overall, 71% of the fruit was higher than 8 ft and 42% was above 12 ft. Hedging probably limited fruit production in the 2 bottom zones. Shading was also a major factor. For closer spaced trees, Boswell et al. (2) measured less light at

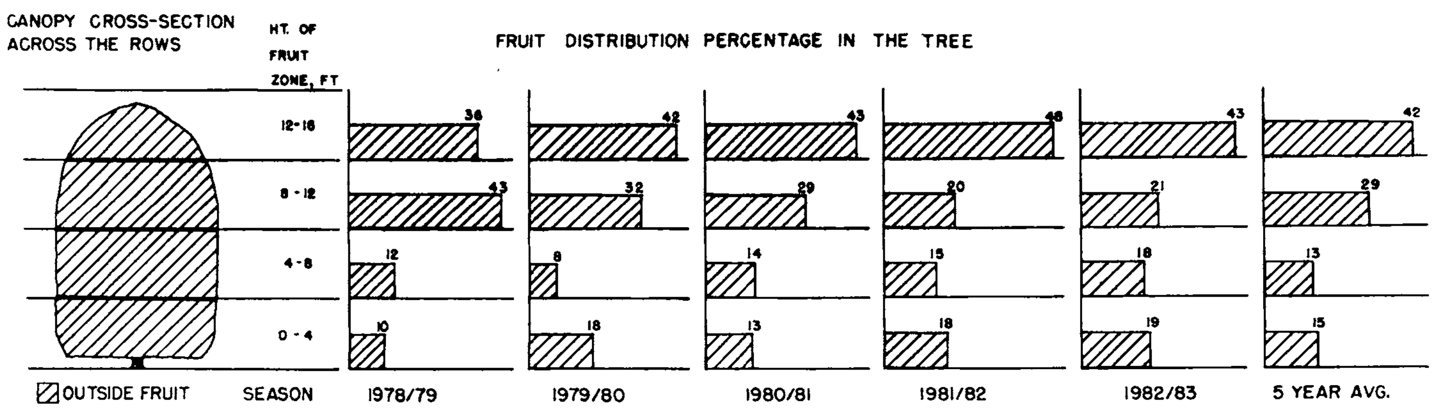

Fig. 3. Fruit distribution of 'Pineapple' orange trees on 10 x 15 ft spacing. Numbers above each bar are the percent fruit in each height zone.

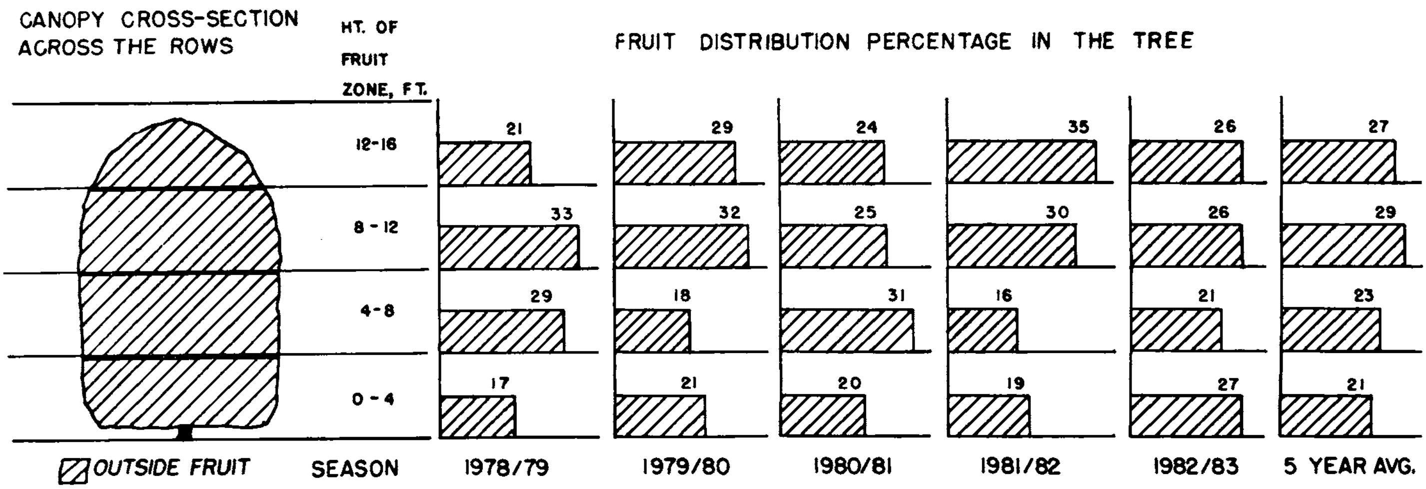

Fig. 4. Fruit distribution of 'Pineapple' orange trees in 2-tree units (end trees) in 10 x 15 ft planting. Numbers on each bar are the percentage fruit in each height zone.

approximately 5 ft above ground at the center between tree rows than for wider spaced trees. Fruit production, however, was not measured with respect to light reception in their study.

The end trees of the 4-tree units (equivalent to 194 trees per acre) in the 10 x 15 ft planting averaged 16.1 ft high. The north-south and east-west canopy dimensions averaged 12.7 ft and 9.1 ft, respectively. Fruit distribution was more uniform than any of those presented above (Fig. 4). The overall average indicated a range in percentage points of only 8% among fruit zones, with a low of 21% at the 0 to 4 ft zone and a high of 29% in the 8 to 12 ft zone.

The overall yield average for the 5 seasons was highest for the 10 x 15 ft hedgerow and lowest for the 20 x 25 ft spacings (Table 1). One reason for the lower average yields at the wider spacings was the lower yields for the last 2 seasons, especially the last season.

Table 1. Fruit yields of 'Pineapple' oranges at 4 tree densities.

	Tree Spacing (ft)			
	20 x 25	15 x 20	10 x 15	
			Hedgerow	2-Tree units[z]
	Trees/acre			
	87	145	290	194
Season	Fruit yield (boxes/acre)			
1978-79	636	767	711	620
1979-80	721	796	540	493
1980-81	422	510	493	497
1981-82	461	537	609	543
1982-83	270	290	754	737
5-Season average	502	580	621	578

[z]Formed by removing every third tree in 10 x 15 ft planting.

Reduced yields in the wider tree spacings may have resulted from greater tree damage during the 1981 and 1982 freezes. Subjective ratings done on the trees after the 1981 freeze indicated the 2 wider spacings were defoliated more than the 10 x 15 ft hedgerow. The continuous canopy of the 10 x 15 ft spacing may trap ground radiation and provide some protection during radiation freezes. Boswell et al. (2) reported slightly warmer minimum temperatures in closer-spaced citrus plantings during 3 winter months.

In yield records from the same grove (different trees), Koo and Muraro (3) showed the 10 x 15 ft hedgerow yielded less than the 2 wider spacings in their last 5 seasons of records. However, their 5 seasons commenced 1 year earlier than the data in this paper. Cumulative yields during the first 15 seasons for the 10 x 15 ft hedgerow were 37% and 6% higher than those for the 20 x 25 ft and 15 x 20 ft spacings, respectively (3).

The difficulty of harvesting seems greatest in the 10 x 15 ft hedgerow. First, an average of 71% of the fruit was above the 8 ft height. Second, placement of the pallet box or tub would be very difficult using conventional fruit handling equipment. Ladder movement across rows would also be difficult. Essentially no inside fruit and higher yields are advantages of the closely spaced planting.

In the case where every third tree was removed in the 10 x 15 ft hedgerow, the fruit distribution was shifted downward (Fig. 3) similar to that of the wider spacings. Space provided by the removed tree would be available for container placement until the trees filled it with foliage. Fruit above the 8 ft height averaged 56% of the total.

At the 2 wider spacings, container placement was not a particular problem, although the 15 x 20 ft trees are now growing together in the row. Fruit above 8 ft high averaged 47% and 44% in the 20 x 25 ft and 15 x 20 ft spacings, respectively. Both of these spacings averaged 14% to 13% inside fruit, respectively.

Summary

In the 12th through 16th seasons of fruit production in 'Pineapple' oranges, 10 x 15 ft hedgerow trees produced higher average yields than trees on 15 x 20 or 20 x 25 ft spacings. Fruit above 8 ft high averaged 71% of the total in the 10 x 15 ft hedgerow, whereas the 2 wider spacings had 44% to 47% above that height. The 10 x 15 ft hedgerow had essentially no inside fruit while the 2 wider spaces averaged about 14%. Placement of fruit containers and movement of ladders across the row as is done in many conventional harvesting operations would be difficult in the 10 x 15 ft hedgerow.

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ORANGE REMOVAL WITH TRUNK SHAKERS[1,2,3]

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Abstract. **'Hamlin' and 'Valencia' oranges** [Citrus sinensis **(L.)** Osb.] **were removed with trunk shakers for the past 4 seasons in replicated field experiments near LaBelle. Two modes of conventional trunk shaking were compared with two modes of linear trunk shaking, with and without abscission chemicals. Fruit removal efficiency and yield data were collected on individual trees. Handpicked checks were included for yield comparisons. In 'Hamlin' oranges, neither abscission chemicals or shakers affected fruit yields. Abscission chemicals increased the fruit removal efficiency of the shakers an average of 23 percentage points from 65 to 88%. In 'Valencia' oranges, fruit yields of trees with and without abscission chemicals were 3.1 and 3.3 boxes/tree, respectively. The fruit yield averages of the shaken trees and handpicked trees were 3.1 and 3.5 boxes/tree, respectively. Abscission chemicals increased fruit removal efficiency of the shakers an average of 14 percentage points from 76 to 90%.**

Mass removal of various deciduous fruits and nuts by means of trunk shakers has been a reality for many years (1). However, application of this technique to harvesting citrus has been difficult because of poor fruit removal, bark damage, and lack of adequate tree trunk area for shaker clamp attachment in a large percentage of Florida groves (2). Previous citrus harvesting experiments with a multi-directional trunk shaker achieved 98% fruit removal in 'Queen' oranges and 86% removal in 'Valencia' oranges with the abscission chemical 5-chloro-3-methyl-4-nitro-IH-pyrazole (Release) (5). Subsequent fruit yields were reduced 15% from the effects of shaker action and abscission chemical. However, the potential for shaking a tree with a single attachment point, the advent of improved abscission chemicals for fruit loosening, and an increase in tree numbers of a size and shape adaptable for trunk shaking make this fruit removal method look increasingly attractive.

The objectives of the experiments described in this paper were to determine fruit removal efficiencies and subsequent yield effects of 4 modes of trunk shaking.

Methods and Equipment

Two identical harvest experiments were designed to collect performance data on trunk shaking 'Hamlin' oranges and 'Valencia' oranges at a location in South Florida. Initially, trees in each experiment were 15 and 8 yr old, respectively, uniform in size and density, with adequate trunk height for grasping with the shakers. These trees were representative of many younger plantings on flatwoods soils in South Florida. Each experiment was a randomized, split-plot design which included 60 trees and 6 replications. One of the two 5-tree main plots in each replication was randomly assigned to be sprayed with abscission chemicals before harvest while the other main plot was not sprayed. Within each main plot, 4 shaker and 1 handpicked check treatment were randomly assigned to each tree.

The trunk shaker and check treatments were as follows:

1. Linear shaker with 133 lb. of unbalanced mass rotating at 6 revolutions/sec with 5.5 inches eccentricity and 1010 lb. of total mass excluding the unbalanced mass.
2. Linear shaker with 200 lb. of unbalanced mass rotating at 5 revolutions/sec with 5.5 inches eccentricity and 600 lb. total mass excluding the unbalanced mass.
3. Multi-directional shaker with two 68 lb. unbalanced masses rotating at 12 revolutions/sec with 4.5 inches eccentricity rotating in opposite directions at slightly different speeds and 992 lb. of total mass, excluding the unbalanced masses.
4. Same shaker as 3 except both eccentric masses rotated in the same direction.
5. Handpicked (check).

Treatments 1 and 2 were conducted with the linear shaker (Fig. 1) with theoretical shaking amplitudes of 0.7 and 1.8 inches, respectively, under no-load conditions. Treatments 3 and 4 were conducted with a commercially available multi-directional shaker with a theoretical shaking amplitude of 0.6 inches (Fig. 1) (3).

Four to 5 days prior to harvest, main plots receiving abscission chemicals were treated in an amount dependent upon fruit and tree condition and cultivar. The normal abscission mixture was 75 ppm Release, 1.5 ppm cycloheximide (Acti-aid), and 0.1% Ortho X-77 surfactant applied at the rate of 4 gal of mix per tree.

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[2]Cooperative research by the U.S. Department of Agriculture, Agricultural Research Service, University of Florida, Citrus Research and Education Center, Lake Alfred, and the Florida Department of Citrus.
[3]Trade names and company names are used in the publication solely for the purpose of providing specific information. Their mention does not constitute a guarantee or warranty of a product by the U.S. Department of Agriculture.