Shakers Affect Florida Orange Fruit Yields and Harvesting Efficiency

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ABSTRACT

ORANGE harvesting studies were conducted with air and trunk shakers plus abscission chemicals and compared with hand harvesting from the 1979-80 through the 1984-85 seasons. These harvesting methods were also superimposed on several tree size management practices. Severe freezes occurred during four of these seasons. The air shaker reduced yields on average of 16% while the trunk shaker reduced yields an average of 5%. Harvesting efficiencies of the air and trunk shakers average 77 and 87%, respectively. Tree size management practices did not affect the fruit removal performance or harvesting efficiencies of the shakers.

INTRODUCTION

Most Florida orange trees over 30 yr of age are spaced 7.6 m x 7.6 m (25 ft x 25 ft) or greater. In the past three decades, Florida citrus growers have been keenly interested in planting trees closer than 7.6 m (25 ft) in-row for higher tree densities and higher fruit production per unit area (Tucker and Wheaton, 1978). Because of questions regarding tree size management in closer-spaced trees and concerns about harvesting, replicated field studies were initiated in the 1979-80 season. Whitney et al. (1983) reported on the results of these studies through the 1981-82 season. Wheaton et al. (1984) presented fruit yield and quality results related to the tree size management practices but excluded mechanical harvesting effects.

The objective of this article is to report on the effects of shakers of fruit yields and harvestng efficiencies for a 1979-85 test period.

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MATERIALS AND METHODS

Whitney et al. (1983) described the details of 12 replicated field studies (experiments) located throughout the citrus producing areas of Florida. Eight of these 12 studies (Nos. 1, 2, 4, 5, 7, 9, 11, and 12 listed in Table 1) included both hand and mechanical harvesting and only the data from these eight studies will be considered in this article. A brief description of the experiments follows.

Most of the trees were in hedge rows and ranged from 7 to 26 yr old when the studies were initiated. The between-row spacing for all trees was 7.6 mm (25 ft) and the aisle or middle for equipment movement was maintained at a nominal 2 m (7 ft) width. The in-row tree spacing ranged from 2.7 to 5.3 m (9 to 17 ft). The three tree size management practices were tree removal (thinning), crosshedging, and topping. Tree removal was

TABLE 1. SCHEDULE OF TREE SIZE MANAGEMENT – CITRUS HARVESTING STUDIES INITIATED IN THE 1979-80 SEASON

Site no.	Location	Citrus area	Orange cultivar	In-row tree spacing in m	Tree age in 1979, yr	Study no. and description
1	Mt. Dora	North	Parson Brown	3	14	1 - tree removal; air shaker and hand harvest; 5 reps.
						2 - crosshedge and flat top; air shaker air hand harvest; 3 reps.
			Valencia	4.6	28	4 - crosshedge; air shaker and hand harvest; 8 reps.
2	32 km north of Lk. Alfred	Central ridge	Pineapple	5.3	25	5 - crosshedge; air shaker and hand harvest; 6 reps.
			Valencia	5.3	25	7 - crosshedge; air shaker and hand harvest; 8 reps.
3	Lucerne Park	Central ridge	Hamlin	2.7	12	9 - gable top; air shaker and hand harvest; 6 reps.
4	LaBelle	South flatwoods	Hamlin	4.6	14	11 - crosshedge; air shaker, trunk shaker, hand harvest; 5 reps.
			Valencia	4.6	7	12 - crosshedge; air shaker, trunk shaker, hand harvest; 6 reps.

Between row tree spacing = 7.6 m. Abscission chemicals were applied to the mechanically (air and trunk shaker) harvested trees prior to harvest, except when excessive freeze damage made it inadvisable.

done in 1979 while cross hedging and topping were done in 1979 and annually thereafter. Management practices were arranged as main plots in a randomized complete block design and harvesting methods (hand, shakers) were randomly assigned to subplots.

Abscission chemicals were applied with standard air blast sprayers several days prior to harvest to trees designated for mechanical harvesting (shakers), except where freeze damage to the trees was judged as severe. RELEASE* (5-chloro-3-methyl-4-nitro-pyrazole) at concentrations up to 125 ppm or mixtures or RELEASE up to 100 ppm and ACTI-AID (cycloheximide) up to 1.5 ppm were applied to early and midseason oranges. ACTI-AID was cleared for use in Florida oanges, and RELEASE was used under an experimental use permit. All abscission chemical spray mixtures included 0.1% ORTHO X-77 surfactant. Because of damage to the fruit peel by the abscission chemicals and shaking, mechanically harvested fruit was only suitable for processing.

At harvest time, fruit was removed mechanically with shakers for subsequent ground pickup. An air shaker with center pivot plates in the air discharge duct (Whitney, 1978) was used in all eight of the studies; an FMC Model 4000 trunk shaker with a 729 shaker head (two eccentric masses, 31 kg each) was only used in two of the studies (Nos. 11 and 12) in south Florida. Actual shaking time per tree varied from 10 to 40 s with the air shaker and from 3 to 7 s with the trunk shaker depending on degree of fruit loosening and operator judgment. To obtain fruit yields and fruit removal efficiencies, the fruit removed to the ground by the shakers and that remaining on the trees were collected by hand and weighed; fruit from the handpicked trees was harvested by conventional hand harvesting methods and weighed.

All data for each study and each season were analyzed statistically and significant differences refer to F values or Duncan's multiple range test at the 0.05 level of significance.

*Trade names and company names are used in this publication solely for providing specific information and do not imply endorsement by the University of Florida or other agencies over other products not mentioned.

RESULTS

None of the tree size managment practices had a consistent or significant effect on the fruit removal percentage by the shakers. The effects of tree size management practices on fruit yields of trees harvested by machine and hand were similar and there were no significant interactions. Thus, the data are presented for each study comparing shaker and hand harvested trees averaged over all tree size management practices.

Significant freezes occurred during four of the seasons January 1981, January 1982, December 1983, and January 1985. Overall, tree damage from the freezes was much more severe in the two northern sites (Studies 1, 2, 4, 5, and 7) than in the two southern sites (Studies 9, 11, and 12). Harvesting occurred subsequent to the freeze dates during the harvest season with one exception. In study 9, harvesting during the 1984-85 season occurred 3 weeks prior to the January 1985 freeze.

The fruit yield, fruit removal, and harvesting efficiency data are presented by study in Tables 2 and 3 as averages of each season for which data were available. Studies 1, 2, 5, 9, and 11 are early and midseason oranges in Table 2; Studies 4, 7, and 12 are late season (Valencia) oranges in Table 3. These eight numbered studies correspond to those discussed by Whitney et al. (1983). At the bottom of each table, the results for the

TABLE 2. FRUIT YIELD, FRUIT REMOVAL, AND HARVESTING EFFICIENCY RESULTS OF AIR AND TRUNK SHAKERS IN EARLY AND MIDSEASON FLORIDA ORANGES

Study no. and cultivar	Attribute*	Season						1980-81 to 1983-84				
		1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	Yield avg.†	Yield TSFY / HPFY	Ratio‡ ASFY / HPFY	1979-80 to 1983-84 avg. fruit rem., %	Avg. harv. eff., %
1 - Parson Brown	HP yield, t/ha	41 a	27 a	18 a	98 a	50 a	—	48 a	—			
	AS yield, t/ha	36 b	23 b	17 a	82 b	50 a	—	43 b	—	0.90	—	—
	AS fruit rem., %	96	64	89	97	—	—	—	—	—	87	78
2 - Parson Brown	HP yield, t/ha	45 a	27 a	20 a	96 a	49 a	—	48 a	—	—	—	—
	AS yield, t/ha	40 b	26 a	15 a	78 b	53 a	—	43 a	—	0.90	—	—
	AS fruit rem., %	92	75	92	98	—	—	—	—	—	89	80
5 - Pineapple	HP yield, t/ha	61 a	55 a	56 a	—	44 a	—	52 a	—	—	—	—
	AS yield, t/ha	64 a	50 b	50 a	—	40 a	—	46 b	—	0.88	—	—
	AS fruit rem., %	99	96	78	—	—	—	—	—	—	91	81
9 - Hamlin	HP yield, t/ha	54 a	—	87 a	36 a	44 a	53 a	55 a	—	—	—	—
	AS yield, t/ha	47 b	—	67 b	29 b	41 a	40 b	44 b	—	0.80	—	—
	AS fruit rem., %	99	—	96	91	90	—	—	—	—	94	75
11 - Hamlin	HP yield, t/ha	51 a	44 a	52 a	28 a	31 a	56 a	42 a	—	—	—	—
	AS yield, t/ha	48 a	31 b	52 a	8 b	34 a	50 a	35 b	—	0.85	—	—
	TS yield, t/ha	51 a	44 a	52 a	25 a	40 a	58 a	44 a	1.05	—	—	—
	AS fruit rem., %	94 c	98 c	96 c	84 c	87 c	—	—	—	—	92 c	76
	TS fruit rem., %	94 c	98 c	90 d	80 c	85 c	—	—	—	—	89d	93
Studies 1, 2, 5, 9, 11 avg. early and midseason oranges	HP yield, t/ha	51 a	40 a	51 a	60 a	43 a	55 a	49 a	—	—	—	—
	AS yield, t/ha	48 b	34 b	43 b	45 b	43 a	45 b	42 b	—	0.86	—	—
	AS fruit rem., %	96	83	90	93	89	—	—	—	—	91	78

*Fruit yields and removals were rounded to nearest whole number; HP = handpick; AS = air shaker; TS = trunk shaker. Means followed by the same letter are not significantly different at the 0.05% level by the Duncan's multiple range test. Separate Duncan tests were performed for means for each study-season combination; for means over all studies for each season; and for means over all seasons for each study.
†Yields were averaged only over seasons with data.
‡TSFY = trunk shaker fruit yields; ASFY = air shaker fruit yields; HPFY = handpick fruit yields.

TABLE 3. FRUIT YIELD, FRUIT REMOVAL, AND HARVESTING EFFICIENCY RESULTS OF AIR AND TRUNK SHAKERS IN LATE SEASON (VALENCIA) FLORIDA ORANGES

Study no.	Attribute*	Season						1980-81 to 1984-85				
		1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	Yield avg.†	Yield TSFY / HPFY	Ratio‡ ASFY / HPFY	1979-80 to 1983-84 avg. fruit rem.,%	Avg. harv. eff.,%
4	HP yield, t/ha	25 a	33 a	60 a	56 a	29 a	—	45 a	—	—	—	—
	AS yield, t/ha	25 a	23 b	51 b	46 b	24 b	—	36 b	—	0.80	—	—
	AS fruit rem.,%	91	95	92	92	—	—	—	—	—	93	74
7	HP yield, t/ha	63 a	34 a	—	16 a	85 a	—	45 a	—	—	—	—
	AS yield, t/ha	63 a	25 b	—	14 a	88 a	—	42 a	—	0.93	—	—
	AS fruit rem.,%	94	95	—	85	—	—	—	—	—	91	85
12	HP yield, t/ha	39 a	41 a	45 c	33 a	25 ab	54 a	39 a	—	—	—	—
	AS yield, t/ha	36 a	23 c	38 b	21 b	20 b	45 b	29 c	—	0.74	—	—
	TS yield, t/ha	39 a	30 b	42 ab	26 ab	31 a	49 ab	35 b	0.90	—	—	—
	AS fruit rem.,%	92 d	96 d	89 d	94 d	89 d	—	—	—	—	92 d	68
	TS fruit rem.,%	94 d	96 d	83 e	93 d	83 e	—	—	—	—	90 e	81
4, 7, 9 avg.	HP yield, t/ha	43 a	35 a	53 a	35 a	48 a	54 a	43 a	—	—	—	—
	AS yield, t/ha	42 a	24 b	45 b	28 b	46 a	45 b	35 b	—	0.81	—	—
	AS fruit rem.,%	92	95	91	90	89	—	—	—	—	92	75

*Fruit yields and removals were rounded to nearest whole number; HP = handpick; AS = air shaker; TS = trunk shaker. Means followed by the same letter are not significantly different at the 0.05% level by the Duncan's multiple range test. Separate Duncan tests were performed for means for each study-season combination; for means over all studies for each season; and for means over all seasons for each study.
†Yields were averaged only over seasons with data.
‡TSFY = trunk shaker fruit yields; ASFY = air shaker fruit yields; HPFY = handpick fruit yields.

handpicked and air shaker are averaged over the studies in each table. The trunk shaker results are not shown in the averages because the trunk shaker was only involved in Study 11 in Table 2 and Study 12 in Table 3.

Early and Midseason Oranges

Harvesting of early and midseason oranges for processing in Florida normally occurs from December through March. In these studies, harvesting occurred within a period from late December through early March.

Initial fruit yields—These yields for the 1979-80 season when the studies were initiated are summarized on the left side of Table 2. There should have been no effects of the harvesting methods (shakers vs. hand) and ideally, all yields should have been equal. The initial yields of the air shaker trees were significantly less than the hand harvested trees in Studies 1, 2, and 9 and were also significantly less (6%) when averaged over all five of the studies. There was no apparent reason for the fairly large initial yield differences of air shaker and hand harvested trees. The trunk shaker trees in Study 11 had the same yields as the hand harvested trees.

Subsequent fruit yields—These results for each subsequent season are listed under the 1980-81 through 1984-85 seasons column headings. Blank spaces indicate data were not available. Data were lost for Study 9 in 1980-81. Freeze damage resulted in no fruit (no data) for Study 5 in 1982-83. Data for Studies 1, 2, and 5 in 1984-85 were unavailable because the freezes killed the trees. Fruit removal data are not shown for the last season for which fruit yield data are available because the fruit was all havested by hand to get only fruit yield data. In the next column to the right, the subsequent yields are averaged over those seasons for which data were available.

The yield data for each study were analyzed for each season or a study-season combination; it was also analyzed over all studies for each season and over all seasons for each study. In Studies 1, 2, 5, and 9, fruit yields of the air shaker trees were significantly less than the hand harvested trees for seven of the 15 study-season combinations that data were available. Over all subsequent seasons, fruit yields of the air shaker trees were significantly less than the hand harvested trees for Studies 1, 5, 9, and 11.

Both air and trunk shakers were used in Study 11. Fruit yields were significantly reduced by the air shaker in three of the five seasons while the trunk shaker did not significantly reduce yields any of the five seasons. Fruit yields in the five seasons averaged 35, 44, and 42 t/ha, respectively, for air and trunk shakers and hand harvesting. Trunk shaker fruit yields averaged 5% more than the handpick fruit yields.

The seasonal averages at the bottom of Table 2 show that the yields of the air shaker trees were significantly reduced during all but the 1983-84 season. When averaged for all studies over the 1980-81 through 1984-85 seasons, fruit yields of air shaker trees averaged 42 t/ha or 86% of the hand harvested yields or 49 t/ha (see bottom right Table 2). These overall yield reductions by the air shaker plus abscission chemicals were significant and were more than those previously reported by Whitney (1972, 1975).

The effects of the freezes on air shaker fruit yield reductions were difficult to assess. Essentially all of the harvesting was done after the freezes had occurred during each harvest season. Consider the air shaker to handpick yield ratios for 1980-81 through 1984-85 inclusive (see Table 2). In Studies 1, 2, and 5 where relative freeze damage was more severe, the yield ratios were 0.90, 0.90, and 0.88, respectively. In Studies 9 and 11 where relative freeze damage was less severe, the yield ratios were 0.80 and 0.85, respectively. These numbers suggest the air shaker yield reductions were less with greater freeze damage, but this was probably not true. The cultivars were different. Growing conditions were also different, in that Study 11 was in the flatwoods of south Florida, whereas the other studies were in the well-drained sandy soils in the northern citrus producing area.

Yield reductions in many cases occurred in subsequent seasons to air shaker harvesting after which no visible damage (defoliation, limb breakage, etc.) significant to

the trees was observed. There was usually no apparent mechanical tree damage which could explain these reductions. Abscission chemicals were ruled out for the most part because in Study 11, yield reductions were not observed with the trunk shaker with identical abscission chemical treatment.

The most obvious case of tree damage inflicted by the air shaker was during the 1981-82 season in Study 11. The January 1982 freeze had partially defoliated the Hamlin orange trees approximately 3 weeks before harvest time. A few days prior to harvest, the abscission chemical RELEASE was applied to the trees which had grown new leaves and set bloom buds. Fruit loosening at harvest time was poor, partially because of 1 cm (0.4 in.) precipitation a few hours after RELEASE was applied. To achieve at least 90% fruit removal, the air shaker was operated at a ground speed of 0.25 m/s (0.6 mph), a 40 s shaking time/tree, and 60 m/s (135 mph) air discharge velocity. Fruit removal averaged 96%, but the trees suffered severe wind burn to the new leaves and buds. The 1982-83 fruit crop for the air shaker trees was 8 t/ha, or 71% less than the handpicked tress, 28 t/ha (Table 2). By way of comparison, the trunk shaker trees were shaken 7 s with 90% fruit removal and some visible leaf and bud damage (shredding). The 1982-83 fruit crop was 25 t/ha or 11% less than the handpicked trees. This situation illustrated that mechanical damage to young growth on orange trees as a result of defoliation from freeze damage can reduce subsequent fruit yields.

Fruit removal—These results are shown in Table 2 by study and season. In addition, fruit removal results are averaged by season for the air shaker (bottom of table) and by study for both air and trunk shakers (right of table) and by study for both air and trunk shakers (right of table). Fruit removals of the air shaker ranged from 64 to 99% and an overall average of 91%. Low removals usually occurred after complete defoliation (low air drag) by a severe freeze and when no abscission chemical was applied (see 1980-81 results). High removals were associated with good fruit loosening by abscission chemicals. In Study 11, the fruit removal efficiency of the air shaker (92%) was significantly higher than that of the trunk shaker (89%) when averaged over all five seasons.

Harvesting efficiency—The harvesting efficiency of the shakers was defined as the product of the average subsequent ratio of shaker fruit yields to hand harvesting fruit yields and the average percent fruit removal of the shakers. Equation [1] defined harvesting efficiency as

$$HE = (SFY/HPFY) \times \%\ FR \quad [1]$$

Where

- HE = harvesting efficiency of the shaker, %
- SFY = fruit yield of the shaker harvested trees, t / h a
- HPFY = fruit yield of the hand harvested trees, t/ha
- % FR = percentage of fruit yield removal from the shaker trees. This includes any preharvest drop from the abscission chemical plus fruit removed by the shaker.

Mechanical harvesting denoted in this paper included fruit removal to the ground with a shaker and abscission chemical and fruit collection by hand. The ratios, removal efficiencies, and harvesting efficiencies of air shaker ranged from 75 to 81% and an average of 78% In Study 11, harvesting efficiencies of the air and trunk shakers averaged 76 and 93%, respectively.

Valencia Oranges

Harvesting Valencia (late season) oranges fo processing in Florida normally occurs from Marcl through June. In these studies, harvesting occurrec between late March and early May with two exceptions Harvesting for Studies 4 and 7 during the 1983-84 seasor was in January and February of 1984 to salvage th severely freeze-damaged fruit from the December 198 freeze. Except for Studies 4 and 7 in the 1983-84 season the young fruit (next season's crop) during harvestin studies ranged from bloom to a diameter of 2 cm (0.8 in)

Initial fruit yields—Table 3 shows the Valencia orange results, which are displayed similarly to the earl and midseason orange results in Table 2. The initia (1979-80 season) shaker and hand harvested fruit yield were not significantly different by study or averaged ove all three studies.

Subsequent fruit yields—These results are shown fo each season under the column headings 1980-81 throug 1984-85. Data were lost for Study 7 in the 1981-8 season. Data for Studies 4 and 7 were unavailable in 1984-85 season because the freezes killed the trees.

The air shaker significantly reduced fruit yields five o the seven study-season combinations in Studies 4 and 7. Over all seasons, the air shaker significantly reduced yields in Study 4 but not Study 7.

Both air and trunk shakers were used in Study 12 Fruit yields were significantly reduced by the air shake in four of the five seasons, 1980-81 through 1984-85. The trunk shaker significantly reduced fruit yields only in the 1980-81 season. Fruit yields in the five seasons averaged 29, 35, and 39 t/ha, respectively, for the air and trunk shakers and hand harvesting. These yields were 26 and 10% reductions by the air and trunk shakers, respectively, and were both significantly less than hand harvesting.

Averaged over all three studies, the air shaker reduced yields in four of the five season. Averaged over all studies and all seasons, the air shaker fruit yield was 35 t/ha o 19% less than the hand harvesting fruit yield, 43 t/ha. This reduction was significant. Valencia yield reductions by the shakers were related to the quantity of young fruit (next season's crop) removed at harvest time. Similar reductions were reported by Whitney (1975, 1976).

There was no apparent effect of the freezes on the magnitude of this reduction. The average air shaker to hand harvest yield ratio for Study 12 was lower than the ratios for Studies 4 and 7, and the relative freeze damage was less in Study 12. However, the initial yields of the air shaker trees in Study 12 were also slightly lower than the hand harvested trees. Also, Study 12 was in the flatwoods of south Florida whereas Studies 4 and 7 were in the well-drained sandy soils in the northern citrus producing area. In addition, the trees in Study 12 were considerably younger (Table 1).

Another concern with trunk shaker in terms of the fruit producing potential of the trees was bark damage resulting from the shaker clamp pads. Valencia trees are very susceptible to bark damage because they are growing vigorously at harvest time. The first (1979-80) season of harvest resulted in bark damage on

approximately one-half the trunk shaker trees, with much less bark damage occurring in each of the subsequent seasons. Much of the bark damage was due to the trunks being too short for the size of the clamp pads and the irregular shape of the trunks. It was not apparent whether a part of the Valencia yield reduction could be attributed to the bark damage. Hedden et al. (1984) reported that abscission chemicals did not significantly reduce Valencia yields in trunk shaker harvest tests conducted in the same area as Study 12 of this report.

Fruit removal—The final removal efficiencies of the air shaker ranged from 85 to 96% and was largely dependent on fruit loosening by RELEASE. The air shaker averaged 92% over all studies. In Study 12, the fruit removal efficiency of the air shaker (92%) was significantly higher than the trunk shaker (90%) when averaged over all seasons.

Harvesting efficiency—The harvesting efficiencies of the air shaker ranged from 68 to 85% with an average of 75%. In Study 12, the air and trunk shakers averaged harvesting efficiencies of 68 and 81%, respectively.

DISCUSSION

The air shaker plus abscission chemicals did reduce fruit yields in all orange cultivars. Quantifying the reductions was a difficult task because the initial (1979-80) yields were generally less with air shaker than for handpicking. They should have been essentially the same since there was no prior shaker treatment that could have affected the fruit production of the trees. In early and midseason oranges (Table 2), the initial air shaker yields averaged 94% ((48/51) X 100) of the handpick yields. If the initial yields are ignored, then the average reduction would be 100 - 86 = 14% as presented in Table 2. However, if the initial yields reflect the yielding potential of the trees, then the reduction could be more realistically defined as 100 - ((86/94) X 100) = 9%. The trunk shaker did not reduce Hamlin orange yields.

In Valencia oranges (Table 3), the initial air shaker yields averaged 98% ((42/43) X 100) of the hand harvesting yields. If, as above, the air shaker yield reductions are related to the initial air shaker yields, the reduction in Valencia yields would be 100 - ((81/98) X 100) = 17% instead of 100 - 81 = 19% as shown in Table 3. The trunk shaker reduced Valencia orange yields an average of 10%.

The harvesting efficiencies in Tables 2 and 3 were calculated using the yield ratios with hand harvested yields as the denominator (see equation [1]). If instead the harvesting efficiencies were calculated using the initial yield of each respective shaker treatment in the denominator, the yield ratio and thus the harvesting efficiencies would generally be higher. For the air shaker, the harvesting efficiencies would be increased from 78 to 83% in early and midseason oranges and from 75 to 76% in Valencia oranges. Harvesting efficiencies for the trunk shaker would not change in Hamlin or Valencia oranges since the initial yields of the trunk shaker and hand harvesting were the same.

As presented in Tables 2 and 3, the harvesting efficiencies of the trunk shaker averaged 15 percentage points higher than the air shaker in Studies 11 and 12. Fruit removal of the air shaker was 2 percentage points higher than the trunk shaker in these two studies. This 2 percentage point higher fruit removal of the air shaker may have been obtained at some cost in subsequent fruit yield.

CONCLUSIONS

The results in the article were based on eight field studies with air shaker and two field studies with the trunk shaker. Abscission chemicals were used with both shakers to improve their fruit removal performance. Severe freezes occurred during four of the six seasons of the studies.

The following conclusions were made about the performance of shakers relative to hand harvesting.

1. Fruit removal efficiencies of the air shaker and trunk shaker were 92 and 90%, respectively.
2. The air shaker reduced early and midseason orange yields 14% and late season (Valencia) orange yields 19%.
3. The trunk shaker did not reduce Hamlin (early season) orange yields but reduced late season (Valencia) orange yields 10%.
4. The harvesting efficiencies of the air shaker averaged 75 to 78%; the harvesting efficiency of the trunk shaker was 93% for Hamlin oranges and 81% for Valencia oranges.

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