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CHEMICAL AND AIR SHAKER ORANGE REMOVAL IN SOUTH FLORIDA (LABELLE)[1,2]

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Abstract. **A series of harvesting experiments was conducted under commercial conditions with oranges** (Citrus sinensis **Osbeck, cv Hamlin). Trees were on 8-row beds with no water furrow. Abscission sprays were applied with air carrier sprayers and trees were shaken with an experimental air shaker using a conical scanning air delivery system at a harvest rate of 1.5 acres (0.6 ha) per hour. Fruit removal percentages ranged from 97 to 99. Uniform spray coverage was necessary to achieve these high recovery rates. The most effective chemical combination was Release (100 ppm) and Acti-Aid (1.5-2.5 ppm). The low Acti-Aid concentrations improved fruit loosening with minimal leaf losses. The number of degree-hours above 60°F (16°C) for January-February, 1979 was computed to be 19% and 40.6% greater than for comparable groves near Lake Alfred (central Florida) and Tavares (north-central Florida), respectively. These higher temperatures could be the principal reason that the fruit removal effort was more successful in the south Florida area.**

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The estimated total cost of removing the fruit to the ground was $0.41/box (40.8 kg).

Over the past 20 years, many harvesting experiments, with or without abscission (loosening) chemicals, have been conducted under field conditions. In general, results of most of these tests with early and midseason oranges (E-MS) have concluded that limb shakers, with or without catching frames, are suitable for most Florida citrus trees which are sufficiently open (or can be opened by light pruning) to allow attachment of the tree clamps (1). Abscission chemicals are not necessarily needed for these systems, however, their use is beneficial as an aid to speed fruit removal, increase removal efficiency and lessen power requirements necessary to shake a tree. Since chemical loosening is not always effective, its use has not allowed development of less powerful and expensive shaking equipment.

The citrus industry is interested in the air shaker method of fruit removal because its high removal rate (capacity) holds removal cost per box of harvested fruit to a minimum. Machine repairs are inherently less as the shaking power is distributed constantly to the tree through the air delivery system without reaction vibrations transmitted into the machine. The problem of adopting the air shaker approach to fruit removal for E-MS oranges has been 1) erratic abscission chemical behavior, which seems to be principally due to adverse weather effects during the winter months, and 2) application of abscission chemicals requires uniform fruit coverage for air harvester operations, as the mode of action as these chemicals is entirely by contact with the fruit (5). It is well recognized that abscission is a biological process, and is temperature dependent.

The purpose of this paper is to summarize experimental fruit removal results achieved during the 1978-79 fruit season in Florida using abscission chemicals and a newly designed conical scanning air shaker for harvesting bedded groves prevalent in south Florida. Fruit collection and handling is covered in another publication (3).

Material and Methods

Trees were sprayed with air carrier sprayers. Sprayers were nozzled so that approx 2/3 of the solution was applied in the top 1/3 of the trees. Nozzles were large-orifice (dilute) type to obtain large droplet sizes for better fruit coverage. Sprayer ground speed was 3/4 mph (1.2 kmh) and application rate was 750 gal (2839 *l*) per acre (0.4 ha). The FDOC modified Agtec Sprayer was used on the first test; an FMC 757 (double oscillating volute) Speedsprayer was used on all subsequent tests. Abscission chemicals used in the test were tank mix combinations of Release (5-chloro-2-methyl-4-nitro-1H pyrazole) and Acti-Aid (cycloheximide) at concn of 100 ppm Release + 1.5-2.5 ppm Acti-Aid with 0.1% Ortho X-77 surfactant. Pik-Off (dioxylglyoxime) was used in one test (no surfactant). Trees were 15-years-of-age, height was 13 ft (4.0 m) and every other tree was cross hedged. Tree planting distances were 15 ft (4.6 m) x 25 ft (7.6 m) on 8-row beds with no water furrows; treatments were of single row either 1/4 mile (0.4 km) or 1/2 mile (0.8 km) in length. Fruit removal force (FRF) readings and fruit drop counts were made from 5 or more randomly selected trees in the row. Leaf drop observations and other pertinent data was also collected from these trees. Fruit removal efficiency was obtained by randomly counting the fruit remaining on 20 trees from each treatment and by computing total number of fruit on trees from weight of fruit recovered in the harvest operations. Removal efficiency was compared to that obtained from an adjacent block handpicked by a commercial crew.

Temp for these tests and other comparative temp data were collected from thermographs located in or near treatment plots where mechanical harvesting operations were conducted regularly. Computation of degrees x hours (dg-hrs) (an integration of the area 60°F (15.6°C) and above on temp-time chart) for each day were manually obtained from these official thermograph records.

An air shaker (Fig. 1) designed and built by the FDOC at AREC-Lake Alfred, utilizing a conical scanning air delivery system, was used for removing the fruit. The machine

Fig. 1. Air harvester developed by FDOC utilizing conical scanning air delivery system.

used a 54-inch diameter vane axial fan driven by diesel engine rated at 150 continuous horsepower. Air was applied to the tree by means of a fixed vane assembly rotated about the axis of air flow, thus distributing the air in a conical pattern as the machine progressed down the tree row. The trees were shaken by making a pass down each side of row.

During harvest operations the fan center was positioned to a height of 7 ft to obtain a shaking action of the tree skirts and at the same time deliver enough air to the top part of the tree for maximum fruit removal.

The shaker was operated at a forward speed of 1 mph (1.6 km/hr), a fan speed of 1500 rpm (25 Hz) and an oscillator rotation rate of 70 rpm (1.2 Hz). These machine settings were determined for this grove situation by tree size, foliage density, fruit load and FRF.

Results and Discussion

Abscission chemicals produced generally excellent and consistent loosening of fruit in the south Florida region (Table 1) when applied under the prevailing climatic conditions for these dates. FRF was low enough (5 lb or less) for the air shaker to achieve high fruit removal efficiencies (96-99%). Preharvest fruit drop ranged from 8 to 97% with the highest dropped at the lowest FRF. When less than favorable weather conditions intervened, causing some retardation of chemical loosening, the air shaker was able to override the lessened activity of the chemical and still achieve an acceptable removal efficiency. However, severe adverse weather (rain following application, etc.) could cause fruit loosening levels that could not be satisfactorily over-ridden. The air shaker's fruit removal efficiencies were comparable in a majority of the tests to the 99% obtained from a hand picking crew in an adjoining block.

Table 1. The effects of date of application and temperatures on the performance of abscission chemicals and air shaker on fruit removal of 'Hamlin' oranges at LaBelle, Florida.

Spray date	Treatment[z]	Days after appl.	60° & above dg-hrs[y]	FRF (lb) & SD	Preharvest drop (%)[x]	Temp 1st day	Air shaker removal (%)[w]
1/18	100 + 2.5	4	629	2.95 ± 2.47	87	76-49	96.7
1/25	100 + 2.5	6	240	5.34 ± 2.53	18	57-42	98.0
2/ 2	100 + 2.5	4	302	1.87 ± 1.65	92	64-40	99.4
2/ 9	100 + 2.0	4	236	3.39 ± 1.83	8	68-34	96.2
2/14	100 + 1.5	4	794	2.63 ± 1.82	65	77-47	99.2
2/22	100 + 1.5	4	1200	1.90 ± 0.98	97	84-66	99.4
2/22	5 qts/500 (PO)	4	1200	2.03 ± 1.35	76	84-66	99.4
Control	(handpick)	—	—	11.98 ± 2.60	0.5	—	99.1

[z]Treatment on 1/18 was applied with FDOC modified Agtec sprayer; all others were applied with FMC 757 (double oscillating volute) sprayer. Treatments were combinations (Release + Acti-Aid) of abscission chemicals except the 2/22 treatment was Pik-Off (PO) at 5 qts/500 gal (300 ppm).
[y]Computed from official NOAA weather thermographs for LaBelle, Florida (located at Alico).
[x]Trees averaged 825 fruit.
[w]Air shaker used was FDOC experimental model with conical scanning air delivery system.

These field observations indicate that to produce excellent fruit loosening following an application of abscission chemicals, 300 or more dg-hrs are necessary within a 3-4 day period (Table 1). Generally, the dg-hrs after spray varies inversely with FRF. The temp at the time of spray application is probably also involved, however, more specific comments regarding these factors must await additional future temp studies under more controlled conditions. Weather and its predictability, through its effect on fruit loosening, play a most important function in the overall success of the air shaker, particularly since the air shaker requires excellent loosening for high fruit removal efficiencies economically necessary in Florida (4).

The air shaker removed fruit at the rate of 650 boxes (26,535 kg) per hr or a harvest rate of 170 trees per hr. This rate was more than adequate to be compatible with other components in a complete mechanical harvest system (3). The air shaker performed well mechanically with only minor adjustments necessary. However, longer periods of use will be necessary to prove machine reliability.

Air shaker performance in other portions of the state has generally been very erratic, usually because of poor fruit loosening. A comparison of locations in south, central and north-central Florida showed a 19 and 36% reduction, respectively, in a total number of dg-hrs during January and February, 1979 (Table 2). (However, individual stations in an area may vary somewhat because of elevation,

Table 2. Integration of temperatures (60°F and above) for the period January 1-February 28, 1979 for 5 locations in the Florida citrus growing region.

Location	Dg-hrs (60°F and above)[z]	% reduction from Alico
LaBelle (Alico)	6176	—
Coke block	5024	19
Experiment Station (LA)	3667	41
Tavares	3945	36
Immokalee Exp. Station	7101	(15)

[z]Integrations were performed manually by computing total degrees x hrs from thermographs located at these locations.

proximity to lakes, etc.). Although these figures alone do not account for all the failures of fruit loosening observed, it is known that warm and dry weather conditions in the winter harvesting period usually produce the most successful fruit removal operations. Very cold periods, wet or dry, almost always have resulted in delayed and inadequate fruit loosening. It would appear from these data that south Florida would be an area where fewer abscission failures due to low temps should occur, and the probability of achieving consistently good air shaker efficiencies should be higher.

The initial spray application (Jan. 18) was made using an AG-TEC sprayer as indicated (Table 1). Although this sprayer had an 8 ft (2.4 m) tower, visual observations showed that spray penetration into the short, thick-foliaged trees was not always thorough. Subsequent observations showed that areas, particularly between trees and in the interior of the tops, showed little or no effects (fruit pitting) from the applied chemical.

All subsequent tests were made using an FMC 757 sprayer which had no tower but utilized double oscillators to divert the carrier air stream so that branches on the trees were caused to move (during the time the sprayer passed the tree) resulting in better tree penetration and coverage. The large droplet size obtained with larger orifices also seemed to improve total coverage. Using this sprayer as described produced almost total fruit coverage with the gallonages used. Our observations of other spraying operations indicated that spraying for abscission will require more care than is currently being displayed by most growers to spray pesticides.

Cost analysis based on a harvest capacity of 1800 boxes per day showed the abscission chemical expense, fixed and variable costs of the spraying and of the shaking operations to be near $0.18, $0.07 and $0.16 per box, respectively. The total cost of dropping fruit to the ground was $0.41 per box (2).

These experiments indicate that when fruit is uniformly, chemically loosened to an FRF of 2-4 lb and substantial percentages have dropped, the conical scanning air shaker can remove fruit at efficiencies comparable to handpicking. The application of these findings to a full scale operation raises other questions that must be appraised: 1) how consistent can effective fruit loosening be achieved during the 50-day harvest season and 2) can a seasonal harvest capacity be achieved to make the system cost effective.

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