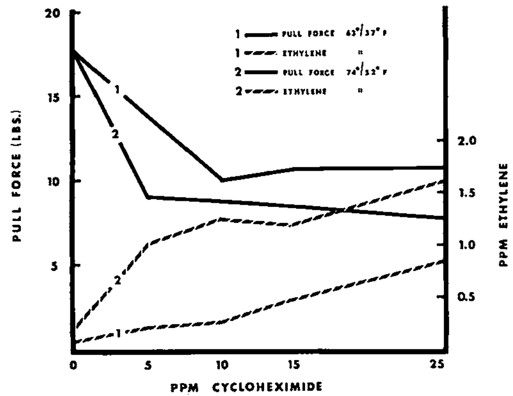

Figure 2.—Pull force and ethylene content of Hamlin oranges from trees sprayed with cycloheximide in two temperature ranges. Ethylene and pull force determinations 5 days after spray application.

half-life of cycloheximide is relatively short in these conditions, so that the temperature soon after application is more important than that closer to harvest.

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PERFORMANCE AND COMPARATIVE COST OF TREE SHAKER HARVEST SYSTEMS[1]

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ABSTRACT

Several citrus harvest systems were operated and evaluated under near-commercial field conditions during the 1968-69 season. These systems all utilized the hydraulic operated, inertia-type tree shaker for fruit removal. The fruit handling equipment included a catching frame, 2 pick-up machines, and 2 methods of windrowing the fruit for pick up.

Field performance, equipment and labor requirements, and costs are presented and compared for the various harvest systems.

[1]Cooperative research by the University of Florida, Citrus Experiment Station; State of Florida, Department of Citrus; and U. S. Department of Agriculture.

INTRODUCTION

The inertia-type tree shaked for citrus has been under development in Florida for the past 12 years as a method of removing fruit from the tree. Catching frames for handling citrus after removal from the tree have been developed along with the tree shaker. This work has been reported to this Society on several occasions. (1, 2, 3, 4).

Many citrus industry people have objected to the size and cost of the catching frame equipment for fruit handling and expressed an interest in pick-up machines as an alternate method of handling fruit in the grove. The State of Florida, Department of Citrus, contracted with a machinery company to build a citrus pick-up machine to their specifications. In addition, a machine was designed and built at the Citrus Experiment Station employing a different pick-up principle (5). Both machines were built to pick up a windrow of fruit, and it was necessary to devise methods for getting fruit from under the tree into a windrow for pick up.

Several complete harvest systems were proposed and used during the 1968-69 season in cooperation with 4 commercial fruit harvesting companies. All of these systems are for harvesting cannery fruit. The objective of the work was to obtain performance and cost data on these harvest systems under conditions as near as possible to those encountered by commercial harvesting firms.

Equipment and Methods

Harvest systems employing the inertia-tree shaker and various methods of windrowing and fruit pick up were compared on the basis of labor requirements, equipment, and harvest rate. These harvest systems were as follows:

1. *Catching frame system using 2 tractor-drawn catching frames with a tree shaker mounted on each frame.*—This system caught the fruit as it was shaken from the tree (Fig. 1) and conveyed it into a 60-box capacity elevated surge bin. The system was constructed at the Citrus Experiment Station, Lake Alfred, and has been tested under a variety of grove conditions over the past 3 years. Three men operated the harvest system. One man operated each tree shaker and catch frame while a third laborer gleaned fruit from the ground and low-hanging limbs.

2. *Ground cloth-rollout windrow method followed by a pick-up machine.*—Fruit was shaken onto a pair of 26 x 13 foot lightweight nylon-vinyl ground cloths placed on the ground under the tree (Fig. 2). Two men grasped the corners of a cloth in line with the tree row and pulled the cloth and fruit over into the middle between the row (Fig. 3) forming a long narrow windrow of fruit. This was repeated on the other side of the tree. Four pairs of ground cloths were used with a tree shaker. After the fruit was windrowed, the men dragged the cloths ahead of the tree shaker and spread them on the ground again.

One tree shaker, either trailer-mounted or tractor-mounted, was used to shake each tree from one side of the row. Two men were used with the tree shaker, 2 men windrowed the fruit with the ground cloths, and one man operated the pick-up machine (Fig. 6).

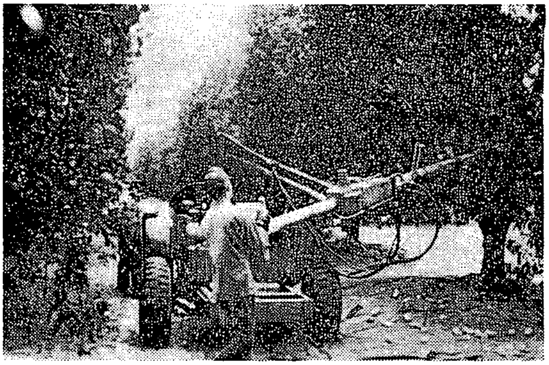

Fig. 2.—Trailer-mounted tree shaker used in harvest trials.

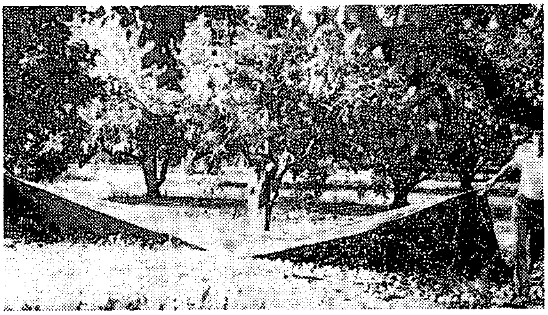

Fig. 3.—Workers pulling ground cloth over to form fruit windrow.

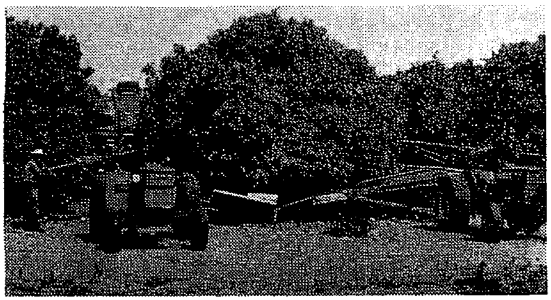

Fig. 1.—Tree shaker-catch frame harvest system,

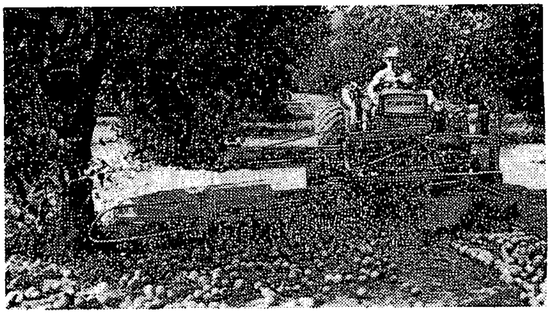

Fig. 4.—Windrowing rake with side-shift control.

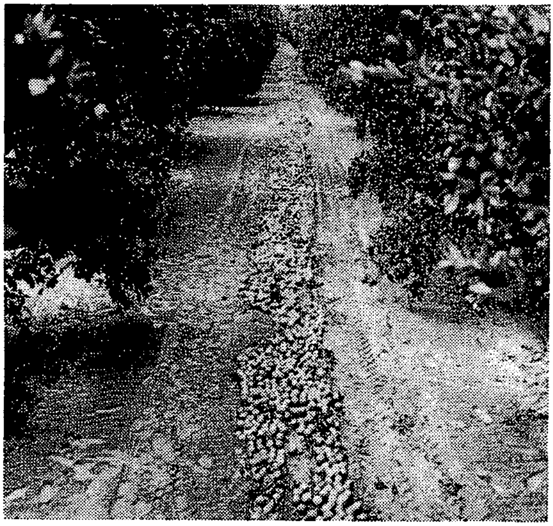

Fig. 5.—A double windrow formed by the rake ready for pick up.

3. *Mechanical windrower followed by a pick-up machine.*—A modified version of an oblique type side delivery rake was designed and constructed at the Citrus Experiment Station to move the fruit, after it was shaken to the ground, from under the tree into a windrow for pick up (Figs. 4 and 5). The windrower was mounted on the front of a tractor and could side-shift around the tree trunk as the tractor moved parallel to the tree row. After the trees were shaken, the windrower passed up one side of the tree row and down the other. The same tree shakers were used with this system as with System No. 2.

Four men operated this harvest system; 2 men with the tree shaker, one man on the windrow rake, and one man operating the pick-up machine.

4. *Ground cloth-rollout windrow method followed by a hand pick-up crew.*—Fruit was shaken onto nylon-vinyl ground cloths, rolled over into a windrow and picked up by a crew of 6 to 1 women using 5-gallon pails. The fruit-filled pails were then dumped into a high-lift truck by the driver. Initially, fruit was shaken on the bare ground and picked up, but the crew much preferred picking up fruit from a concentrated windrow to having it scattered all over the ground. Therefore, the windrow method was used for this evaluation.

Like the catching frame, the pick-up machines elevated the fruit into an overhead surge bin where 60 to 80 boxes of fruit were accumulated for unloading into high lift grove trucks. Harvesting or production grove labor from the various cooperating companies were trained and used as machine operators whenever possible and supplemented with Citrus Experiment Station technicians when necessary.

All systems were used for several weeks under varying grove conditions though the majority of data presented here were obtained in fairly level, sandy, clean grove conditions. Field data are presented on the systems as they were actually used and as they could be most efficiently used if sufficient equipment were available to work each machine to its field capacity. For example, the pick-up machine and windrow rake have the capacity to handle the output from 6 tree shakers but only one tree shaker was available for these trials.

Most of the equipment used in these harvest systems needs further development and is not commercially available. These analyses are based on past experience and the best experimental equipment that was available. Estimates of initial machine cost, service life, annual usage, and field efficiency were made to complete a cost analysis of each system (Table 1). Straight line depreciation was used for all equipment. Prevailing labor costs of $1.55/hour for tractor drivers and $1.35/hour for grove laborers were used in the cost analysis for all systems.

No allowance was made in the analysis of these harvest systems for fruit left on the tree since the tree shaker was used as the method of fruit removal in all systems.

RESULTS AND DISCUSSION

System No. 1 was used for the past 3 seasons to harvest the high-yielding 'Hamlin' orange grove described by Coppock (3). The 3-man crew maintained an effective field capacity (including time losses) of 10 trees/hour.

The initial cost of this system was assumed as $33,000 for 2 tractors, catch frames, and tree shakers having a service life of 10 years from the tractors and 4 years for the remaining equipment. A harvest season of 768 hours annually (16 weeks, 6 days/week, 8 hours/day) was estimated for early and midseason oranges and grapefruit.

On the basis of figures actually obtained in the field and estimated annual performance data, System No. 1 had a per tree cost of $0.44 for labor, $1.64 for equipment, and a total harvest-

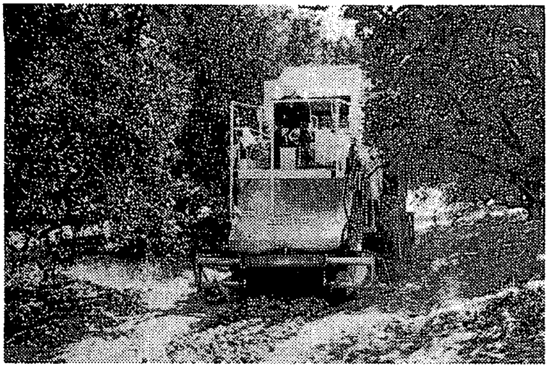

Fig. 6.—Pick up machine produced specifically for citrus.

ing cost of $2.08/tree into a high-lift truck. This system had a 97% fruit recovery with no supplementary gleaning.

The same annual use period was assumed for System No. 2 using a tractor-mounted tree shaker, ground cloths, and a pick-up machine. The pick-up machine had sufficient capacity to keep up with 6 tree shakers, so that the machine cost per tree was proportionally lower. The data in Fig. 7 show labor costs double that of System No. 1, but the total cost per tree harvested was $0.14/tree less.

System No. 3 (shake, rake, and pick up) involved 3 separate pieces of equipment requiring a semi-skilled operator for each machine. The effective field capacity of a windrower was equal to that of 6 tree shakers. Due to the high field capacity of the rake and pick-up machine relative to the catching frames, the labor cost of this system was only $0.50/tree (Fig. 7), lowest of all the systems compared. The total system cost was $1.55/tree.

The fourth system (shaker, ground cloths, hand pick up) had the highest labor cost ($1.80/tree) and the highest total harvest cost ($2.58/tree) as well as the least amount of machinery involved. The labor cost was calculated using a 5-box/tree yield and $0.20/box for hand pick up. An 8-box/tree yield would raise the labor cost from $1.80 to $2.40/tree. This system was used commercially for the past 3 sea-

Table 1.--Data used in analysis of tree shaker harvest systems.

System component	Initial cost $	Annual use (hrs.)	Labor No. req.	Labor Wage* $/hr.	Field cap. (tree/hr.)	Serv. life (year)**	Annual over-head $	Fuel, rep. & maint. $
Tree shaker and catch frame	33,000 (incl. 2 tractors)	768	2 1	1.55 1.35	10.2 (85%)	4	7,418	4,939
Tree shaker	10,000 (1 tractor)	768	2	1.55	7.2 (85%)	4	2,107	1,488
Ground cloths	650/8 (8 required)	768	2	1.35	7.2 (85%)	1	700	0
Rake	7,000 (1 tractor)	768	1	1.55	45.0 (85%)	4	1,275	1,382
Pick-up machine	25,000	768	1	1.55	40.0 (75%)	4	5,835	3,908

*Fringe benefits, Social Security, etc. not included.

**Tractors have a 10-year life.

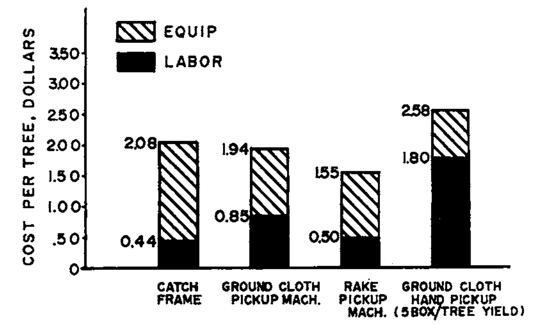

Fig. 7.—Comparative costs of tree shaker harvest systems.

sons by a grower to harvest a high-yielding seedling-type grove with high tree skirts on level ground. The handpicking cost with conventional bag and ladder method would be from $0.40 to 0.60/box which would average $2.80/tree, including loading and crew foreman. Thus, in "hardship" picking where trees are tall but high-yielding, all 4 tree shaker harvest systems would be substantially lower in cost than handpicking.

Fruit on low-hanging limbs was generally gleaned by the third man in the catching frame system and also by the men using the ground cloth windrowing method. No such gleaning was accomplished when the windrow rake was used so fruit losses were higher. Under prevailing fruit prices in most years it is not economical to have extra people gleaning fruit left in the tops of trees. For example, in one harvest trial, fruit removal was 90% of a 5-box/tree yield leaving 1/2-box of fruit on the tree. Five people were each paid $1.30/hour to glean fruit with ladders and "shiner poles" behind the tree shaker harvesting at 8.3 trees/hour. The base labor cost was $1.62/box of fruit under these conditions.

Some pruning was required in most cases to accommodate tree shaker harvest methods. Tree skirts had to be high enough for the catching frames, windrow rake, or ground cloths to be used. Tree shaker efficiency was increased considerably when the operator had a clear view of the main scaffold limbs of the tree and bark damage was avoided. Some older groves are already high-headed and the main limbs are easily visible. Most groves, however, would require pruning approximately every 3 years at a cost of about $0.45/tree ($0.15/tree/year) or $31.50/acre. Extensive tree skirt pruning would be even more expensive. This cost must be charged against harvesting.

Varying quantities of sticks, leaves, rotten fruit, and other trash were encountered using the 4 harvest systems. System No. 1 using the catching frame delivered the cleanest fruit because no ground trash or sand came in contact with the fruit. The ground cloth windrowing method eliminated ground trash under the trees, but some sand and sticks were picked up by the pick-up machine. The windrow rake provided the dirtiest fruit of all the systems tested because all trash under the trees was brought out into the windrow aand picked up. Much of the sand, leaves, and sticks was eliminated by the trash belt and grates on the pick-up machine; but cans, bottles, and considerable rotten fruit were carried over into the load.

Disking before harvest reduced fruit damage in the ground pick-up systems as well as reducing the amount of trash picked up. Ground trash was eliminated in several harvest trials by first making a "dry run" with the rake and pick-up machine to get the trash out of the grove. This procedure would be advantageous the first year that such a harvest system is used.

Dirty fruit also resulted when it was picked up while wet, either with dew or rain. The wet fruit rolled on the sand and became covered with a coating of sand that did not come off as it went through the pick-up machine conveyor system.

In comparing these harvest systems, only direct labor costs were used with no allowance for fringe benefits, Social Security, housing, transportation, etc., which increase with the amount of labor required. On the other hand, a higher degree of skill or mechanical aptitude was required with increased mechanization; therefore, the type of labor available should be considered in selecting a harvest system. Equipment such as ladders, buses, loading booms, baskets, or tubs was eliminated with these harvest systems.

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