Citrus Tree Size Management Affects Fruit Yields and Mechanical Harvesting Efficiency

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ABSTRACT

THE effects of removing (thinning), crosshedging, and topping hedgerow trees were investigated as tree size management practices when harvested by hand and mechanical methods. Overall, compared with the hedgerow, tree removal reduced fruit yields only the 1st year whereas crosshedging reduced fruit yields 7% to 14% over all years. Annual tree topping reduced fruit yields an average of 20%. The efficiency of fruit removal for air and trunk shakers averaged 90% and were not generally affected by tree size management practices. Compared with hand harvest, the air and trunk shakers reduced fruit yields 15 and 8%, respectively.

INTRODUCTION

Most Florida orange trees over 30 yr of age are spaced 7.6 m × 7.6 m or greater. However, in the last three decades, many trees have been set closer than 7.6 m in-row in higher density plantings to achieve higher fruit production per ha (Tucker and Wheaton, 1978). The following questions arose about the management of these plantings when the tree canopies began to compete for available space in-row (Phillips, 1978): (a) should the trees in-row be maintained as individual or multiple units by pruning (crosshedging), (b) should some of them be removed or (c) should they be allowed to grow together in a hedgerow and should tree height be controlled by topping? With conventional hand harvesting, short trees are preferred and frequent in-row spaces are needed for placement of fruit containers and cross-row movement of ladders, containers, and pickers (Whitney and Hedden, 1978). The efficiency of mechanical harvesting systems may vary with different in-row and tree height management practices.

The objective of the studies reported in this paper was to determine the effect of several tree size management practices and harvesting methods on fruit yields and mechanical harvesting efficiency.

MATERIALS AND METHODS

Twelve studies involving different combinations of three tree size management practices - crosshedging, topping, and tree removal - and two harvesting methods (mechanical and hand) were initiated in the 1979-80 season (see Table 1). The trees in the four grove sites selected for these studies ranged in age from 7 to 28 yr and the sites were located throughout the citrus producing area of Florida with the furthermost sites, 1 and 4, being separated by 260 km. The between-row spacing at all sites was 7.6 m and the aisle or middle for equipment movement was maintained at a normal 2 m width. The in-row tree spacing ranged from 2.7 to 5.3 m.

Management practices were arranged in a randomized complete block design and the plots were split for the harvesting practices.

Tree Removal

Trees were removed in Studies 1 and 10 by cutting the trunk at ground level. In Study 1 (Table 1), 90 trees were used in five replications and yields were taken from three trees in each plot. The original 3.0 m in-row planting was a hedgerow with 429 trees/ha (T/ha) and was compared to removing every other tree (1-tree unit, 214 T/ha) and removing every 4th tree (3-tree unit, 322 T/ha). The two harvesting treatments were air shaker and hand.

In Study 10, the original 2.7 m in-row planting (hedgerow, 476 T/ha) was compared to removing every 5th tree (4-tree unit, 381 T/ha) on 24 trees. The fruit was hand harvested from 2-tree plots in six replications.

Crosshedging

Crosshedging (pruning between adjacent trees in the row) involved removing a straight-side envelope of tree foliage which was 1.2 m wide at ground level and increased in width with height at a 10-deg angle on each side of the envelope. In Studies 3, 4, 5, 7, 11, and 12, a continuous hedgerow system was compared with two crosshedging practices of (a) maintaining single-tree units by crosshedging opposite tree sides in the row biennially and (b) maintaining double-tree units by crosshedging biennially on opposite sides. Hand and mechanical harvesting were compared in all studies except Study 3, in which case only hand harvesting was used. All measurements were made on 2-tree plots with five to eight replications.

Tree Topping

Trees were topped annually to control tree height. Some trees were flat topped while others were topped as a gable roof profile with a 15-deg slope on each side. In the latter case, the reference height was at the apex.

Hedgerow plantings maintained at different heights were compared in Studies 6, 8, and 9. Tree heights of 4.3 m and 5.2 m were compared in Studies 6 and 8, each with seven replications of 2-tree plots. All harvesting was with the air shaker. In Study 9, the air shaker and hand harvesting were compared among gable-topped trees at 3.7 m, 4.6 m, and 5.5 m in height. Six replications of

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TABLE 1. SCHEDULE OF TREE SIZE MANAGEMENT — CITRUS HARVESTING STUDIES INITIATED IN THE 1979-80 SEASON.

Site no.	Location	Citrus area	Orange cultivar	In-row tree spacing m	Tree age In 1979, yr	Study no. and descirption
1	Mt. Dora	North ridge	Parson Brown	3	14	1 — tree removal; air shaker and hand harvest
						2 — crosshedge and flat top; air shaker and hand harvest
				4.6	14	3 — crosshedge; hand harvest
			Valencia	4.6	28	4 — crosshedge; air shaker and hand harvest
2	32 km north of Lake Alfred	Central ridge	Pineapple	5.3	25	5 — crosshedge; air shaker and hand harvest
						6 — flat top; air shaker
			Valencia	5.3	25	7 — crosshedge; air shaker and hand harvest
						8 — top; air shaker
3	Lucerne Park	Central ridge	Hamlin	2.7	12	9 — gable top; air shaker and hand harvest
						10 — tree removal; hand harvest
4	LaBelle	South Flatwoods	Hamlin	4.6	14	11 — crosshedge; air shaker, trunk shaker, hand harvest
			Valencia	4.6	7	12 — crosshedge; air shaker, trunk shaker, hand harvest

Between row tree spacing = 7.6 m. Abscission chemicals were applied to the mechanically (air and trunk shaker) harvested trees prior to harvest, except when excessive freeze damage made it inadvisable.

2-tree plots were used.

Tree Topping and Crosshedging

Study 2 considered trees flat-topped at 4.6 m vs. 5.5 m high, hedgerow vs. crosshedging in single-tree units, and hand vs. air shaker harvesting. Crosshedging in single-tree units in this study was accomplished by pruning any given tree space every third year. There were three replications of 3-tree plots.

Harvest Methods

Mechanical and hand harvesting methods were compared in all except Studies 6, 8, 10, in which only one of the methods was used. Fruit was removed mechanically with an air shaker with center pivot plates (Whitney, 1978) or with the FMC* Model 4000 trunk shaker with the 729 shaker head (two eccentric masses, 31 kg each). Actual shaking time per tree varied from 3 to 7 s with the trunk shaker and from 10 to 40 s with the air shaker, depending on degree of fruit loosening and operator judgment. Abscission chemicals were applied with standard air blast sprayers prior to harvest to trees designated for mechanical harvesting, except where freeze damage to the trees was judged as severe. Mixtures of RELEASE* (5-chloro-3-methyl-4-nitro-pyrazole) and ACTI-AID* (cycloheximide) were usually applied to early and midseason oranges. Only RELEASE was applied to late (Valencia) oranges. At harvest time, fruit on the mechanically harvested trees were shaken to the ground, picked up, and placed in a container for weighing. Fruit remaining on the trees were later picked and weighed to determine the total fruit yield and the percentage fruit removal by mechanical harvesting method.

*Trade names and company names are used in this publication solely for providing specific information and do not imply endorsement by the University of Florida or other agencies over other products not mentioned.

RESULTS

Fruit yield and shaker fruit removal efficiency results for three seasons are presented in the form of bar graphs (Figs. 1 to 12). Fruit yield is presented as a function of tree management practices (averaged over harvest methods) and as a function of harvest methods (averaged over management practices) because interactions were usually not significant. The fruit yields are shown in t/ha (metric tons/hectare) and were calculated from plot yields and number of plots per ha.

While tree management practices could have affected fruit yield results for all three seasons, harvest methods (hand vs. shaker) should have only affected the fruit yield results for the last two seasons.

Fruit removals by shakers are presented as functions of the tree management practices. Severe freezes in January 1981 and 1982 had considerable effect on both yield and removal results.

All of the data were statistically analyzed. Statements

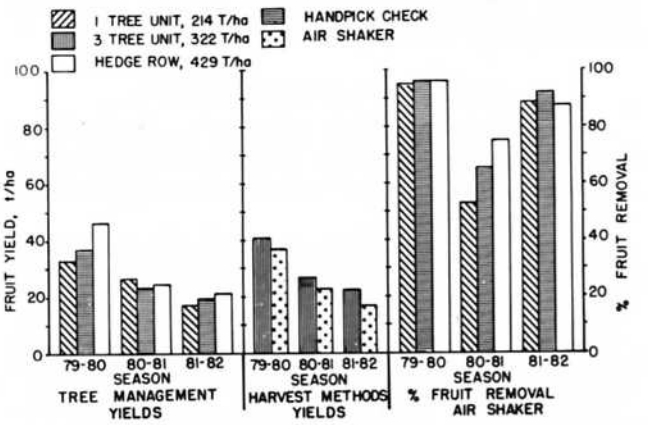

Fig. 1—Effects of tree removal and harvest methods on fruit yields and removal efficiency, Study 1, Parson Brown oranges. T/ha is the number of trees/hectare.

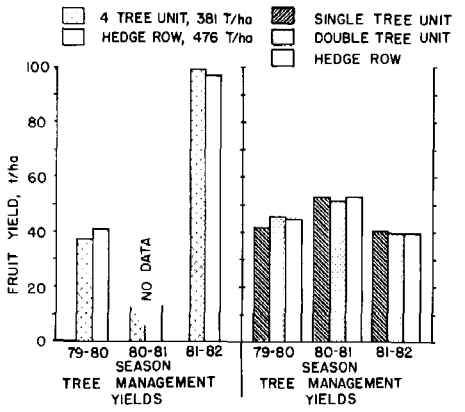

Fig. 2—(Left). Effects of tree removal on fruit yields, Study 10, Hamlin oranges. T/ha is number of trees/hectare.

Fig. 3—(Right). Effect of crosshedging on fruit yields, Study 3, Parson Brown oranges.

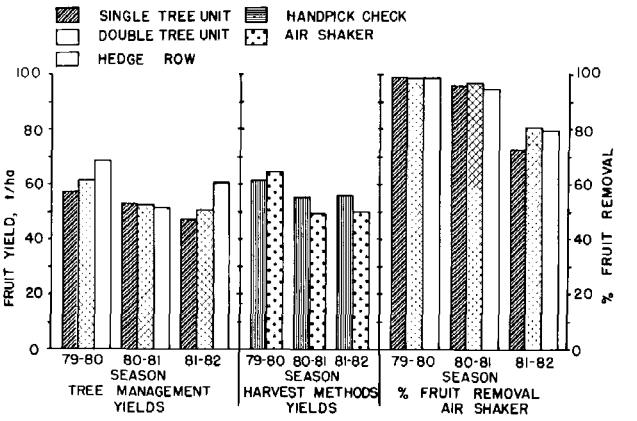

Fig. 4—Effects of crosshedging and harvest methods on fruit yields and removal efficiency, Study 5, Pineapple oranges.

made about significant differences refer to the statistical F test at the 0.05 level.

Tree Removal

In Study 1, tree removal significantly reduced fruit yields compared with the original hedgerow planting for the first season (see tree management yields, Fig. 1). In Fig. 1, as well as Fig. 2, trees per hectare corresponding to the various tree management practices are abbreviated as T/ha. By the last two seasons, however, yields of all tree management practices were not different. The January 1981 freeze defoliated many of the trees in the study, and markedly reduced the yields for the 1980-81 and 1981-82 seasons.

Yield of the trees harvested with the air shaker was significantly less (about 20%) than that of the hand picked trees for the 1980-81 and 1981-82 seasons (see harvest method yields, Fig. 1). However the yield for the 1979-80 season (when there should have been no method effect) was 11% less for the air shaker plots.

Fruit removal by the air shaker (right side, Fig. 1) was not affected by tree removal, except for the 1980-81 season. No abscission chemical was applied that season because of freeze damage to the trees. Higher removals for the hedgerow and 3-tree units probably resulted because these trees generally had more leaves (more air drag) and less mass of fruit per unit canopy volume, than did the 1-tree units.

In Study 10, removing every 5th tree provided fruit yields comparable to the original hedgerow planting (Fig. 2). Data were lost for the 2nd (1980-81) season, but the overall fruit crop appeared to be less than either of the other two seasons. All trees were handpicked.

Crosshedging

For discussion purposes, early and midseason oranges will be separated from late or Valencia oranges in this section.

Early and midseason oranges - In Study 3, the fruit yields were not affected significantly by either of the two crosshedging treatments when compared to the hedgerow (Fig. 3).

In Study 5, crosshedging into single- or double tree units singificantly reduced fruit yields in the 1979-80 and 1981-82 seasons (Fig. 4). Substantial freeze damage occurred prior to harvest the last two seasons, but did not drastically reduce yields.

The reduction of yields by the air shaker (compared with handpicking) was approximately 10% and significant only for the 1980-81 season. Abscission chemicals were not used with the air shaker during the last two seasons because of freeze damage.

Fruit removal by the air shaker was not significantly affected by crosshedging treatments. Removal efficiency in the 1981-82 season averaged only 78% because the trees were severely defoliated, much of the fruit had high attachment strengths, and no abscission chemical was applied.

In Study 11, crosshedging in single-tree units significantly reduced fruit yields for all three seasons, and reductions by double-tree units were significant the 1st and 3rd seasons (Fig. 5). Overall, the crosshedging treatments reduced fruit yields by 15%.

Fruit yield reductions by the air shaker were significant only for the 1980-81 season, whereas the trunk shaker did not reduce yields in either of the last two seasons. No obvious explanation was apparent for the different response to the two shakers.

Fruit removal was comparable for the two shaker methods except for the last season when the air shaker provided significantly higher fruit removal.

Valencia oranges - In Study 4, significant reductions in yields were associated with the single-tree unit for all seasons and for the double-tree unit in the 1980-81 season (Fig. 6). The air shaker significantly reduced fruit yields for the 1980-81 and 1981-82 seasons by 30% and

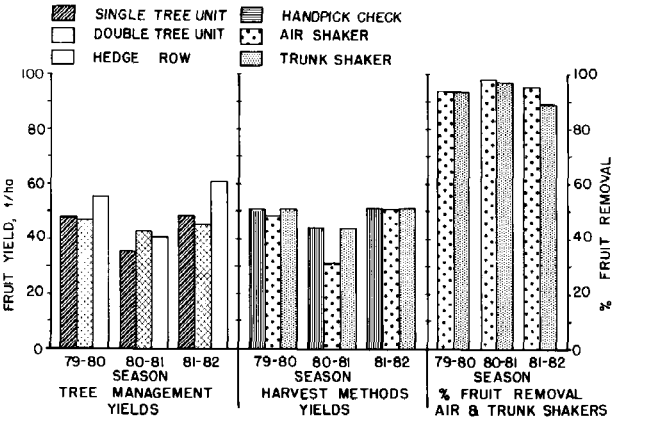

Fig. 5—Effects of crosshedging and harvest methods on fruit yields and removal efficiency, Study 11, Hamlin oranges.

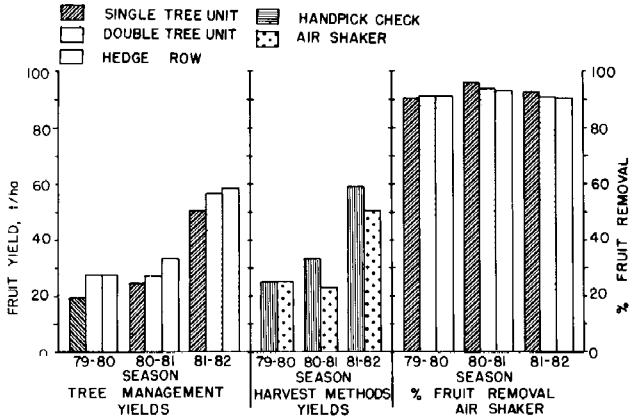

Fig. 6—Effects of crosshedging and harvest methods on fruit yields and removal efficiency, Study 4, Valencia oranges.

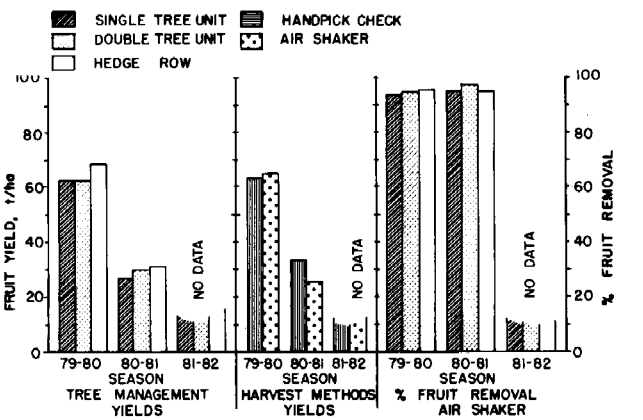

Fig. 7—Effects of crosshedging and harvest methods on fruit yields and removal efficiency, Study 7, Valencia oranges.

15%, respectively. Young fruit size at the time of the 1979-80 and 1980-81 harvests was approximately 1 to 2 cm in diameter.

In Study 7, fruit yields were significantly reduced by the single-tree unit for the 1st and 2nd season and for the double-tree unit the 1st season (Fig. 7). The air shaker reduced yields by about 25% for crosshedging treatments.

In Study 12, fruit yields were not affected by crosshedging in the first two seasons because the trees were young, not crowding in-row, and were pruned little by the crosshedging treatments (Fig. 8). In the 3rd season, however, crosshedging resulted in significant yield reductions.

The air and trunk shaker harvest methods significantly reduced yields an average of 29% and 15%, respectively, for the last two seasons. In the 1979-80 season when there should have been no harvest method effect, air shaker yields averaged 9% less than those of the handpick check and trunk shaker. The reasons for greater reductions with air shaker were not apparent. Young fruit diameter was approximately 1 cm at the 1979-80 harvest and just emerging from the bloom period at the 1980-81 harvest. Fruit removals for both shaker harvest methods were similar except for the last season when fruit removal with the air shaker was significantly higher than the trunk shaker.

Tree Topping

The first topping in the early and midseason oranges (Study 6) in 1979 removed very little foliage at the 5.2 m height, while foliage was removed from all trees at 4.3 m height. There was a significant difference in fruit yield between the two heights in the 1979-80 and 1981-82 seasons (Fig. 9). Freeze damage to the trees was quite severe prior to the harvests of the last two seasons. Fruit removal by the air shaker was not affected by topping height. Abscission chemicals were not applied the last two seasons because of the freeze damage.

In Study 9, the trees were approximately 6 m in height when they were initially topped in 1979. In the 1979-80 season, the reductions in fruit yield were related to the amount of foliage removed from the tree tops (Fig. 10). Compared to the 5.5 m topping height, the reductions in yield for the 4.6 m and 3.7 m heights, 36% and 64%, respectively, were significant. Data were lost for the 1980-81 season, but the fruit crop appeared to be noticeably less than that of the 1979-80 season. By the 1981-82 season, the trees had adjusted somewhat to the topping heights, but topping at 3.7 m and 4.6 m still significantly reduced yield compared to the 5.5 m height.

The air shaker significantly reduced fruit yield by 23% in the 1981-82 season. Again, however, the initial (1979-80) yields were also significantly less by 14% for the air shaker. It is possible that the initial difference in yield may represent the difficulty encountered in trying to obtain accurate yield data on 2-tree plots in a well-developed hedgerow with a 3 m in-row spacing.

Percent fruit removals of the air shaker were not affected by tree height in the 1979-80 season; however, in the 1981-82 season, removal at the 5.5 m height was significantly less than at 4.6 m.

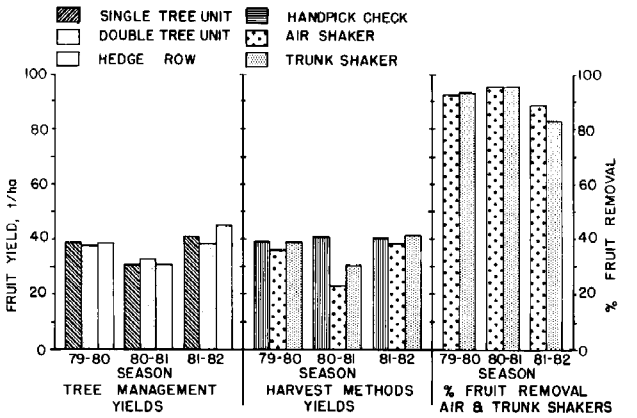

Fig. 8—Effects of crosshedging and harvest methods on fruit yields and removal efficiency, Study 12, Valencia oranges.

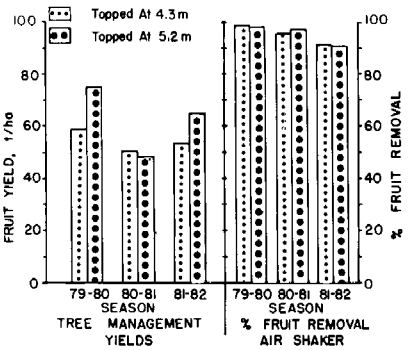

Fig. 9—Effects on topping on fruit yields and removal efficiency, Study 6, Pineapple oranges.

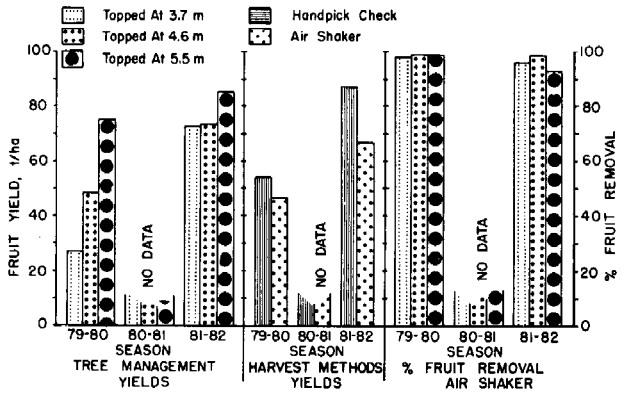

Fig. 10—Effects of topping and harvest methods on fruit yields and removal efficiency, Study 9, Hamlin oranges.

Initial tree height before topping in Valencia oranges (Study 8) was approximately the same as for Study 6 above. There was a significant difference in fruit yield between the 4.3 m and 5.2 m topping height for the 1st season, but not the second season (Fig. 11). Average yield dropped drastically for the second season because of severe freeze damage. No data were obtained for the 3rd season.

Fruit removal by the air shaker was not affected by tree height. Fruit removals were considerably better the 2nd season than the 1st because fruit loosening was much better with the abscission chemical.

Tree Topping and Crosshedging

Study 2 - The initial tree height before topping in this experiment varied from 4 m to 6 m. Overall, the fruit yield of trees topped at 4.6 m and 5.5 m was not significantly different (Fig. 12). Crosshedging reduced yield significantly when compared to the hedgerow for the 1st and 2nd seasons. The air shaker yields were significantly less than those of the check for only the 1979-80 season, when harvest method should not have had an effect.

Fruit removals by the air shaker were not significantly affected by topping height or crosshedging.

DISCUSSION

Tree Management Practices and Yields

Tree removal in the 2.7 m and 3.0 m in-row plantings

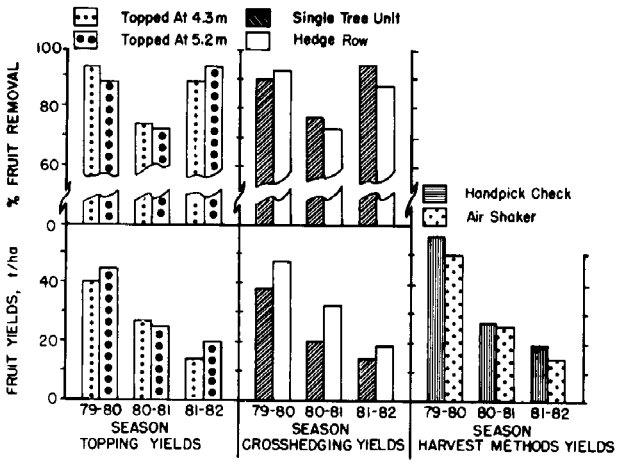

Fig. 12—Effects of topping, crosshedging, and harvest methods on fruit yields and removal efficiency, Study 2, Parson Brown oranges.

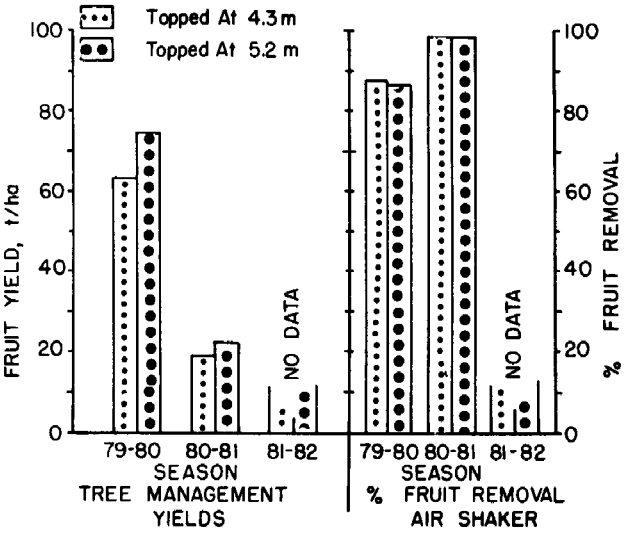

Fig. 11—Effects on topping on fruit yields and removal efficiency, Study 8, Valencia oranges.

reduced yields of the first harvest after the trees were removed. By the second season, however, trees adjacent to the removed trees had recovered sufficiently so that yields were comparable to the original hedgerow. In Study 1, the fruit yields of 1980-81 and 1981-82 were severely reduced by the freeze damage of January 1981. In Study 10, freeze damage has not particularly been a factor and the 2.7 m space created by the removed tree has been largely filled by the adjacent trees after 3 yr.

Crosshedging generally reduced yield when compared to the hedgerow where the in-row tree spacing varied from 3 m to 5.3 m. Crosshedging the trees as single and double units reduced yield an average of 14% and 7%, respectively, in early and midseason, and late season (Valencia) oranges. It should be remembered that the Valencias included in Study 12 were small, young trees which were unaffected bvy crosshedging until the 3rd season.

Annual topping also reduced fruit yield. Compared with the greatest topping height over all three seasons, removing 0.9 m of the tree top reduced yield by 38%. Yield reductions were greatest the first season, with the reductions being moderated the two subsequent seasons.

In Study 2, the cumulative average effect of removing 0.9 m of the top and crosshedging was to reduce fruit yields 35% (9% topping, 26% crosshedging) as compared to those with no topping or crosshedging. This planting had a 3 m in-row tree spacing (close for crosshedging), but was conducted as a continuation of the program being used by the grower when the study was initiated.

Shaker Yields and Fruit Removal

For 1980-81 and 1981-82, average yields of early and midseason oranges indicated that fruit yields of the air shaker harvested trees were 15% less than the handpick trees. This reduction is more than reported in previous papers on air shaker removal of early and midseason oranges (Whitney, 1972; Whitney, 1975). For no apparent reason, however, the average yields for the 1979-80 season, when there should be harvest method effects, were 7% less for the air shaker trees than for the handpick trees. In the one study with the trunk shaker (Study 11), fruit yields associated with the trunk shaker and handpicking were nearly identical for all seasons.

Fruit removal with the air shaker averaged 89.5% for all studies in early and midseason oranges. Percentage fruit removals that were low were all associated with freeze damaged, defoliated trees (Studies 1, 2, 5) where abscission chemicals were not applied. Although excessive abscission is normally associated with freeze damaged trees, many of the oranges were shaken off with attached stems, indicating high attachment strengths. In Study 11, fruit removal by the trunk shaker was comparable to that of the air shaker.

Average fruit yields of air shaker and handpick trees (Valencia oranges) were comparable in the 1979-80 season. Averaging all yields in 1980-81 an 1981-82 showed that the air shaker yields were 34% and 14% less than those of the handpick check in the 1980-81 and 1981-82 seasons, respectively, or an average for both seasons of 24%. This agreed fairly well with previous research (Whitney, 1975; Whitney, 1976). Young fruit (next season's crop) was 0.5 to 2 cm diameter at the time of most harvests.

Fruit yields associated with the trunk shaker over the 1980-81 and 1981-82 seasons averaged 15% less than those with handpicking in Study 12 and the reduction was similar to previous reports (Whitney, 1975). In addition, the shaker clamp damaged trunk bark on approximately one-half the trees in the 1979-80 harvest. Some bark damage, but to a much lesser extent, occurred during the 1980-81 and 1981-82 harvests. Much of the bark damage resulted because the trunks were too short for the size of the shaker pads and the irregular shape of many of the trunks. Also, Valencia trees are more susceptible to bark damage than those of early and midseason oranges because the Valencia tree is usually growing vigorously at harvest time while the early and midseason orange tree is more dormant. Thus far, the fruit yields have not been affected by the bark damage on the trunks. Bark damage was not reported in earlier research (Whitney, 1975) on larger, more mature Valencia trees.

Fruit removal efficiencies of the air shaker in Valencia oranges averaged 93% for all three seasons. Fruit loosening by abscission chemicals ranged from poor to good. Fruit removal efficiencies of the trunk shaker were comparable to the air shaker in Study 12, except for the 1981-82 season, when fruit loosening by abscission chemicals was very poor.

Overall, tree size management practices have shown no consistent effects on percentage fruit removals by the mechanical harvesting methods. When these studies were planned, it was felt that hedgerows, for example, may lower percentage fruit removals compared with individual trees because limbs are sometimes tangled where trees grow together in hedgerows and can impair limb movement and thus fruit removal of shakers.

These data represent 3 yr of work on studies scheduled for 5 yr duration. Interpretation of the results has been complicated by severe freezes for 2 consecutive yr.

Thus far, some trends have been observed in tree responses to the freezes, as these responses are affected by the various tree size management practices and harvest methods. It is hoped that these trends, if real, will be readily apparent by the 5th year of these studies. Later publications will stress the horticultural aspects of this work to include fruit quality measurements.

Further studies have been initiated to investigate (a) ways of alleviating the bark damage problem with the trunk shaker in Valencia and (b) the effect of tree spacing, tree height, and rootstock on fruit yield and harvest methods.

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