Trunk Shaker Removal of Oranges

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ABSTRACT

TWO types of trunk shakers were each used in two shaking modes to harvest oranges of two major cultivars over three harvest seasons. Treatments were applied with and with no use of fruit abscission agents. Fruit removal in 'Hamlin' and 'Valencia' oranges was increased an average of 26 and 12 percentage points, respectively, by the use of abscission chemicals. The two shaking modes of the linear shaker gave the highest and lowest fruit removal results in both cultivars while the multi-directional shaker modes were in between. The shaking amplitudes obtained were not consistent from season to season. Abscission chemicals did not affect yields of either cultivar in any season but shaking treatments did significantly affect 1983 fruit yields. Trunk circumference did not affect operating frequencies of the shaker treatments.

Mass removal of various deciduous fruits and nuts by means of limb or trunk shakers has been a reality for many years (Brown et al. 1983). Application of this technique to harvesting citrus has been difficult because of factors such as high fruit bonding force, machine reliability, marginal economics, and presence of dual crop in late season 'Valencia' oranges (Hedden et al. 1983). Trunk shakers, in particular, have not been accepted because of low fruit removal, bark damage, and lack of adequate tree trunk area for shaker clamp attachment in a large percentage of Florida grove conditions. Previous citrus harvesting experiments (Whitney, 1975) with a multi-directional trunk shaker achieved 98% fruit removal in 'Queen' oranges and 86% removal in 'Valenica' oranges with the abscission chemical RELEASE (5-chloro-3-methyl-4-nitro-pyrazole). Subsequent fruit yields were reduced 15% from the effects of shaker and abscission chemical. However, the potential for shaking a tree with a single attachment point, the advent of abscission chemicals for fruit loosening, and an increase in tree numbers of a size and shape adaptable for trunk shaking make this fruit removal method look increasingly attractive.

The objectives of the experiments described in this paper were to determine fruit removal efficiencies and subsequent yield effects of four modes of trunk shaking.

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METHODS AND EQUIPMENT

Two identical harvest experiments were designed to collect performance data on trunk shaking early season oranges ('Hamlin') and late season oranges ('Valencia') at a location in South Florida. The trees in each experiment were 15 and 8 years old, respectively, and quite uniform in size and density and had adequate trunk height for grasping with the shaker clamps. Each experiment was a randomized, split-plot design which included 60 trees and six replications. One of the two 5-tree main plots in each replication was randomly assigned to be sprayed with abscission chemical before harvest while the other main plot was not sprayed. With each main plot, four shaker treatments and 1 handpick check treatment were randomly assigned fruit removal methods to each tree or subplot. After the initial treatment assignment, the same treatment was applied to each tree for each of the 3 years.

The trunk shaker and check treatments were as follows:

1. Linear shaker with 60.4 kg of unbalanced mass rotating at 6 r/s with 14 cm eccentricity and 458.2 kg of total mass excluding the unbalanced mass.
2. Linear shaker with 90.9 kg of unbalanced mass rotating at 5 r/s with 14 cm eccentricity and 272 kg total mass excluding the unbalanced mass.
3. Multi-directional shaker with two 30.9 kg unbalanced masses rotating at 12 r/s with 11.4 cm eccentricity rotating in opposite directions at a speed difference of 18.5% and 450 kg of total mass, excluding the unbalancd masses.
4. Same shaker as 3 except both eccentric masses rotated in the same direction.
5. Handpicked check.

Treatments 1 and 2 were conducted with a linear shaker (Fig. 1) with theoretical shaking amplitudes of 1.8 and 4.7 cm, respectively, under no-load conditions. Treatments 3 and 4 were conducted with a commercially available multi-directional shaker with a theoretical shaking amplitude of 1.6 cm (Fig. 1).

Four to 5 days prior to harvest, the abscission chemicals were applied in an amount dependent upon fruit and tree condition and cultivar. The normal abscission mixture was 75 ppm RELEASE, 1.5 ppm ACTI-AID (cycloheximide), and 0.1% ORTHO X-77 surfactant applied at the rate fo 15 L of mix per tree.

The shaker treatment trees were shaken for 7 s. Data were collected on fruit removal and yield for three seasons (1981, 1982, 1983). Bark damage was observed as each plot was harvested. Trunk circumference at 20 cm above ground level was measured in the 1982 season; shaker clamp height above ground level was measured the 1982 and 1983 seasons. In addition, for the 1982 and 1983 harvest seasons, each tree trunk shaken was instrumented with an accelerometer package which

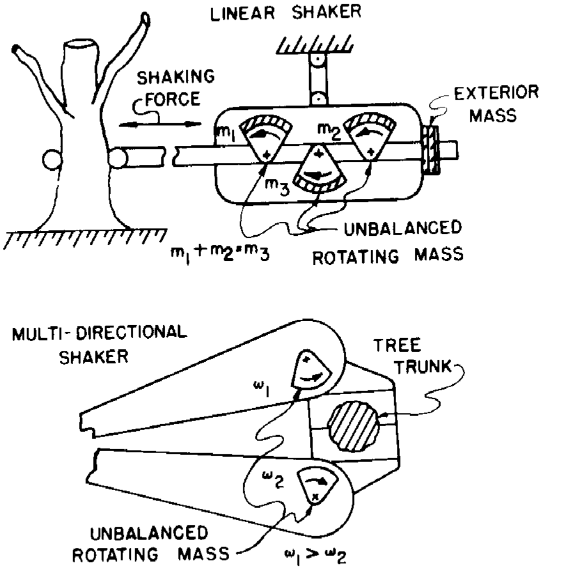

Fig. 1—Schematic diagram of the linear and multi-directional trunk shakers used in these experiments. Shown are mass configurations for Treatments 1 and 3. Treatment 2 had added rotating mass and no exterior mass. Treatment 4 had both masses rotating in same direction.

measured tree trunk acceleration on two perpendicular axes in a plane parallel to the ground. The acceleration analog signal was double integrated to determine tree trunk amplitude. The height of the accelerometer package above ground level was also measured.

Since the accelerometer package was fastened at varying heights above ground level, trunk amplitude values were normalized by dividing by the respective heights. The resulting value was the angular movement of the trunk in radians, assuming that the tree trunk at ground level was essentially stationary and that trunk movement pivoted about ground level.

All data were statistically analyzed and significant differences refer to F values at the 0.05 level. Fruit yields of all five treatments were included in the statistical analysis. Fruit removal efficiencies of Treatment 5 (handpicked check) were 100% and were not included in the statistical analysis.

RESULTS AND DISCUSSION

Hamlin Oranges

Fruit Removal - Fig. 2 shows the fruit removal data, in bar graph form, of the four shaker treatments for all three seasons. In descending order of magnitude the removal efficiencies of the shaker treatment were 2, 4, 3, and 1. Fruit removal efficiency was increased significantly each season by the abscission chemical. The experiment average was 65% with no abscission chemical and 91% with abscission chemicals or an increase of 26 percentage points. The increases for Treatments 1, 2, 3, and 4 were 35, 19, 29, and 22 percentage points, respectively. In general, the difference in removal efficiencies with no and with

Table 1. Tree Trunk Movement in Radians*

	Hamlin		Valencia	
Treatment	1982	1983	1982	1983
1. Linear	0.047	0.035	0.074	0.052
2. Linear	0.065	0.045	0.112	0.071
3. Multi-dir.	0.058	0.044	0.075	0.056
4. Multi-dir.	0.051	0.039	0.074	0.054

*Average of maximum trunk amplitude per tree divided by accelero-

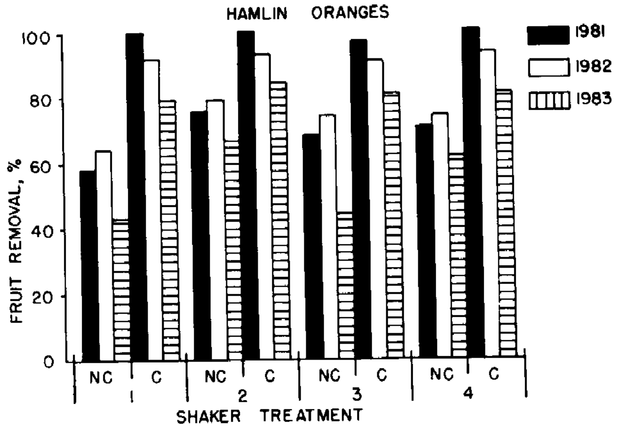

Fig. 2—Trunk shaker removal of Hamlin oranges with (C) and with no (NC) abscission chemical.

abscission chemicals was inversely related to the removal efficiency with no abscission chemicals. The removal efficiencies of all shaker treatments with no abscission chemicals increased slightly from 1981 to 1982 and then decreased somewhat in 1983. This decrease for the 1983 season might be explained to some extent by the reduction in trunk amplitudes from 1982 to 1983 (Table 1). This was thought to be due in part to the fact that in 1983 the ground was thoroughly saturated with water by heavy rains just prior to harvest, and may have increased the trunk resistance to movement.

The average shaker amplitude values for 1982 and 1983 were 2.5 cm and 1.9 cm, respectively. Removal efficiencies for all shaker treatments with abscission chemicals were highest in the 1981 season and lowest in the 1983 season. The lower removal efficiences in the two seasons were due to (a) rainy and cool weather decreasing the effectiveness of the abscission chemicals, (b) lesser amounts of chemicals were applied as compared to the 1981 season because of freeze damage to the trees in 1982, and (c) reduced trunk amplitude in 1983 as described above. Averaged over the abscission chemical effects, fruit removal efficiences of the shaker treatments were significantly different for all three seasons. Treatment 1 was lowest and Treatment 2 was the highest.

Fruit Yields - the fruit yield data to include the handpick check are illustrated in Fig. 3. In 1981, the first year of harvest, the yields were very uniform. The chemical and/or shaker effects on the fruit yielding potential of the trees could only have resulted in 1982 and 1983. The chemical effect was not significant for 1982 or 1983, although in 1983 the mean yields of the

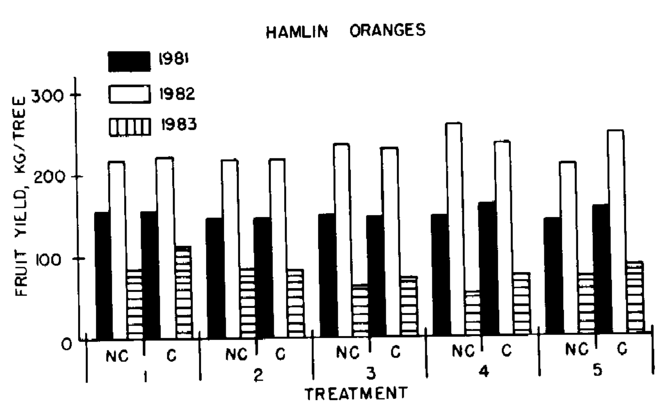

Fig. 3—Hamlin orange yields for 4 trunk shaker harvest treatments and a handi-picked check with (C) and with no (NC) abscission chemical.

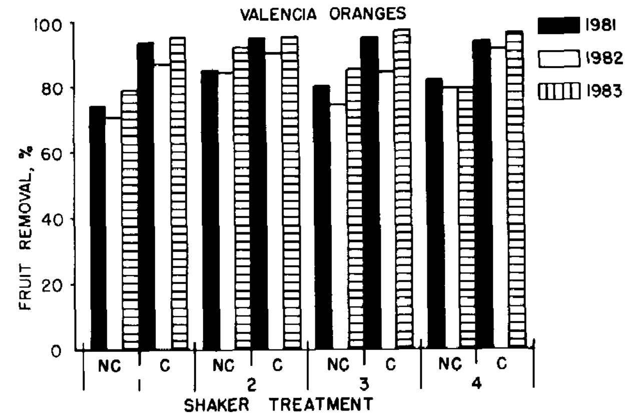

Fig. 4—Trunk shaker removal of Valencia oranges with (C) and with no (NC) abscission chemical.

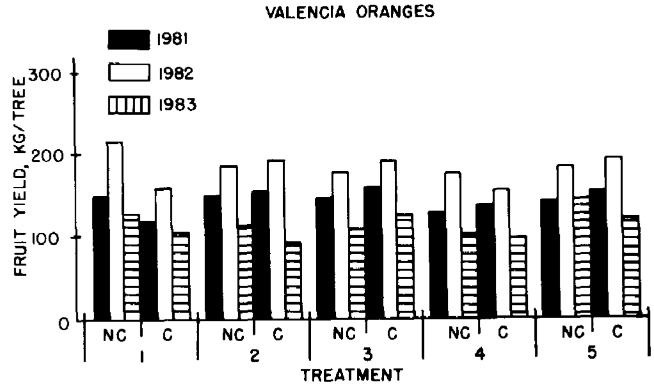

Fig. 5—Valencia orange yields for 4 shaker treatments and the handpicked check. NC = no abscission chemical, C = abscission chemical.

chemically treated trees were higher than those with no chemical.

The shaker effect was not significant in 1982 but was in 1983. Ranked in descending order of fruit yield magnitude in 1983 and including the handpick check, they were Treatments 1, 5, 2, 3, and 4. One possible explanation for this result is that the trees were harvested subsequent to the 1982 freeze which severely defoliated the older leaves. Young flush and petal bloom were on the tree at harvest time. It was observed that the higher frequency shaking of Treatments 3 and 4 shredded the young flush and bloom more than the lower frequency shaking of Treatments 1 and 2. It is possible that the shaking of Treatment 1, which was the least severe of shaking treatments, may have thinned the bloom to an optimum number compared to essentially no thinning with the handpick check and probably the most thinning of Treatments 3 and 4.

Valencia Oranges

Fruit Removal - Fig. 4 shows the fruit removal data. Abscission chemicals increased removal efficiency significantly in all three harvest seasons, the average increase being 12%. Fruit loosening by the abscission chemical was lowest in the second (1982) season, partially because the fruit as in a non-responsive period (Wheaton, et al. 1977) to the chemical when harvested.

The effect of the shakers on fruit removal efficiency was significant only for the 1982 season. As with the Hamlin experiment, Treatments 1 and 2 generally gave the lowest and highest removal efficiencies, respectively. In 1983, the shaker-chemical interaction was significant because the range of removal efficiences with and with no abscission chemical was greater than in the other seasons. For Treatment 2, the abscission chemical increased fruit removal efficiency by only 3 percentage points (92% to 95%), while for Treatment 4 the increase was 17 percentage points (79% to 96%). Fruit removal efficiency was fairly well correlated (simple correlation, coefficiency: 0.349) with trunk amplitude divided by accelerometer height. The overall efficiency was 86% in Valencia compared to 78% in Hamlin and was probably related to greater trunk amplitude in Valencia than Hamlin oranges. Tree height and trunk circumference were larger for the Hamlin orange trees and resulted in lower fruit removal.

Fruit Yield - The effect of abscission chemicals was not significant for 1982 and 1983, although the means were slightly less for the chemical treated trees (Fig. 5).

The effect of the shaker treatments on fruit yields, including the handpick check, was significant only in 1983. For that season, the fruit yields ranked in descending order were Treatments 5, 3, 1, 2, and 4. The handpick check mean was 17 percentage points greater than the shaker treatment (1 to 4 means). The reduced yields for shaker treatment in 1983 were probably due, in part, to the fact that the young fruit size (1983 crop) was larger (1 cm diameter) when the trees were shaken in 1982, and a significant number were removed by shaking. In contrast, the young fruit size in 1981 was much smaller (petal bloom) when the trees were shaken, and the subsequent 1982 yields were not affected.

General Discussion

The difference in trunk circumference did not affect the operating frequency of the shaker treatments. However, there was some difference due to their mode shaking. The linear shaker (Treatments 1 and 2) operated from 5-6 r/s while the multi-directional shaker (Treatments 3 and 4) operated at 10-12 r/s or twice as fast as the linear shaker. This means that in the 7 s shaking duration, the multi-directional shaker moved the trees through twice as many oscillations.

Bark damage is a factor in operating any shaking equipment, particularly on Valencia orange trees which are in a growth period at time of harvest. However, in these experiments, observed bark damage was minimal. Static shaker clamping forces and contact areas were measured on a cylinder 51 cm in circumference which was the average tree circumference.

Averge clamping pressure over the contact area was 642 kPa for the linear shaker and 1217 kPa for the multi-directional shaker. The difference in height of the clamp pads on the two shakers was 7.6 cm when clamped on a tree; the smaller height being on the linear shaker. For this reason, the linear shaker could grasp the limited trunk area of most trees more easily.

The fruit yield and removal data for these two experiments indicate that there is no advantage to using a multi-directional shaker over a linear type and better fruit removal was obtained with the linear shaker producing the largest amplitude (Treatment 2).

References

1. Brown, G. K. (Ed.). 1983. Status of harvest mechanization of horticultural crops. ASAE Special Publication 0383, 78 pg.

2. Hedden, S. L., G. E. Coppock, and J. D. Whitney. 1983. Citrus harvest mechanization in Florida-current situation. TRANSACTIONS of the ASAE 26(2):397-398.

3. Wheaton, T. A., W. C. Wilson, and R. E. Holm. 1977. Abscission response and color changes of 'Valencia' oranges. J. Amer. Soc. Hort. Sci. 102:580-583.

4. Whitney, J. D. 1975. Orange yield and removal studies with air and trunk shaker using two abscission chemicals. Proc. Fla. State Hort. Soc. 88:120-124.