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# HARVESTING 'VALENCIA' ORANGES WITH A LIMB SHAKER

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ABSTRACT

A limb shaker was evaluated for harvesting 'Valencia' oranges. In one test where trees were shaken for 3 seasons in a mode to remove a minimum of young fruit, the subsequent yields were reduced 5% at harvests made before the end of the main young fruit drop period. The subsequent yields of trees harvested after this period were reduced an average of 32%. Two separate tests for one season using the same mode of shaking resulted in a negligible reduction in subsequent yield at harvests made when the young fruit was 0.5 inches in diameter. A test where the trees were shaken for 90% removal of fruit showed a subsequent yield reduction from 8 to 28% over the season. Shaker selectivity was directly related to subsequent yield reduction when compared over the season. The optimum shaker adjustment for selectivity was 8-inch stroke at 150 cpm frequency.

## INTRODUCTION

Harvesting 'Valencia' oranges with a limb shaker presents a unique problem. At harvest time, the next year's crop is on the trees in the form of young fruit. To harvest this variety, maximum mature fruit removal is desired with a minimum removal of the young fruit. This is desired to reduce the possibility of causing a reduction in the subsequent crop. Theoretically, this selection might be accomplished by shaking because of the weight differential of young and mature fruit. However, the weight differential decreases as the young fruit grows, making selection more difficult as the harvest season progresses (3).

The number of young fruit removed with a shaker varies with the stage of the natural young fruit drop. Over 20 young fruit are set for each mature fruit produced (3). Most of the excess young fruit drops during the first 4 to 5 weeks following bloom. During this period, it seemed possible that a reduction would not occur in the subsequent crop if some of this fruit was removed by the shaker. Hedden and Coppock (4) found evidence of this in a 5-year study of harvesting with a limb shaker.

Limb shakers have been developed and used commercially to harvest early and midseason oranges (1). By extending their use to 'Valencia' oranges, economic justification would be made easier by the extension of the machine use period. Also, it would tend to balance the harvest labor demands. Tests were conducted from 1968 through 1971 to study the possibility of harvesting 'Valencias' with a limb shaker.

## METHODS AND MATERIALS

A self-propelled limb shaker developed at the Citrus Experiment Station was used (2), Figure 1. Shaking frequency was infinitely variable up to 350 cpm. The stroke of the unbalanced weight was adjustable to 4, 6, and 8 inches. The stroke was fixed at 6 inches for all tests except for the stroke and frequency test when it was varied the full range. The fruit was shaken on the ground and picked up by hand.

Three tests were conducted to study the relationship of young fruit diameter at harvest time to (a) shaker selectivity, (b) subsequent fruit yield, and (c) the natural young fruit drop. A fourth test was conducted to study the relationship of shaker frequency and stroke to (a) shaker selectivity, (b) subsequent yield, (c) mature fruit removal, and (d) actual shake time (time tree is exposed to shaking force).

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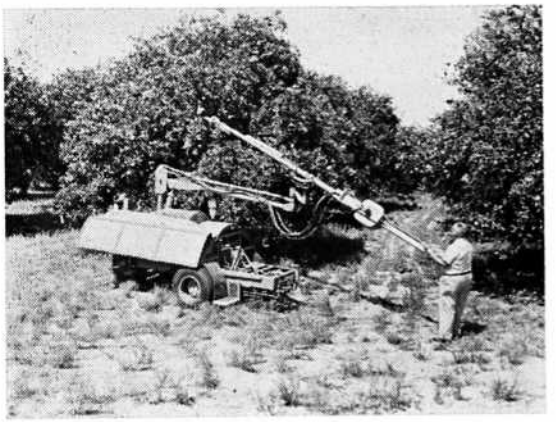

**Figure 1.—Self-propelled limb shaker used to harvest 'Valencia' oranges.**

Shaker selectivity was measured by the number of mature fruit removed for every young fruit removed. It was convenient to measure by counting the fruit on the ground following harvest. Subsequent yield was measured as a percentage of the yield of the handpicked trees.

All tests were conducted in the same general grove area. The trees were 35 years old on an 18 x 24-foot spacing and 18 feet in height. Crowding had been controlled by hedging the middles. The general shape of the trees was well suited for shaker harvest.

*Test 1* was extended over 3 harvest seasons (1968, 1969, 1970). Nine 3-tree plots were used in which the trees were selected for similar harvesting characteristics. Three replications of 3 harvest treatments were applied at 3 dates of harvest, each date corresponding to a specific young fruit diameter. One of the following treatments was applied to each tree in a plot for 3 seasons: (a) subdued shaking intensity, (b) maximum shaking intensity, and (c) handpicked. At maximum intensity, the objective was to obtain maximum removal of mature fruit without regard to the removal of the young fruit while at subdued intensity, maximum removal of the mature fruit with a minimum removal of young fruit was the objective.

The following data were collected: (a) young fruit diameter, (b) young and mature fruit removed, (c) subsequent fruit yields, and (d) actual shake time. The natural young fruit droppage was determined for the test area at various dates during the season.

*Test 2* was conducted for one season (1969). Nine 2-tree plots were selected so that the trees in each plot had similar harvesting characteristics. One tree in each plot was shaken at maximum intensity (as described on Test 1) and the other one was handpicked. The plots were replicated 3 times at 3 harvest dates during the season.

The following data were collected: (a) young fruit diameter, (b) young and mature fruit removed, (c) subsequent fruit yields, and (d) actual shake time. The natural young fruit droppage was determined for the test area at various dates during the season.

*Test 3* was conducted in 1970. Three replications of 2-tree plots were harvested approximately every 2 weeks during the season. One tree in each plot was shaken and the other one was handpicked. The trees were shaken until a 90% removal of mature fruit was obtained because it was felt that this removal efficiency would be necessary for the shaker to be practical.

The following data were collected: (a) young fruit diameter, (b) young and mature fruit removed, (c) subsequent fruit yields, and (d) actual shake time. The natural young fruit droppage was determined for the test area at various dates during the season.

*Test 4* was initiated in 1970 to determine the optimum shaker adjustment for selective harvest. The test was conducted as a 3 x 4 factorial with 3 maximum frequency levels plus handpicking and 3 strokes of the shaker (4, 6, and 8 inches). The factorial was replicated 3 times on June 8 when the young fruit was 1.25 inches in diameter. This was after the main young fruit drop had occurred. Nine 4-tree plots were used. One tree in each plot was harvested at each one of the 3 test frequencies and one handpicked. Frequencies were different at each stroke because of machine limitations. The trees were shaken at the desired shaker adjustment until the rate of mature fruit removal approached zero. Shake time was allowed to vary. The following data was collected: (a) actual shake time, (b) mature fruit left on the tree, (c) young and mature fruit removed, and (d) subsequent yield.

## Results and Discussion

The operating characteristics of the shaker in Test 1, 2, and 3 are given in Table 1. The effect of shaking trees repeatedly for 3 seasons at subdued and maximum intensity (Test 1) on subsequent yields is shown in Figure 2. Subsequent yields of shaken trees were measured as a percentage of that for handpicked trees. Each bar represents the average for 3 trees over 3 seasons.

Table 1. Operating characteristics of the shaker in Tests 1, 2, and 3.

| Test | Year | Mode of shaking | Actual shake time, min.* | Mature fruit removal, % |
|---|---|---|---|---|
| 1 | 1968-71 | Maximum intensity | 1.55 | 86 |
| | | Subdued intensity | 0.56 | 76 |
| 2 | 1969 | Maximum intensity | 1.29 | 79 |
| 3 | 1970 | 90% removal of mature fruit | 4.37 | 92 |

*Excludes time lost in attaching the shaker and moving from tree-to-tree.

The difference between subdued and maximum shaking intensity was not significant at the 95% confidence level. The first harvest was before and the other two were after the main young fruit drop period. The subsequent yields of the shaken trees were reduced an average of 5% when harvested before the end of the main drop period. After this period, they were reduced an average of 32%. This substantiates the findings of Hedden and Coppock that 'Valencia' oranges might be harvested during the early part of the harvest season without a large reduction in subsequent yields.

Figure 3 shows the relationship of the equatorial diameter of the young fruit to the natural young fruit droppage, subsequent fruit yield, and shaker selectivity for the first year of Test 1, 2, and 3. The yield in Test 1 is for an average of subdued and maximum shaking intensity.

Yield reductions at 0.5-inch young fruit diameter were negligible in Tests 1 and 2 where

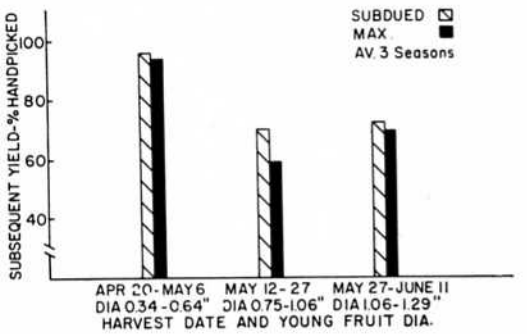


**Figure 2.—The effect of shaking trees for 3 seasons on subsequent yields. Test 1.**

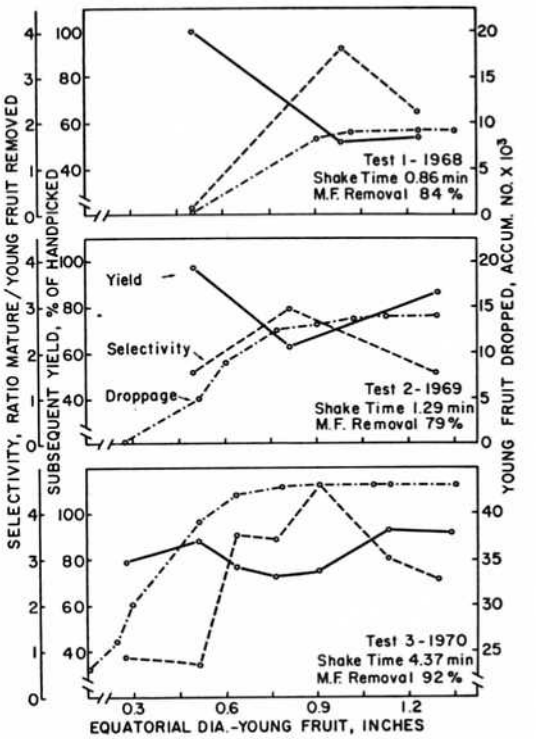


**Figure 3.—Relationships of the equatorial diameter of young fruit to the natural young fruit droppage, subsequent fruit yield, and shaker selectivity for Tests 1, 2, and 3.**

the average shake time was 0.86 and 1.29 minutes, respectively. Yield was reduced 12% at this young fruit diameter in Test 3 where the average shake time was 4.37 minutes.

The rate of young fruit droppage decreased

sharply when the fruit was about 0.85-inch in diameter. A yield reduction occurred at harvests made after the fruit had reached this diameter. This reduction, however, seemed to be less later in the season when the young fruit was larger. This may have been the result of "off-bloom" stimulated by the shaking force since "off-bloom" fruit was included as part of the fruit yield. Evidence of this was observed, especially in Test 3 where the shaking was the most severe. In Tests 1, 2, and 3, yield reductions were directly related to shaker selectivity. This relationship before the end of the main young fruit drop period can be explained by the fact that some of the young fruit removed at harvest would have dropped anyway. After this drop period, the relationship can be partially explained by the observation that some "off-bloom" fruit production was stimulated by the shaker activity of the previous season. Selectivity was the greatest immediately following the young fruit drop period then decreased as the young fruit diameter increased above 1.00 inch. This might be expected since the weight differential of young and mature fruit decreases rapidly near the end of the harvest season (3).

The results of Test 4 are given in Table 2. The shake time decreased with increases in frequency. Mature fruit removal increased with increases in frequency at 6 and 8-inch strokes, but it was about the same for all frequencies at the 4-inch stroke. Subsequent yields decreased with increases in frequency at 6 and 8-inch strokes, but this relationship was reversed at the 4-inch stroke. There was fairly good inverse correlation ($r=0.631$) between subsequent yield reduction and shaker selectivity. The maximum selectivity was obtained at a frequency of 150 cpm at an 8-inch stroke. The mature fruit removal was 81% and the shake time per tree was 4.23 minutes. Note that the shaker adjustment in Tests 1, 2, and 3 was 350 cpm maximum frequency at a 6-inch stroke. This adjustment was poor for selectivity but good for actual shake time.

These tests indicate that 'Valencia' oranges can be harvested with a limb shaker until near the end of the main young fruit drop period when the young fruit is about 0.85 inch in diameter without fear of a large reduction in subsequent yields. However, care must be exercised in the operation of the shaker. Caution should be observed after the young fruit reaches 0.5 inch in diameter. Harvests made after the young fruit diameter is greater than 0.85 inch may reduce the subsequent yield up to 50% if "off-bloom" fruit is discounted.

A mature fruit removal of about 76% may be expected when operating the shaker for minimum removal of young fruit (shake time of 0.56 minute, Table 1). At this mode of operation, a total harvest rate (tree-to-tree) of 6 trees per hour was obtained. The average boxes per hour rate

Table 2. Effect of frequency and stroke on the performance of the limb shaker in harvest Test 4.*

| Freq. cpm. | Stroke inches | Shake time min. | Mature fruit removal % | Subsequent yield, % of handpicked | Selectivity mature/young fruit removed |
|---|---|---|---|---|---|
| 150 | 8 | 4.23 | 81 | 90 | 6.73 |
| 250 | 8 | 1.88 | 89 | 69 | 2.98 |
| 264 | 8 | 1.07 | 89 | 72 | 2.68 |
| 150 | 6 | 4.43 | 49 | 81 | 5.40 |
| 250 | 6 | 2.34 | 73 | 77 | 2.53 |
| 350 | 6 | 1.37 | 84 | 70 | 2.44 |
| 250 | 4 | 3.48 | 79 | 66 | 3.63 |
| 300 | 4 | 2.90 | 77 | 71 | 4.98 |
| 360 | 4 | 1.87 | 74 | 79 | 4.68 |

*June 8, 1970 harvest date; means of 3 replications; young fruit diameter 1.25 inches.

was 27 computed from a yield of 6 boxes per tree and a mature fruit removal of 76%. Using an estimated machine cost of $5.75 per hour, the cost for shaking the fruit on the ground was $0.21 per box. If the fruit remaining on the tree is abandoned, its economic value at an on-tree price of $1.00 per box would be $0.33 per box of harvested fruit. The total cost assuming no reduction in subsequent yields would be $0.54 per box and the fruit still would have to be picked up. This cost is too high to compete with handpicking cost of $0.35 per box in good groves.

Obviously, some method of increasing the harvest rate and mature fruit removal without reducing subsequent yields is needed. Abscission chemicals that loosen the mature fruit have been shown to increase the harvest rate and mature fruit removal, but they have been too inconsistent for practical use.

Increasing the stroke of the shaker from 6 to 8 inches and reducing the maximum operating frequency from 350 to 150 cpm greatly increased selectivity. However, the shake time per tree was increased from 1.37 to 4.23 minutes. Some improvement in harvest rate and mature fruit removal may be possible through better methods of attaching onto the limbs and operating the shaker to give the operator better control of the shaking force. This approach is being investigated.

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