

HARVESTING EARLY AND MIDSEASON CITRUS FRUIT
WITH TREE SHAKER HARVEST SYSTEMS¹

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ABSTRACT

During the 1966-67 harvest season, 2 tree shaker harvest systems were used successfully to harvest cannery fruit on a commercial basis from tall or high yielding early and midseason citrus trees. One harvest system consisting of 2 catching frames, each equipped with a tree shaker, harvested 10 trees per hour with a 3-man crew. The other harvest system consisting of a tractor-mounted shaker and a hand pick-up crew harvested 6.3 trees per hour.

Fruit removal for both systems was 90 to 95% and the harvest cost was less than that for hand harvesting under certain grove conditions.

INTRODUCTION

The problem of harvesting the Florida citrus crop continues to be aggravated by higher labor costs and larger production. Labor cost for picking has increased 40% over the past 3 years (4) and in the 1966-67 season, production increased over 42%. The sudden increase in production lowered the price of fruit to a point where the value of fruit on the tree was less than the cost of harvesting in many groves. These factors have greatly stimulated interest in the development of mechanical fruit harvesters.

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Hedden and Coppock (3) reported in 1965 on the "state-of-the-art" of a tree shaker and catching frame harvest system. The system was limited to harvesting early and midseason citrus because in 'Valencia' oranges it removed too much of the subsequent year's crop. This variety has the subsequent year's crop on the trees in the form of small immature fruit when the mature fruit is ready to harvest. This work was done under limited and controlled grove conditions and the industry was reluctant to accept the system without further testing. Consequently, machinery manufacturers were not interested in developing the necessary equipment.

Since this harvest system had exhibited considerable merit for harvesting a certain segment of the citrus crop, a prototype tree shaker and catching frame harvest system was built at the Citrus Experiment Station incorporating the latest research findings. It was operated commercially by grower cooperators to study some of its practical aspects.

Two tractor-mounted tree shakers were built by a local manufacturer and sold for harvesting tall orange trees which could not be harvested economically by hand. The fruit was shaken onto the ground and picked up by hand labor. This report covers the operation and performance of these harvest systems under commercial conditions in early and midseason oranges and in grapefruit being harvested for the cannery.

HARVEST SYSTEMS AND GROVE CONDITIONS

The basic concept of the tree shaker and catching frame harvest system was the same as described by Hedden and Coppock (3) with the exception of major changes in the fruit handling method. Many of the machine components were redesigned for greater durability.

To operate the harvest system, the catching frames were pulled into position on opposite sides of a tree and extended until they met and formed a fruit seal around the base of the tree (Fig. 1). The shakers detached the fruit by shaking individual limbs. The fruit dropped onto the surface of the catching frame where it was collected and conveyed into a 60-box storage bin located on the rear of 1 frame (Fig. 2). When the bin was full, it was emptied into a conventional high-lift grove truck which transported the fruit to a semi-trailer at the roadside.

The system employed 2 skilled men to operate the shakers and catching frames, 1 laborer to pick up fruit that missed the frame, and 1 driver to operate the high-lift grove truck.

The shaker and hand pick-up system consisted of a tractor-mounted tree shaker, a hand pick-up crew, and a high-lift grove truck. The design of the shaker was described by Coppock and Hedden (2) in 1966. Several modifications were made in construction details by the manufacturer.

To operate the shaker and hand pick-up system, the tree shaker was moved into a convenient position near the tree to be shaken. If necessary, the tractor was shuttled back and forth so the shaker could be attached on each main limb (Fig. 3). The fruit was shaken onto the ground and left to be picked up by a hand crew. The hand crew picked up the fruit and put it into buckets. Later the buckets were emptied into a high-lift grove truck which transported the fruit to the roadside. The system employed 2 semi-skilled operators, a pick-up crew of laborers, and an operator for the high-lift grove truck. To reduce the possibility of damaging the fruit, the ground was disked before harvesting.

The shaker and catching frame system was operated in 3 different groves. Performance data for the system in these groves are given in Table 1. The first was a 29-year-old 'Hamlin' orange grove with trees 18 feet high spaced 30 x 30 feet and yielding an average of 15 boxes. Tree skirts were pruned to a 3-foot height to facilitate moving the catching frames. This involved removing primary limbs parallel to the ground and water sprouts. An opening was cut in the canopy on both sides of the tree to make shaker manipulation and attachment to limb easier.

In the second grove, both harvest systems were used. It was a 54-year-old 'Pineapple' orange grove with trees spaced 25 x 25 feet and varying in height from 25 to 35 feet and yielding an average of 8 boxes per tree. It was typical of many groves located in the older citrus growing areas. No pruning was required. Tree skirts were from 8 to 10 feet above the ground and the canopy openings were adequate to allow easy shaker attachment.

Both harvest systems were used in the third grove. It was a 40-year-old 'Marsh' grapefruit grove with trees on a 25 x 25-foot spacing which had been topped and hedged the previous year to a tree height of 18 feet and a middle opening of 7 feet. Yield averaged 6 boxes per tree. Very little pruning was necessary to get the trees in shape for harvesting.

PERFORMANCE AND DISCUSSION

Approximately 10,000 boxes of fruit were harvested with the shaker and catching frames system during the harvest season without any serious mechanical trouble; however, it was evident some design changes were needed. Performance of the catching frames was not satisfactory on terrain with slopes of more than 5° at right angles to line of travel. On steep slopes, the fruit falling on the deflector frame would not roll across the seal between the catching frames and into the conveying system. The fruit handling system carried sticks and leaves into the storage bin along with the fruit.

This trash tended to damage the fruit and occasionally clogged the conveying system on the machine and at the processing plant. A stick and leaf removal device built into the catching frame conveyor would reduce this trouble.

The operation of the shaker and catching frame system was a very demanding job which required skilled and dependable labor. Training the operator was not difficult if he had some mechanical aptitude. The availability of this type of labor must be considered in evaluating the merits of this system.

Some performance data for both harvest systems are summarized in Table 1. The harvest rate varied greatly with different operators and grove conditions; however, it seemed possible that an average down the row rate of 12 trees per hour and an overall daily rate of 10 trees per hour could be maintained. The daily rate takes in account the time required to turn at the ends of the grove and to service the equipment. It took 1 minute to move and position the catching frames and 4 minutes to clamp and shake all major limbs. This time was greatly affected by the tree shape and fairly independent of tree yields.

A down the row harvest rate for the tractor-mounted shaker of 7.5 trees per hour and a daily harvest rate of 6.3 trees per hour was obtained in groves with tall and fairly open trees. These rates are slightly higher than the per shaker rates for the shaker and catching frame because of the greater mobility possible with the tractor-mounted shaker.

Fruit removal with the tree shaker in both harvest systems was 90 and 95% in oranges and grapefruit, respectively. Tree structure had the greatest affect on fruit removal of any factor. Those trees which had limbs spaced so that the shaker could be attached in a manner which would enable it to shake the fruit vertically had the highest percentage of their fruit removed.

Fruit from all the groves was delivered to the processing plant in semi-trailer trucks and processed within 24 hours without noticeable decay problems. Samples taken of the fruit as the trailers were unloaded at the plant showed the amount of fruit split ranged from .7 to 3% and the amount of fruit with stems ranged from 8 to 32%. The greatest amount of fruit was split when harvesting groves with tall trees. In these groves, the fruit would split if it fell on top of other fruit already on the ground. Fruit falling on the catching frames split less since the chances of one fruit falling on another one were much less. The fruit with stems caused the greatest problem in processing the fruit. These stems had to be removed by hand or they reduced the efficiency of the fruit handling equipment and the juice extractor. The cost of removing these stems is part of the mechanical harvesting cost.

Grove condition had a tremendous effect on harvesting cost. The shaker and catching frame system showed a savings over hand harvesting of 18 cents per box in tall trees which were difficult to get harvested by hand and a loss of 19 cents per box in a grapefruit grove where hand harvesting was easy. Although the harvest systems performed the complete operation of separating the fruit and placing it into a roadside truck, only that part dealing with the separation and placement of the fruit into a grove vehicle is considered in this report. However, it was evident that some savings over the 10-box basket method of moving the fruit to the roadside was obtained by eliminating the need for baskets and a boom loader in the shaker and catching frame system.

COST ANALYSIS

The per box cost of harvesting by either system was influenced by the cost of the machine, fruit abandonment, grove shaping, and fruit preparation after harvest. Only machine and fruit abandonment costs were considered in this analysis. Fixed and variable operating costs accounted for the total machine cost. It was a relatively fixed amount per tree based on operational time per day. For the shaker and catching frame, it was \$1.95 per tree for an 8-hour operation. A 16 and 24-hour operation would reduce this cost by 25 and 32%, respectively. The per tree cost for the tractor-mounted shaker not including picking up fruit was \$1.26 for an 8-hour operation.

Per box cost varies with tree yields as shown by the curves in Fig. 4. These curves were determined using certain assumed economic values. The assumed values were based on good estimates obtained from extensive field experience and from comparison with similar commercial machines (1). An annual use period of 672 hours was assumed for both systems. This period covered 14 weeks of operation, 6 days per week, and 8 hours per day extending from December to April. The following machine cost and expected life was assumed: 2 shakers and catching frames at \$18,000 with a life of 4 years and 2 tractors at \$10,000 with a life of 10 years; a tractor-mounted shaker at \$5,000 with a life of 4 years and a tractor at \$5,000 with a life of 10 years. This cost analysis included only the operation of removing the fruit and placing it into a grove truck.

The Shakers removed 90 to 95% of the fruit. If it is not practical to hand glean the fruit left on the tree, then it must be abandoned and its value charged to the cost of harvesting the fruit removed. The abandonment cost varies with removal efficiency of the shaker and the "on tree" price of fruit (Fig. 5). For example, if the shaker removes 90% of the fruit from trees yielding 10 boxes and the "on tree" price of the fruit was 60

cents per box, the abandonment cost per box of harvested fruit would be 6.7 cents.

From Fig. 4, the machine harvesting cost for the tree shaker and catching frames in a grove yielding 10 boxes per tree is 22 cents per box. Adding this to the fruit abandonment cost, the total mechanical harvesting cost becomes 28.7 cents per box. This cost compares favorably with hand harvesting cost under good harvesting conditions.

The harvesting cost was greater for the shaker and hand pick-up system than that for the shaker and catching frame system. This is attributed to the cost of hand labor required to pick up the fruit. A cost of 20 cents per box was used in calculating the curve in Fig. 4; however, it may be possible to get this done for less depending on the type and price of labor available.

Also, fruit pick-up machines are under development which may reduce the cost of this operation.

CONCLUSIONS

The foundation has been laid for the successful harvesting of cannery fruit from tall or high yielding early and midseason citrus trees. The shaker and catching frame system has the greatest labor and cost saving potential; however, it will require skilled and dependable labor. Considerable pruning will be required in many groves to facilitate moving the catching frames. The shaker and hand pick-up system seems to be better suited for use with unskilled labor in groves with large trees.

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Table 1. Performance of mechanical harvesting systems.

| Fruit type | Tree height (ft.) | Tree yield (boxes) | Daily harv. rate (tree/hr.) | Mech. harv. cost (\$/box) | Savings** (\$/box) | Fruit cond.* | |
|-------------------------|-------------------|--------------------|-----------------------------|---------------------------|--------------------|--------------|---------|
| | | | | | | Splits % | Stems % |
| Shaker and catch frame | | | | | | | |
| 'Hamlin' oranges | 18 | 15 | 9 | 0.19 | 0.06 | 0.7 | 32 |
| 'Pineapple' oranges | 32 | 8 | 10 | 0.32 | 0.18 | 3.0 | 20 |
| 'Marsh' grapefruit | 18 | 6 | 12 | 0.39 | -0.19 | 1.0 | 9 |
| Shaker and hand pick up | | | | | | | |
| 'Pineapple' oranges | 32 | 8 | 6.3 | 0.39 | 0.11 | -- | -- |
| 'Marsh' grapefruit | 18 | 6 | 8 | 0.44 | -0.24 | 2.0 | 8 |

* Samples taken at processing plant.

** Hand picking cost minus mechanical harvesting cost.



Fig. 1.--Catching frames being positioned around a tree in the tree shaker and catching frame harvest system.

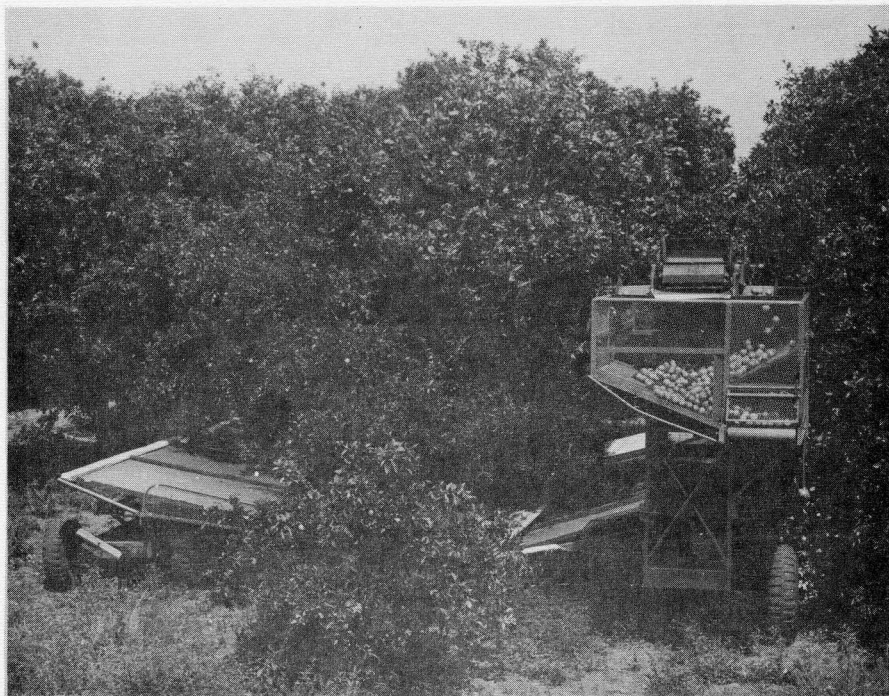


Fig. 2.--Fruit storage bin on catching frame. The bin empties the fruit into a conventional high-lift grove truck.



Fig. 3.--Tractor-mounted tree shaker being used to shake fruit onto the ground. This shaker is available commercially.

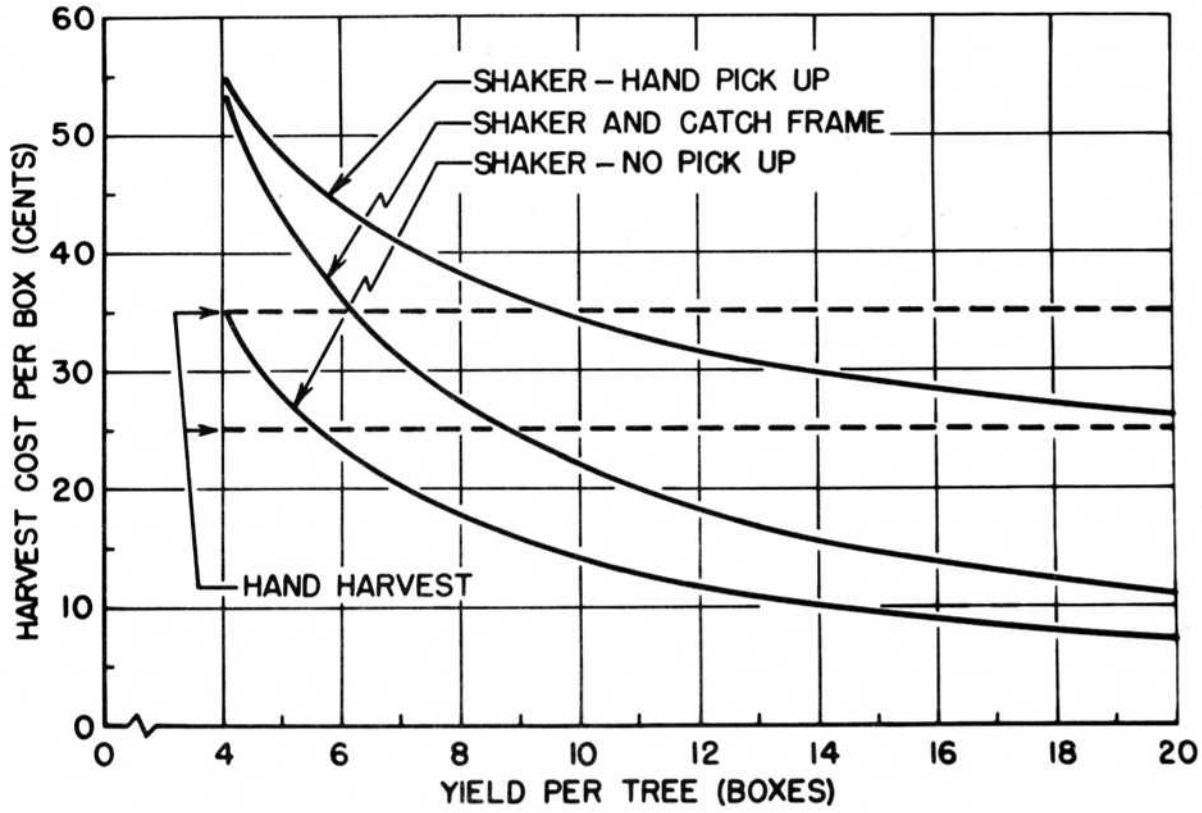


Fig. 4.--Comparison of harvest cost for several systems assuming a 100% removal for all systems.

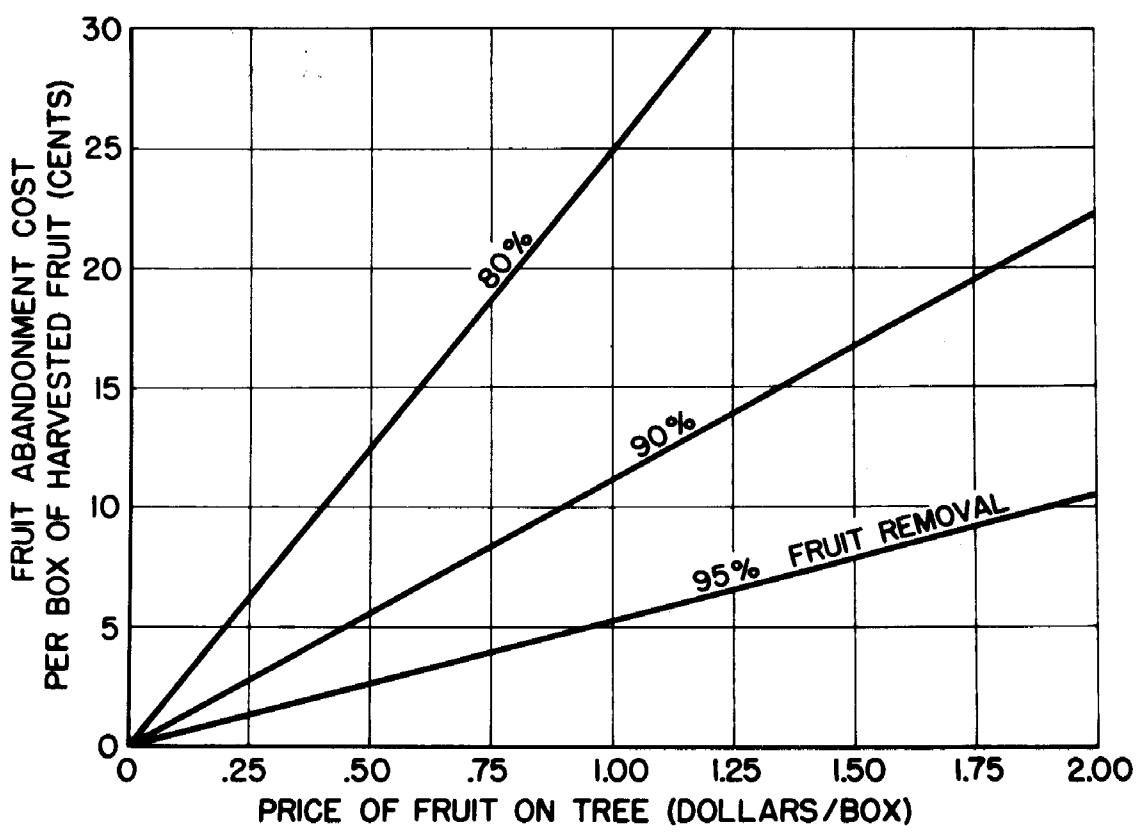


Fig. 5.--Fruit abandonment cost per box of harvested fruit as affected by removal and fruit price.