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CITRUS HARVEST RESULTS WITH THE AIR SHAKER CONCEPT

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Abstract. **In 1969 and 1970, harvest tests were conducted with the FMC air shaker and abscission chemicals in 'Hamlin,' 'Parson Brown,' and 'Valencia' oranges. Subsequent 'Hamlin' and 'Parson Brown' yields in 1970 and 1971 were not significantly reduced by machine or chemical treatments. In 'Valencia' oranges, yields were reduced 15 to 40% by the machine treatments, but none by the chemical treatments. These effects in 'Valencia' oranges were associated with the time in the harvest season when the immature fruit diameter was approximately 1.5 inches. Mature fruit removal for all 3 varieties ranged from 55 to 100%.**

In 1971, harvest tests were conducted with the AREC-LA air shaker and abscission chemicals in 'Pineapple' and 'Valencia' oranges. In comparison with 1971 yields, 1972 'Pineapple' yields were reduced by 88% and 65% in machine-chemical and handpicked treatments, respectively. The 1971-72 winter freezes obviously affected 1972 yields. In 'Valencias' (late in season) yields were reduced 20 to 30% by both air shaker and chemical. Fruit removals in both varieties ranged between 50 and 98%.

The annual value and yield of the Florida citrus crop averaged 264 million dollars and 145 million boxes over the past decade (1). During the same period, the cost of picking oranges and grapefruit increased by 75% (3). In recent years, per acre picking costs have often doubled the production costs in high yielding orange groves. In an effort to slow or halt this upward trend in picking costs, development of mechanical harvesting concepts has been underway over the last several years (2). Previous development work and results on the air shaker concept were reported to this society in 1968 (4). This paper reports results since 1969.

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Materials and Methods

FMC-3 Two-Year Study

A 2-year harvesting study of 'Hamlin,' 'Parson Brown,' and 'Valencia' oranges was initiated in 1969 to evaluate FMC's latest model air shaker (FMC-3) (See Fig. 1). Tree heights in the 3 varieties averaged 20, 15, and 22 feet, respectively. Abscission chemicals were used in an attempt to reduce the fruit bonding force. The objectives of this study were to determine (with and without abscission chemicals) (a) the effect of the air shaker concept on subsequent fruit yields and (b) the percentage fruit removal of the concept.

A harvesting experiment was set up in each variety in a similar manner as follows. Twenty-four trees were included in a split-plot-in-space-and-time (season) design with 4 replications. Each replication was split into 2 main units. One main unit was sprayed with an abscission chemical. The other was left as a control for the chemical treatment. Each tree received approximately 15 gallons of spray mixture. In 1969, 'Hamlins' and 'Parson Browns' were sprayed with hexamic acid (2 lb./tree) while 'Valencias' were sprayed with cycloheximide at 20 ppm (4% cycloheximide, 23 ml/tree). In 1970, a 20 ppm mixture of cycloheximide (CHI) was used on all 3 vari-

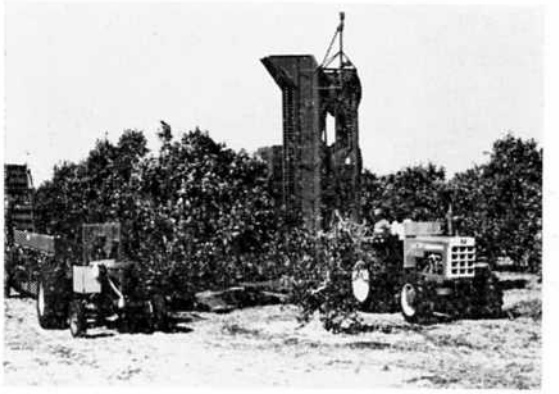

Fig. 1. Front view of FMC-3 harvest system. The air shaker is the vertical tower on the right. Air was discharged at 100 mph from 2, 10-inch wide openings, 20 feet high, 39 inches apart, and converging at a 30° acute angle. Air was oscillated by wobble plates at 70 cpm.

ties. Within each main unit, 3 harvesting treatments (methods of removal) were used, one method per tree. The treatments included in the 2 main units in each replication are shown in Table 1. With the treatments involving the FMC-3, 2 passes were made per tree or 1 pass on either side of the tree.

Pull tests were made to determine the bonding force of both fruit and leaves. Individual fruit weights were also determined to calculate a ratio of fruit bonding force (F) to fruit weight (W), or a F/W ratio, which is a measure of the ease of fruit removal. Leaf bonding force was recorded because, in previous experiments, leaf droppage had been observed after the application of some abscission chemicals. Increased leaf removal by the FMC-3 was inevitable if the bonding force of the leaves was reduced significantly and could be detrimental to tree health and vigor. This could also conceivably reduce the fruit removal effectiveness of the FMC-3 since it depends on air drag of the leaves to impart shaking energy into the tree.

Yields and removal data were recorded in 1969 and 1970 while only yield data were recorded in 1971. In all cases, data in successive years for a given treatment represent the same trees.

AREC-LA Air Shaker

'Pineapple' oranges. The first experiment with AREC-LA air shaker (Fig. 2) was initiated in 1971 in 'Pineapple' orange trees ranging from 12 to 20 feet in height. Prior to the experiment, the trees had sustained severe freeze damage and had dropped 1.5 boxes of fruit per tree. The dropped fruit was destroyed and 7 boxes remained per tree. Eighty-two trees were sprayed in February with 20 ppm cycloheximide (23 ml of 4% cycloheximide in 20 gallons of water per tree). Fruit bonding forces were determined by pull tests and the fruit was harvested at 5, 6, and 7 days after spraying. In 1972, fruit yields on the same trees were estimated.

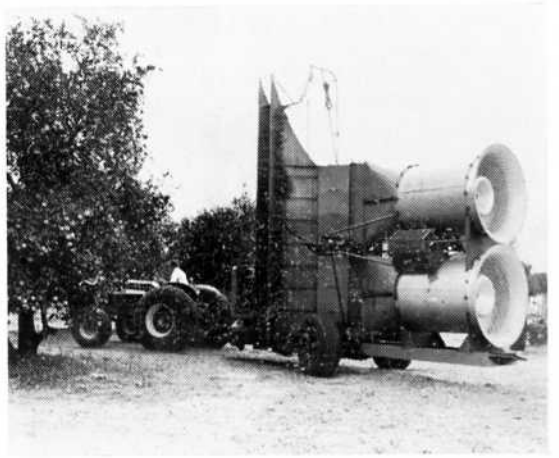

Fig. 2. AREC-LA air shaker. Air was discharged at 100 mph through one opening, 1 foot wide by 14 feet high. Air manipulated by oscillating, out-of-phase, horizontal vanes at 60 cpm.

'Valencia' oranges. This harvest experiment was initiated in 1970 on 45 trees which averaged 20 feet high. It was designed to (a) test the effectiveness of cycloheximide in loosening mature 'Valencias' late in the harvest season and (b) determine the mature and young fruit removal characteristics of the AREC-La air shaker. On each of 3 dates at weekly intervals starting June 1, 3 harvesting treatments were applied to 15 trees or 5 replications (trees) per treatment. The treatments were cycloheximide + air shaker, cycloheximide + handpick, and handpick. The cycloheximide spray solution was applied approximately 4 days prior to harvest at each date. Cycloheximide spray mixtures (Table 2) were applied in 10 gallons of water per tree. Phosphoric acid (H_3PO_4) was added in the latter tests because an alkaline condition on the fruit was thought to have reduced the effectiveness of CHI on the May 27 application. Data were recorded in 1971 on mature fruit yield, mature and young fruit removal and bonding forces, and harvest rate. In 1972, only mature fruit yields were recorded.

Results and Discussion

FMC-3 Two-Year Study

Fig. 3 summarizes the results of the 2-year study. Percent removal and related data are shown for 1969 and 1970. Bars representing yields compare the average in 1969 with overall average in 1970 and 1971, inclusive. In addition, the percentage increase or decrease in yield is shown at the top of the bars. Statistical analyses were conducted on the 1970-71 yield data at the .05 level of significance.

In 'Hamlin' oranges, chemical effects and method of harvest had no significant effect on yields. Percent fruit drop prior to harvest was greater with the chemically treated trees (Treatments 2, 4, 6), the result of a reduced F/W ratio for the fruit. As expected, percentage fruit removal of the FMC-3 was greatly increased as a result of the reduced F/W. In fact, the F/W was reduced sufficiently in 1970 that near 100% re-

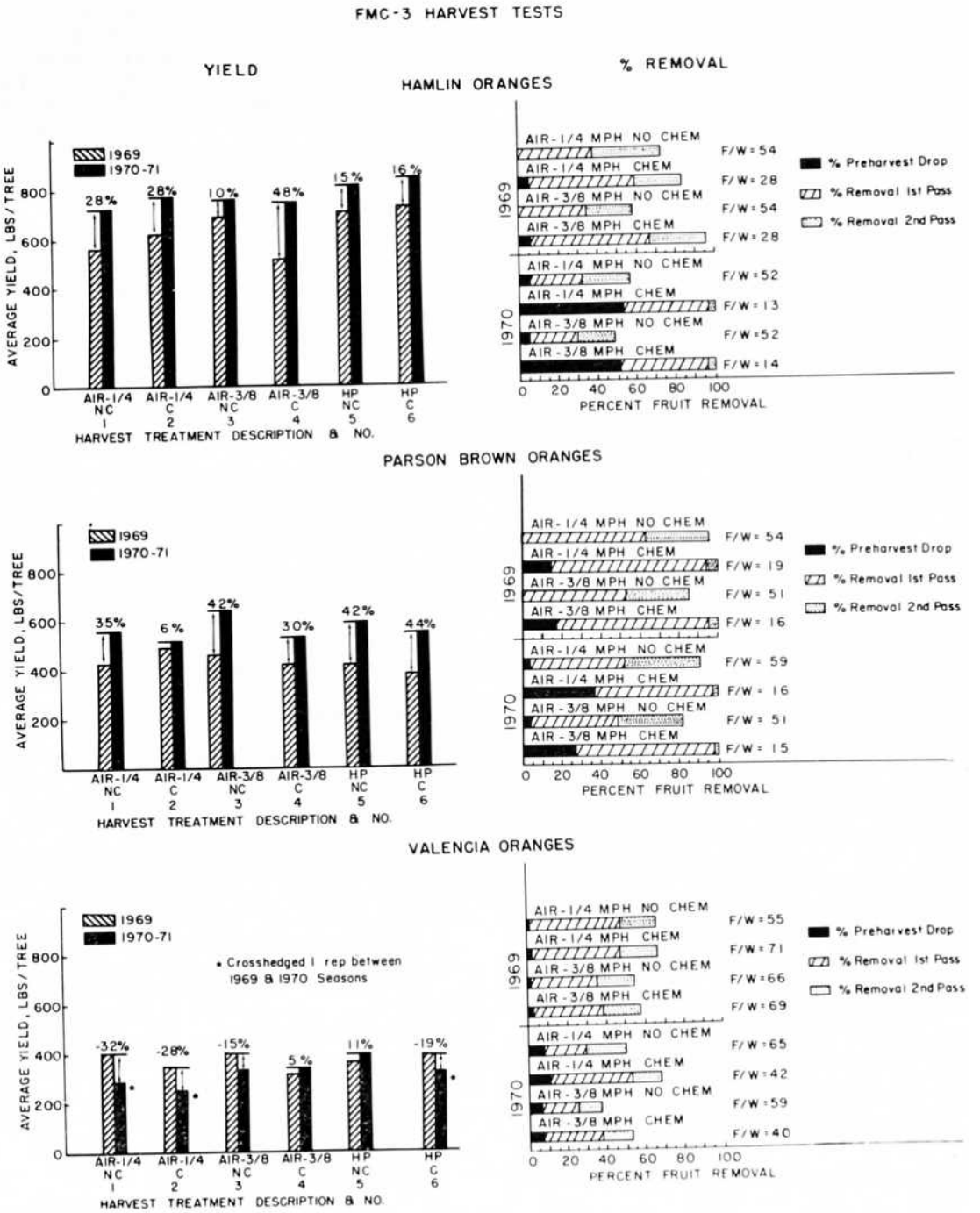

Fig. 3. Yield and percent fruit removal from trees in the FMC-3 2-year study. NC=no abscission chemical; C=abscission chemical. FMC-3 operated at ground speeds of 1/4 and 3/8 mph.

Table 1. Treatments applied in the FMC-3 two-year study.

Treatment No.	Description[z]
1	FMC-3, 1/4 mph ground speed, no chemical applied
2	FMC-3, 1/4 mph ground speed, chemical applied
3	FMC-3, 3/8 mph ground speed, no chemical applied
4	FMC-3, 3/8 mph ground speed, chemical applied
5	Handpick, no chemical applied (check)
6	Handpick, chemical applied

[z]Air discharged from FMC-3 at approximately 100 mph from two, 10-inch wide discharges, 39 inches apart and converging at a 30° acute angle. Two passes were made per tree. One-spiral wobble plate 9 inches apart on shaft operating at 70 rpm. Rotation of wobble-plate shafts was synchronized.

moval could probably have been obtained at 1/2 to 3/4 mph and 2 passes per tree since better than 95% removal resulted after 1 pass at 3/8 mph. Leaf bonding force was not significantly affected by the chemicals.

Average 'Parson Brown' per tree yields for 1970 were significantly higher (643 lb.) than those of 1971 (484 lb.). Neither chemicals or methods of harvest significantly affected yields for 1970 or 1971. Chemicals did not significantly reduce the leaf bonding force. Chemicals reduced the F/W ratio of the fruit by 2/3 and markedly increased preharvest fruit drop and percent fruit removal of the FMC-3, especially at 3/8 mph. As with 'Hamlin' oranges, percent removal by the FMC-3 with the chemically sprayed trees would probably have been near 100% at 1/2 to 3/4 mph and 2 passes per tree.

'Valencia' young fruit diameters averaged 1.36 and 1.67 inches, respectively, at the time of the 1969 and 1970 harvests. The 1970 yield average (346 lb.) of all trees was significantly higher than that of 1969 (291 lb.). Chemical effects were not statistically significant when all treatments were considered. However, Wilson (5) has observed that some abscission chemicals, when applied early portion of the season, can substantially reduce 'Valencia' yields. Yields associated with Treatment 5 (handpick check) were significantly greater than those of all other treatments. In addition, yields associated with the handpick method (Treatments 5 and 6) were not significantly greater than FMC-3 method at 3/8 mph (Treatments 3 and 4). The FMC-3 method at 1/4 mph (Treatments 1 and 2) significantly reduced yields when compared to the other 2 methods. It should be stated that average yields for 1970-71 were lowest for Treatments 1, 2, and 6; these were also the treatments in which 1 tree or 1 replication (out of 4) was accidentally cross-hedged between the 1969 and 1970 harvests. The yield data from these 3 trees were included in the above analysis of variance. With and without chemicals, 'Valencia' yields were reduced an average of 15 and 40% with FMC-3 at 3/8 mph and 1/4 mph, respectively. The time of harvest associated with these yield reductions corresponds to a young fruit diameter in the neighborhood of 1.5 inches.

Percentage mature fruit removal in 'Valencia' oranges was not good in 1969 or 1970, even with the chemical. In 1969, the chemicals were applied twice with no mature fruit loosening. The F/W ratio of the mature fruit in 1970 was reduced by about 1/3, but was not adequate to substantially increase mature fruit removal. The F/W of the young fruit and the leaf bonding force were not affected by the chemical in either year.

Table 2. Chemicals used in 10 gal of water per tree in the 3 AREC-LA air shaker harvest tests in 'Valencia' oranges.

Date	4% CHI, mls	X-77 surfactant, mls	H_3PO_4, mls
5/27	25	40	0
6/3	25	40	50
6/10	20	20	50

AREC-LA Air Shaker

'Pineapple' oranges. Results are shown in Table 3. Excellent fruit loosening, substantial preharvest fruit drop, and high percent removals and harvest rates resulted in this test. Leaf abscission, preharvest and post harvest, was excessive. It was felt that the uniformity and magnitude of fruit and leaf loosening must be attributed to both the chemical and freeze damage. Also, a high brix/acid ratio (17.4) probably contributed to the excellent fruit loosening.

Fruit yields in 1971 were estimated. Although no check trees were provided in the experiment, fruit yields of trees in adjacent rows which had been handpicked in 1971 were estimated for com-

Table 3. Summary of AREC-LA air shaker harvest results in 'Pineapple' oranges (1971).

Date	Avg. F/W[z]	No. of trees	Est. preharvest drop, % of yield	% Removal[y]	Harvest rate boxes/hr[x]
2/17	32	14	7	89	135
2/18	22	13	15	94	260
2/19	18	54	25	97	660

[z]F/W fruit bonding force (paralled to fruit axis) to fruit weight ratio.

[y]Includes preharvest drop.

[x]Includes preharvest drop and assumes 100% time efficiency.

Table 4. Summary of AREC-LA harvest results in 'Valencia' oranges, 1971-72.

Treatment	Fruit yield ratio, lb/lb, 1972/71[z]	Avg., fruit F/W[y] Mature	Immature	% Removal mature fruit	Mature fruit Harvest rate boxes/hour[x]
Handpick	$\frac{648}{521}$ = 1.24	49	464	100	-
CHI & handpick	$\frac{557}{544}$ = 1.02	35	508	100	-
CHI & air shaker	$\frac{449}{472}$ = 0.95	35	508	58.8	70

[z]Average per tree fruit yield ratio, 1972/1971. Harvest tests in 1971 conducted June 1-16.

[y]Bonding force (straight pull paralled to fruit axis) to fruit weight ratio. Average mature and immature fruit weight was 0.45 lb. and 19.6 grams, respectively.

[x]Assume 100% time efficiency.

parison. Fruit yields of the treatment and handpicked trees were estimated at 1 and 3 boxes, respectively. Since the 1971 yield (prior to freeze damage) averaged 8.5 boxes per tree, treatment and handpicked yields were reduced 7.5 and 5.5 boxes. respectively.

'Valencia' oranges. Table 4 summarizes the AREC-LA 'Valencia' harvest results at the 3 harvest dates from first to mid-June. Fruit yields of the CHI + handpick and CHI + air shaker trees were reduced by 20 to 30% when compared to the handpicked trees (see fruit yield ratio column). Mature fruit loosening by CHI was not adequate to obtain a high percentage removal and harvest rate with the air shaker.

To summarize the results for all orange varieties and both air shakers, harvest tests were conducted over a 4-year period under varying grove and weather conditions. Percentage fruit removals (50 to 100%) and fruit removal rates (70 to 500 boxes per hour) were very much dependent on the fruit bonding force. Satisfactory percentage fruit removals and removal rates were achieved when the average bonding force was approximately 5 to 8 lb. Cycloheximide was not consistent in providing this magnitude of fruit loosening. Subsequent fruit yields in early and mid-season oranges were materially affected only when complicated by severe freeze damage to the trees. Excessive leaf removal did occur when the leaf bonding force was significantly reduced by either freeze or chemical. In harvesting 'Valencia' oranges late in the season, subsequent mature fruit yields were reduced by 20 to 40%, mainly the result of immature fruit removal. Also, low percentage fruit removals and rates of removal were generally obtained in 'Valencia' oranges.

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