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FIELD TEST RESULTS WITH MECHANICAL CITRUS FRUIT REMOVAL DEVICES

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Abstract. **The field performances of four machines were evaluated for mechanical removal of oranges from the tree during the 1995-96 season. After 5 to 20 sec of shaking per tree, Compton trunk shakers removed 67 to 98% of the fruit and Orchard and Grove Machinery trunk shakers removed 63 to 96% of the fruit. Trunk diameters ranged from 5 to 11 inches. Fruit removal was directly related to shaker head displacements which varied from 1 to 2 inches. A canopy shaker with 2 nylon-spoked drums oscillating at 3.5 inches displacements removed 70 to 90% of the fruit in the canopy volume penetrated by the spokes and 52 to 70% between the outer canopy and the trunkline or tree center. Fruit removal generally decreased with increasing ground speed from 1 to 2 mph. The fourth unit was the Crunkelton machine which had a rectangular array of 7 ft long tubes with spring loaded fingers which were inserted and withdrawn from the tree canopy. Within the canopy volume penetrated by the tubes, 67 to 77% of the fruit was removed after 1 insertion and 73 to 91% was removed after 2 insertions.**

Citrus harvesting research and development efforts in Florida through 1994 have been reviewed by Whitney (1995). Most of these efforts were undertaken from the late 1950s to the early 1980s. During the decade of the 1980s, the Florida citrus industry experienced a succession of very devastating freezes which reduced production to about one-half the record 1979-80 crop. High fruit prices coupled with low production and very adequate harvesting labor minimized interest in mechanical harvesting until 1991 when new citrus plantings in South Florida were reaching full production and fruit prices dropped significantly. At the request of the industry, new harvesting research was initiated in 1992 and the effects of manual harvesting practices on fruit quality were investigated and reported by Miller et al. (1995). One company, Fruit Harvesters International, initiated development of a commercial mechanical harvesting system (trunk shake-catch) in 1993.

To further assess the harvesting situation and recommend courses of action, a harvesting symposium (Florida Citrus Commission, 1993) and a think tank (Florida Citrus Commission, 1994) were sponsored by the Florida citrus industry. Subsequently, a research and development program with the purpose of developing harvest methods to ensure the harvesting of future crops at a competitive cost was established in 1994 and administered by the Florida Department of Citrus (FDOC). For the 1995-96 season, the FDOC contracted with several individuals and companies to build mechanical citrus removal devices or machines to be field tested.

The objective of this study was to evaluate four mechanical citrus fruit removal devices under field conditions for early, midseason, and Valencia oranges intended for processing. The evaluations included measuring fruit removal performance and tree characteristics, and observing tree damage. More details on the field evaluations can be found in the 1996 final report on FDOC Contract 95045 (Whitney, 1996) and Whitney (1997).

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Materials and Methods

The four machines evaluated were trunk shakers from Compton Enterprises, Inc. (Chico, CA) and Orchard Grove and Machinery Company (Albany, GA), a canopy shaker from the USDA (Kearneysville, WV), and the Crunkelton machine from William S. Crunkelton (Avon Park, FL).

Trunk shaker tests. All trunk shaker tests were conducted in early, midseason, and Valencia orange groves in South Florida. The trees were planted on 2-row beds and tree spacings of 22 to 26 ft by 10 to 15 ft. To provide access for the shakers to the trunks, tree canopies were skirted to a height above ground of about 18 to 20 inches at the trunk and 3 ft at the edge of the canopy. Shaker treatments were replicated 4 to 6 times on individual or paired trees in a replicated block design. All shaker heads were side mounted and used a scissors-type clamp with cylindrically shaped pads filled with plastic particles. The unbalanced masses which provided the shaking action were belt driven with hydraulic motors.

Compton shaker tests. Two Compton trunk shaker heads (1 & 2) were tested in Hamlin, Parson Brown, Pineapple, and Valencia orange trees. Each head had 2 sets of unbalanced masses which rotated in the same direction about a single vertical shaft near the center of the head. One set of masses rotated 10 to 15% faster than the other and they operated at 8 to 10 Hz for all tests. Shake times per tree ranged from 5 to 15 sec. Shaker heads 1 and 2 developed displacements of ca. 1.6 and 2+ inches, respectively. Seven tests were conducted with shaker head 1 in early and midseason oranges between December 1995 and February 1996. Eight tests were conducted with shaker head 2 in early, midseason, and Valencia oranges between January and May 1996. Four of the tests with each shaker compared the performance of the 2 shakers under similar grove conditions.

Orchard Grove and Machinery shaker tests. Three Orchard Grove and Machinery (OG&M) shaker heads were tested. Shaker heads 1 and 2, manufactured by Orchard Machinery Corporation, Yuba City, CA, rotated 2 sets of unbalanced masses in the opposite and same directions, respectively. They were configured similar to the Compton shaker heads. One test each was conducted with the shaker heads 1 and 2 in Valencia orange trees. Shaker head 3, a OG&M modified version of shaker head 2, rotated only 1 unbalanced mass about its mounting shaft. Two tests were conducted with shaker head 2 in Valencia orange trees. For shaker heads 1 and 2, shake times per tree ranged from 10 to 20 sec at up to 15 Hz; for shaker head 3, shake times per tree ranged from 5 to 20 sec at 8 to 10 Hz. Shakers 1 and 2 developed displacements of ca. 1 inch while shaker 3 developed displacements of ca. 1.6 inches.

Canopy shaker tests. Peterson (1997) has described the USDA canopy shaker which was tractor drawn. Two spoked drums were mounted on vertical shafts and oscillated horizontally in opposite directions for dynamic balance. Each drum was 5 ft tall, 8 ft in diameter, and had six, 15-spoke wheels spaced 1 ft apart. The spokes were nylon, 1.25 inches in diameter, 46 inches long, and bolted to hubs on the drum shafts. Each drum was free wheeling on its shaft except for a disc brake which could be adjusted to change the drum's resistance to free wheeling. The shaker was towed parallel to the tree row so the spokes penetrated 1 side of the tree row canopy and turned the free wheeling, oscillating drums. Initial testing indicated a drum shaft displacement of 3.5 inches at a frequency of ca. 5 Hz appeared to give optimum fruit removal results, and it was operated at these settings unless otherwise noted. The spokes penetrated the canopy in a rectangular cross section 44 inches wide and 67 inches high with the bottom of the rectangle 16 inches above ground.

Hedgerow or near hedgerow conditions were selected for all field tests to minimize fruiting in a vertical plane in the trunkline. A total of 6 tests were conducted in Valencia orange trees in South (2-row beds) and Central (Ridge) Florida. The shaker was towed at 1 and 2 mph for each test and was replicated at least 3 times on 2 to 6 half tree canopies per replication in a replicated block design. Mature fruit removal was measured in the canopy volume penetrated by the spokes (shaken zone) and/or to the trunkline (whole canopy or cross section width from trunkline to outer canopy).

Crunkelton machine. This unit (Crunkelton, 1992) consisted of 180, 1 inch square aluminum tubes 7 ft long, was 7 ft high and 4 ft wide, and was mounted on a truck with a hydraulic lift. Each tube had 6 specially shaped fingers 2.5 inches long spaced 1 ft apart and mounted at a 45 degree angle to the tube. Each finger was mounted horizontally on a vertical pin, 3 on each side of the tube, and was spring loaded to resist pivoting (tripping) about the pin. To harvest fruit, the array of tubes was inserted horizontally into the canopy ca. 7 ft and as the tubes were withdrawn, mature fruit was removed when the fingers hooked a fruit stem and did not trip. Immature Valencia fruit of small diameters are not removed. The canopy insertion force of each tube was spring loaded and the tube could retract if it encountered a large limb, etc.

To test the unit, the array of tubes was inserted perpendicular to the tree row into a bottom canopy position and withdrawn. It was then raised to its upper position and the operation repeated for trees over 7 ft tall. This procedure was repeated once or twice per position and every 3 ft parallel to the tree row until the canopy width in-row was covered. A total of 7 tests were conducted on Pineapple and Valencia orange trees in Central and South Florida. Because of mechanical problems with the unit, the number of trees per test varied from 1 to 8. Orange removal was measured only in the canopy volume where the tubes were inserted.

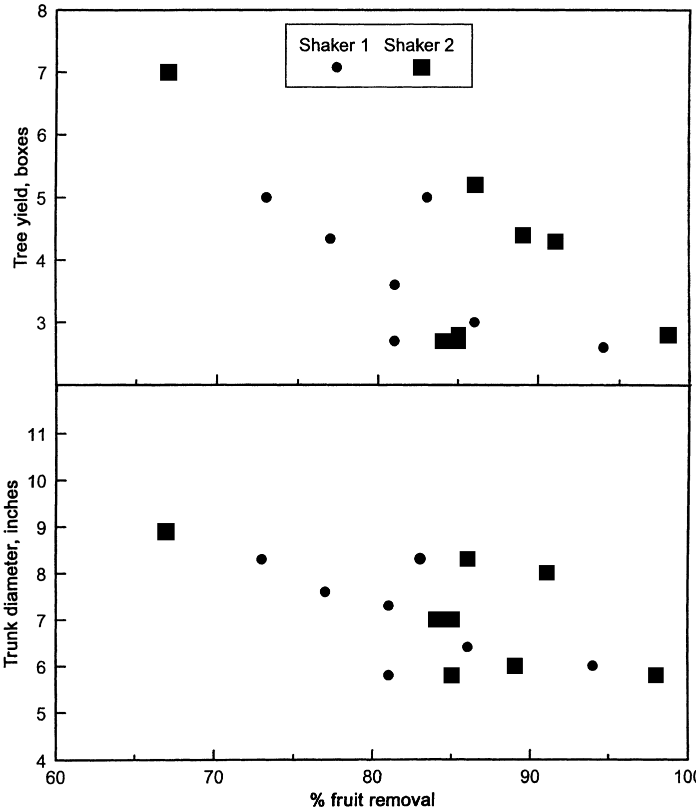

Figure 1. Fruit removal vs. tree yield (top) and trunk diameter (bottom) of Hamlin, Parson Brown, Pineapple, and Valencia orange trees with Compton trunk shakers during 1995-96 season.

Results and Discussion

Compton shaker tests. Fig. 1 shows the results with the Compton shaker heads. Percentage fruit removal is plotted vs. tree fruit yield and trunk diameter. Percentage fruit removals tended to be inversely related to tree yield and trunk diameter and ranged from 67% in the larger trees to 98% in the smaller trees. Standard errors of the percentage fruit removal means averaged 2.9 and ranged from 1 to 6.5. In the comparative tests of the 2 shaker heads, shaker head 2 with the larger displacement removed 4 to 13% more fruit than did shaker head 1. No assessments were made of immature Valencia fruit removal. In late (Valencia) oranges, some bark damage was observed with shaker head 2.

Orchard Grove and Machinery shaker tests. Fig. 2 shows the results with the OG&M shaker heads and percentage fruit removal is plotted vs. tree fruit yield and trunk diameter. Percentage fruit removals tended to be inversely related to tree yield and trunk diameter and varied from 62 to 96%. Standard errors of the percentage fruit removal means averaged 3.2 and ranged from 1.1 to 5.7. Only 1 test each was conducted with shaker heads 1 and 2 because the fruit removal was less than 80% and below acceptable levels. With a larger displacement, shaker head 3 removed up to 96% of the fruit. In young Valencia trees with 5.4 inch diameter trunks and 0.8 inch diameter immature fruit, shaker head 3 removed 94% mature fruit and 5 mature fruit for every immature fruit. In older Valencia trees with 11 inch diameter trunks and 1 inch diameter immature fruit, shaker head 3 removed 79% mature fruit and 3 mature fruit for every immature fruit. Bark damage was not apparent with any of the shaker heads.

Canopy shaker tests. Fig. 3 shows the results of the field tests in which percentage fruit removal is plotted vs. bottom canopy width and ground speed. Fruit removals generally decreased with increasing ground speed and averaged about 80% in the shaken zone and 60% in the whole canopy (to the trunkline). Standard errors of the percentage fruit removal means averaged 4.1 and ranged from 1.5 to 10.1. As might be expected, percentage fruit removal in the whole canopy was less at the larger bottom canopy widths because the spokes penetrated a smaller portion of the canopy width. No assessments were made of immature Valencia fruit removal. Some small limb and crotch breakage resulted from the spoked drums engaging the outer tree canopies.

Crunkelton machine. Fig. 4 shows the field test results. Percentage fruit removal (in the penetrated canopy volume) is plotted vs. bottom canopy width and number of tube insertions per position. One insertion per position removed 67 to 81% of the fruit while 2 insertions removed 73 to 91%. Fig. 4 shows a tendency for fruit removal to increase with bottom canopy width. This may be indicating that a greater proportion of the fruit in the larger canopies is located closer to the outer periphery of the canopy, presenting more opportunities for the spring-loaded fingers to hook stems and remove fruit than in smaller canopies. In the last Valencia test, the immature fruit averaged ca. 1.2 inches in diameter. For 1 inser-

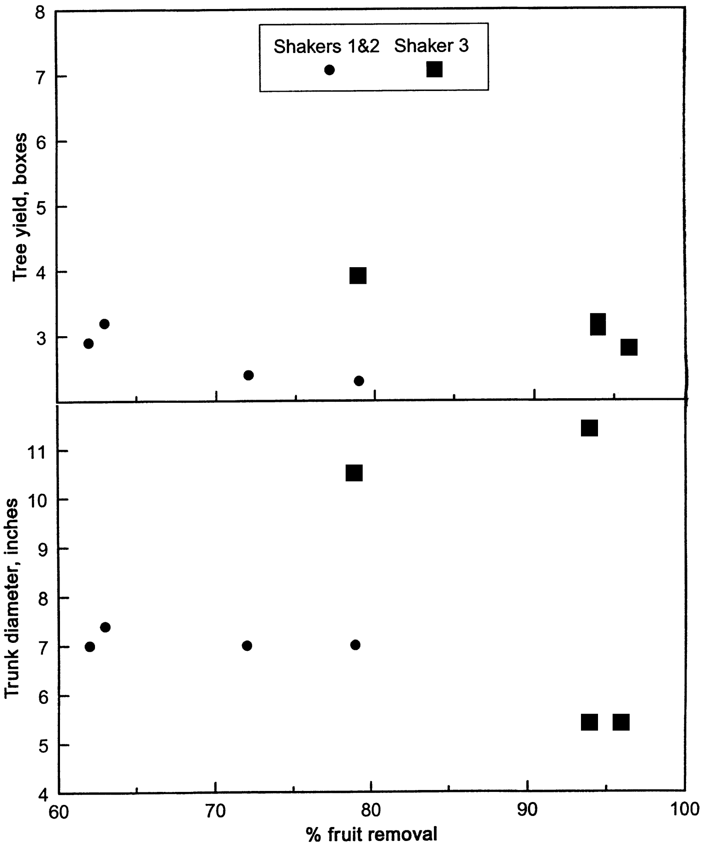

Figure 2. Fruit removal vs. tree yield (top) and trunk diameter (bottom) of Valencia orange trees with Orchard Grove and Machinery trunk shakers during 1995-96 season.

tion, 81% of the mature fruit was removed and the ratio of mature/immature removed was 6. For 2 insertions, 91% of the mature fruit was removed and the ratio of mature/immature was 5. Little or no tree damage (bark or limb breakage) was observed with this machine.

Summary

Field tests were conducted during the 1995-96 season to determine the orange removal performance of 4 machines. Percentage orange removal with trunk shakers was directly related to shaker head displacements between 1 and 2 inches, and generally inversely related to tree yield and trunk diameter. Compton trunk shaker heads removed 67 to 98% of the oranges while Orchard and Grove Machinery trunk shaker heads removed 62 to 96%. Late in the Valencia harvest season when the immature fruit was ca. 1 inch in diameter, the Orchard and Grove Machinery shaker achieved 79 to 94% mature fruit removal while removing 3 to 5 mature fruit for every immature fruit. Shaking times per tree of 5 to 10 sec at 8 to 10 Hz were usually required. Bark damage was evident on some Valencia trunks. With the USDA canopy shaker, orange removals in the shaken zone and to the trunkline (whole canopy) ranged from 71-91% and 52-70%, respectively, and were inversely related to ground speed. Orange removals to the trunkline were higher with narrower bottom canopy widths and this shaker appeared to be best suited to narrow-width, hedgerow canopies with minimal inside fruiting. Some small limb and crotch breakage resulted from the spoked drums engaging the outer tree canopies. The Crunkelton machine (parallel array of tubes) removed up to 90% of the mature oranges in the canopy zone penetrated by the tubes, and demonstrated fairly good selectivity (5 mature fruit removed/1 immature fruit) when immature Valencias were 1.2 inches in diameter.

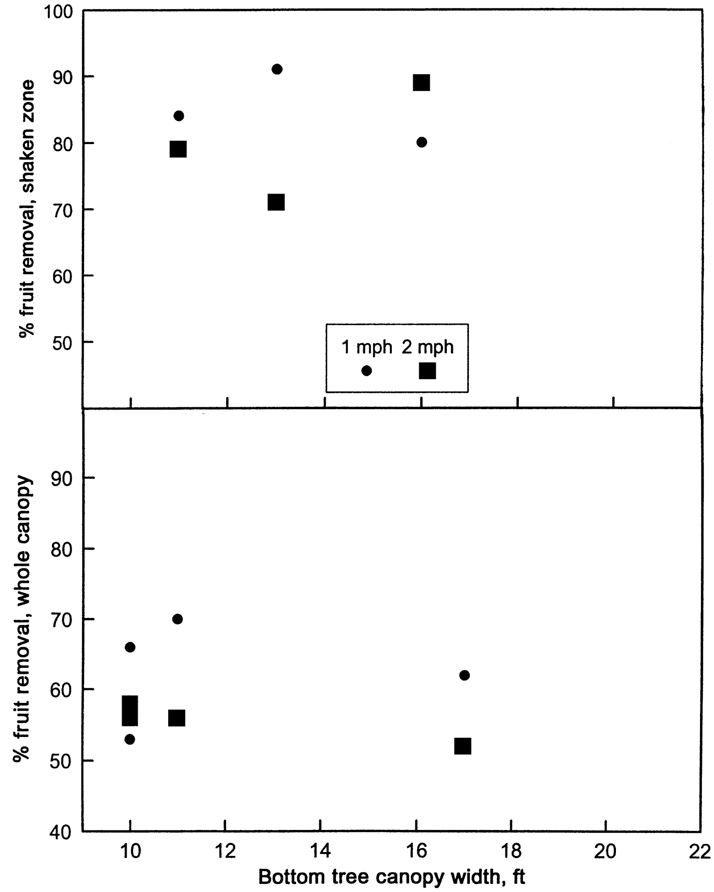

Figure 3. Fruit removal in shaken zone (top) and whole canopy (bottom) vs. bottom tree canopy width and ground speed in Valencia orange trees with USDA canopy during 1995-96 season.

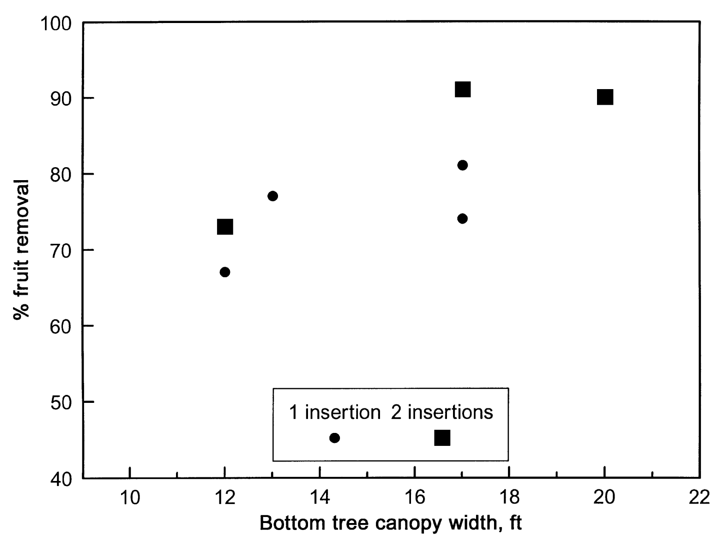

Figure 4. Fruit removal vs. number of insertions and bottom canopy width in Pineapple and Valencia orange trees with the Crunkelton machine during 1995-96 season.

Future Recommendations

Performances of these machines could be improved by several changes in the machines and/or tree design. All machines would benefit from smaller trees and canopy sizes. Trunk shaker fruit removal performance could probably be improved with larger displacements at lower frequencies. In addition, increased trunk heights would improve shaker leverage and would help alleviate bark damage caused by shaker clamps on many of the existing short trunks. Improved shaking patterns may also alleviate bark damage in Valencia trees. With the canopy shaker, fruit removal performance can be improved by better matching the machine and the tree canopy—a solid hedgerow in which the spokes penetrate the entire canopy volume. This will probably involve increasing the size of the machine and controlling the canopy size and shape by pruning. In a similar manner, improving the fruit removal performance of the Crunkelton machine will require canopy sizes which can be completely penetrated by the tubes. The Crunkelton machine, however, does not require hedgerow conditions to be effective.

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ACQUIRING WEATHER INFORMATION VIA A DECISION MAKING SYSTEM (DISC)[1]

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Abstract. **Information is increasing at a rate that makes acquisition of information seem like drinking from a fire hose. Privatization of weather information dissemination has made the information marketplace seem voluminous if not chaotic. Hope to resolve this situation for citrus led to the development of DISC [Decision Information System for Citrus]. A proposal to develop such a system was funded by the Florida Citrus Production Research Advisory Council. The system is expected to contain a number of weather sensitive production, harvesting and marketing modules. The links through which weather information may flow to various weather sensitive models are diagrammed. Potential users are represented in the development team. Their participation promises a system that is tailored to their needs and for which they feel ownership. Their enthusiasm for weather information provides encouragement to the VARs [value added retailers] of weather information. The role private enterprise may play in a system created in part in the public domain is a manifestation of privatization in the information marketplace. Potential users of such a system have an opportunity to play a critical role in designing the system for their use.**

The manner in which agriculturists, more specifically citrus growers, acquire and use weather information in weather sensitive decisions they make is changing rapidly [Martsolf, 1997]. This is due in part to the recent demise of the Federal-State Frost Warning Service in Florida, which had been in existence since 1935 [Martsolf, 1995a]. These changes include not only the manner in

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