

HARVESTING ORANGES WITH A FULL-POWERED POSITIONING LIMB SHAKER¹

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Abstract. The performance of a self-propelled full-powered positioning limb shaker was evaluated in four grove sites sprayed with an abscission chemical. The system increased the harvesting rate and reduced operator fatigue as compared with hand-assisted shaker positioning. Fruit removal efficiency was 96% in trees sprayed with an abscission chemical and 90% in unsprayed check trees. The harvesting rate was 15 to 36 trees/hour, depending on tree structure and number of limb attachments required per tree.

Limb shakers have been used to harvest early and midseason oranges in Florida for several years (3,4). The development of a self-propelled, one-operator shaker was reported by Coppock, 1973 (2) for use in a shake-pickup harvesting system. The shaker was a crank-drive inertia-type that was pendulously hung. It was controlled remotely from the operator's handle on the shaker. A similar limb shaker was also used with catch frames developed for harvesting citrus (1). These limb shakers were effective in removing a high percentage of fruit by imparting a long stroke to limbs at a low frequency and were not as dependent on the use of abscission chemicals, as were other mass-removal machines (air shaker, trunk shakers, and water shakers).

Unbalanced rotating weights have been used on trunk shakers to produce large shaking forces and small displacements at high frequencies. The large displacement required for shaking citrus limbs (5) can also be obtained with unbalanced rotating weights.

A self-propelled shaker unit with an unbalanced rotating weight limb shaker was developed by USDA (U. S. Department of Agriculture) engineers at the Agricultural Research and Education Center at Lake Alfred, Florida over the

past two years. The shaker unit was designed to reduce operator fatigue and increase harvesting rate above that of present limb shakers.

The objective of the tests described in this report was to field test and evaluate the FPP-RW (full-powered positioning-rotating weight) limb shaker unit in several grove sites.

Equipment and Methods

The FPP-RW limb shaker unit was used in all tests (Fig. 1). It consisted of a pendulously hung shaker mechanism weighing 700 pounds and a remote controlled hydraulically powered positioner mounted on a three-wheel transport system. The shaking mechanism (240 lb rotating weight with a 6-1/4-inch eccentric) had a maximum operating speed of 500 rpm and was powered by a 65-hp air cooled engine. The operator station was located at the rear of the shaker unit which gave the operator a view of the tree limbs along the axis of the shaker boom in most limb attachment situations.

Plot Test

Four plot tests were designed to evaluate the performance of the FPP-RW limb shaker unit in early and 'Valencia' orange varieties with and without the aid of abscission chemicals to loosen the fruit. The two abscission chemicals used were 'Acti-Aid' marketed by Tucco Division of Upjohn Company and 'Release' marketed by Agricultural and Veterinary Products Division of Abbott Labo-

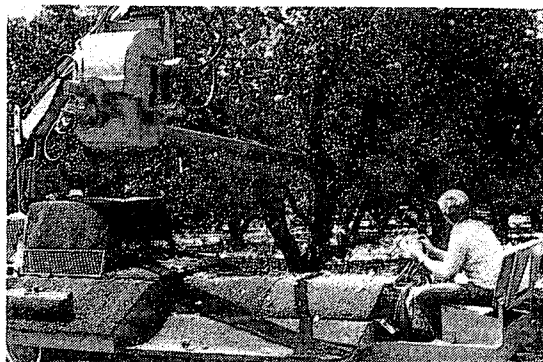


Fig. 1. The self-propelled full-powered positioning system with a rotating-weight limb shaker.

¹Cooperative research by the University of Florida, Agricultural Research and Education Center, Lake Alfred; State of Florida, Department of Citrus; and U. S. Department of Agriculture.

The authors wish to thank Orange-co of Florida, Inc., and Patrick Fruit Company for their help and cooperation in providing the grove areas for the tests reported in this paper.

ratories.² Data collected included: preharvest fruit drop, fruit left on trees after they were harvested, number of limb clamp attachments per tree, time spent shaking limbs, total harvesting time, and number of green fruit removed in 'Valencia' orange test. The same operator harvested all trees, and he shook limbs for a 90 to 95% fruit removal efficiency.

Chemical vs Check Test Twenty-four 'Parson Brown' orange trees that were about 15 ft high and spaced at 15 x 30 ft were harvested January 9, 1975. Treatments consisted of unsprayed check trees and trees sprayed with one unit of Acti-Aid and two units of Upjohn surfactant 'B' in 500 gallons of water per acre. Three trees per treatment were replicated four times for the time and motion data, and one tree per replication was selected for removal data.

Acti-Aid vs Release Test Forty-eight 'Parson Brown' orange trees approximately 18 ft high and spaced at 15 x 30 ft were harvested January 14, 1975, to evaluate the shaker performance as influenced by two abscission chemicals. The treatments were: (1) Trees sprayed with 1.4 units of Release and 1.2 liters of Ortho X77 surfactant in 500 gallons of water per acre, (2) trees sprayed with 1.4 units of Acti-Aid and 2.8 units of Upjohn surfactant 'B' in 500 gallons of water per acre. Four trees per treatment were replicated six times for the time and motion data, and one tree in each replication was randomly selected for fruit removal data. The treatments resulted in two abscission loosening levels. These levels were determined by counting preharvest drop of mature fruit.

'Valencia' Test I and II Ten 'Valencia' orange trees approximately 18 ft high and spaced 16 x 26 ft were harvested on May 12, 1975 (Test I) and May 28, 1975 (Test II). Treatments consisted of unsprayed check trees and trees sprayed with 5 units of Release and 2.16 liters of Ortho X77 surfactant in 900 gallons of water per acre. The shaker operator shook limbs for a high rate of mature fruit removal, but shaking was stopped as soon as removal diminished, so that the removal of young fruit would be minimized.

Field Test

The FPP-RW limb shaker unit was operated

in a continuous harvesting operation in two grove sites to determine its field performance.

Orange-co of Florida, Inc. Field Test This test was conducted with 'Parson Brown' orange trees approximately 16 ft tall and spaced at 15 x 30 ft. They had skirts about 2-1/2 ft above the ground and two to four main limb sections. Trees were sprayed with 1.4 units of Acti-Aid and 2.8 units of Upjohn surfactant 'B' in 500 gallons of water per acre. This grove site was the same one used for the Acti-Aid vs Release test, but limb, motion, and removal data were not recorded.

Patrick Fruit Co. Field Test The FPP-RW limb shaker unit was compared with a Pounds two-man operated, tractor-mounted, crank-drive shaker in a field harvesting operation at a grove owned by Patrick Fruit Co. For this test, 'Pine-apple' orange trees that were about 18 ft high and spaced 25 x 25 ft were used. They had five to seven main limb sections. The trees were sprayed with 1/4 to 1/3 units of Acti-Aid at the rate of 500 gallons per acre.

The experienced USDA operator operated the shaker in the grove to demonstrate to and teach Patrick Fruit Co. shaker operators to use the FPP-RW limb shaker unit. Then the newly trained men operated it for several days to compare it with the Pounds shaker.

Results and Discussion

Plot Tests

The harvesting results of the field plots are given in Table 1. These results showed that the fruit removal was 96.1% for trees sprayed with abscission chemical and 90.0% for unsprayed trees. Average limb attachments per tree were less for sprayed trees (2.4) than for unsprayed trees (4.1). The average harvesting rate was 35.6 trees/hr for sprayed trees and 22.5 trees/hr for unsprayed trees.

In the 'Valencia' tests (I and II) fewer green fruit were removed from the chemically sprayed trees than from the unsprayed trees, and the shaking time was about the same.

Field Tests

High leaf drop and a 26.2% preharvest fruit drop resulted from the abscission chemical applications in the Orange-co 'Parson Brown' grove. The resulting open trees gave the shaker operator a good view of the attachment point on the limb and enabled him to increase his harvesting

²Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

Table 1. Data and Results of Plot Test With FPP-RW Limb Shaker

Test Date	Chemical vs check		Acti-Aid vs Release		Valencia I		Valencia II	
	Jan. 9		Jan. 14		May 12		May 28	
Variety	Parson Brown		Parson Brown		Valencia		Valencia	
No. trees	24		48		10		10	
Treatment	Chem.	Ck.	A.A.	Rel.	Chem.	Ck.	Chem.	Ck.
Limbs/tree, No.	2.9	4.4	1.9	2.1	2.0	3.4	3.2	4.6
Shake time/ limb, min	0.06	0.07	0.06	0.09	0.13	0.12	0.09	0.10
Fruit predrop, %	15.3	0	26.2	9.3	11.4	0	16.0	0
Fruit removed, %	94.9	91.6	98.3	96.2	95.7	89.7	95.5	88.6
Green fruit removed, No.	77	174	211	289
Harvest rate (trees/hr)	31.6	26.7	43.8	42.3	33.3	22.1	26.8	18.6
Fruit yield (lb/tree)	415	301	452	355	527	434	366	419

efficiency over that in other groves. Also, only one limb attachment was required in a high percentage of the trees to produce good shaking action and fruit removal from the entire tree. The harvesting rates, which were recorded for four 30-minute time periods, were 52, 62, 74, and 66 trees per hour respectively. These harvesting rates were for ideal harvesting conditions (loose fruit, open trees, minimum number of limbs, experienced operator and good weather). Ideal harvesting conditions do not occur in a high percentage of the average orange groves. However, the results indicated that under proper conditions, harvesting rates can be high with the FPP-RW limb shaker unit.

The abscission chemical applied in the Patrick Fruit Co. grove was not effective, and no leaves or fruit drop occurred before harvest time. About six limb attachments were made per tree, and it was difficult for the operator to get the shaker into the tree and make attachments. The harvesting rate with the FPP-RW limb shaker unit was 20 trees per hour with the experienced USDA operator. The harvesting rate with the Pounds shaker, which required two Patrick Fruit Co. operators, was only 10 to 12 trees per hour.

Shaker operators with the Patrick Fruit Co.

used the FPP-RW limb shaker unit for several days to compare the full-hydraulic-powered positioning system with the semi-powered system of the tractor-mounted shaker. After a day of operating, they were able to harvest 15 or more trees per hour. They liked the one-man full-powered positioning system because it required less operator effort and was more efficient than was the Pounds tractor-mounted shaker. The FPP-RW limb shaker unit had adequate shaking power and was effective in shaking large limbs. It also required fewer limb attachments than did the Pounds limb shaker. About one day was required for a new operator to get familiar with the shaker and its controls and to obtain a harvesting rate near the full shaker capacity in a particular grove situation. However, only two hours were needed to obtain what was considered an acceptable harvesting rate.

Problems found in the machine design were:

(a) The shaker boom was too short, (b) wheel sweeps were needed to remove fruit from under the wheels, and (c) the limb clamp was too large and would not hold on wet limbs. The FPP-RW limb shaker harvested over 700 orange trees over the last two harvest seasons, with only a few minor changes and repairs.

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ORANGE YIELD AND REMOVAL STUDIES WITH AIR AND TRUNK SHAKERS USING TWO ABSCISSION CHEMICALS

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Abstract. The abscission chemicals Release and Acti-Aid were applied to 'Queen' oranges during the bloom period and to 'Valencia' oranges at 3 stages of young fruit development. In 'Queen' oranges, air and trunk shakers averaged 98% and 92% mature fruit removal with Release and Acti-Aid, respectively; in 'Valencia' oranges, 86% and 74%. Subsequent fruit yields of 'Queen' orange trees were not significantly reduced by the use of either shaker or chemical. In 'Valencia' oranges, Acti-Aid significantly reduced subsequent yields when harvested at the early stages of young fruit development, whereas Release did not reduce yields at any stage on handpicked trees. The average effect of both shakers with Release reduced subsequent fruit yields 15%.

During past seasons and up until the 1975 'Valencia' season, fruit removal in mechanical harvesting systems used by Florida growers has been for the most part by air, trunk, and limb shakers with the fruit loosening assistance of the abscission chemical, Acti-Aid. Fruit removal with shakers during each season has been confined mainly to early and midseason oranges prior to the period of tree flush and bloom. During this period and through the 'Valencia' season, shaker concepts (with or without Acti-Aid) have not demonstrated an acceptable level of performance because of low percentage mature fruit removals and/or reductions in subsequent yields.

Tests on a new abscission chemical, Release (formerly ABG-3030), were reported in 1973 (4) and 1974 (1). It demonstrated little or no apparent damage to new growth, blooms, and young fruit while usually providing a significant amount of mature fruit loosening. During the 1975 'Valencia' season, an experimental use label was obtained from the EPA on Release for use on round oranges.

In this paper, fruit removal efficiencies and subsequent yields are reported on experiments of one year duration using the OMC trunk shaker and the AREC air shaker with Acti-Aid or Release. Similar reports have been made to this Society on air shakers and Acti-Aid (2,3) but not on trunk shakers or Release.

Methods and Materials

Figs. 1 and 2 show the AREC air shaker and the OMC trunk shaker used for mechanical fruit removal in the experiments. The air shaker was constructed in 1973 and consisted of 2 engines and 3 vane-axial fans with a total air moving capability of approximately 180,000 cfm. For fruit removal, the air shaker made 2 passes per tree, 1 on each side in the wide middle. The trunk shaker was OMC's latest 3-wheel model designed for citrus. Fruit removal was achieved by first clamping and shaking the tree trunk. If mature fruit removal was judged to be too low, additional clamping and shaking proceeded on the main lateral limbs.

A total of 5 tests were conducted with Tests 1 and 2 in 'Queen' oranges and Tests 3, 4, and 5 in 'Valencia' oranges. Each test included 28 trees with 7 treatments (Table 1) replicated 4 times on 1-tree plots. Treatments 1 through 6 were arranged in a split plot design with abscission chemicals (Release and Acti-Aid) as the main plots and removal methods (air, trunk, hand) as sub plots. Treatment 7 (handpick, no chemical)

¹Florida Agricultural Experiment Station Journal Series No. 7039.

²Cooperative research by the University of Florida, Agricultural Research and Education Center, the U.S. Department of Agriculture, and the State of Florida, Department of Citrus at Lake Alfred, Florida.