Performance of Three Air Shaker Patterns in Citrus

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ABSTRACT

THREE air manipulation systems (center pivot plates, wobble plates, and upstream pivot plates) were designed, constructed and mounted on an air shaker to evaluate their effectiveness of removing citrus fruit from the tree. Field performance tests in four groves indicated that the center pivot plates were superior and could remove equivalent percentages of fruit 30 to 50 percent faster than the wobble plate and upstream pivot plate systems. Air velocity (pressure) measurements emanating from the air shaker substantiated the superior shaking pattern of the center pivot plate system.

INTRODUCTION

Air shakers for citrus fruit removal have been under development in Florida for the past two decades. Some of the main problems with the air shaker are that the power requirements are high, capital investment is large, and it is dependent on the fruit loosening by the use of abscission chemicals for satisfactory performance. Research efforts have dealt with alleviating these problems by investigating efficient ways of manipulating the air.

Methods of manipulating the air which subsequently removes fruit from the tree have been described by Whitney and Schultz, 1975. Three systems which have been used most extensively in the field have been the center pivot plates, wobble plates, and upstream pivot plates. Observations in the field have indicated that there were differences in the fruit removal performance of the systems. However, each system had been mounted on a different air shaker (different air source) and comparative performance data on the systems were not available.

The objective of the research reported in this paper was to evaluate the performance of the center pivot plate, wobble plate, and upstream pivot plate systems of manipulating the air from the same air source.

MATERIALS AND METHODS

System Designs

The upstream pivot plate, center pivot plate, and wobble plate systems were designed and constructed to be mounted on an air shaker described by Whitney, 1977. Each system consisted of a duct, air-manipulation plates and mounting shafts, and the necessary drive train components to operate the plates. Each duct was 61 cm (2 ft) deep (parallel to air flow from fan), 4.7 m (185 in.) high, 122 cm (4 ft) wide where it bolted to the fan casing, and 71 cm (28 in.) wide at the discharge (Figs. 1, 2, 3).

The upstream pivot plate system (Fig. 1) consisted of airfoil plates 30 cm (12 in.) wide parallel to the direction of air flow and spaced 32 cm (12.5 in.) vertically. The plates were driven through a total oscillation arc of 1.66 rad (95 deg) by a crank disk or crank rocker linkage arrangement. Each disk was set 0.44 rad (25 deg) out of phase with adjacent disks.

The center pivot plate system (Fig. 2) consisted of flat plates 30 cm (12 in.) wide parallel to the direction of air flow and spaced 32 cm (12.5 in.) vertically. Each

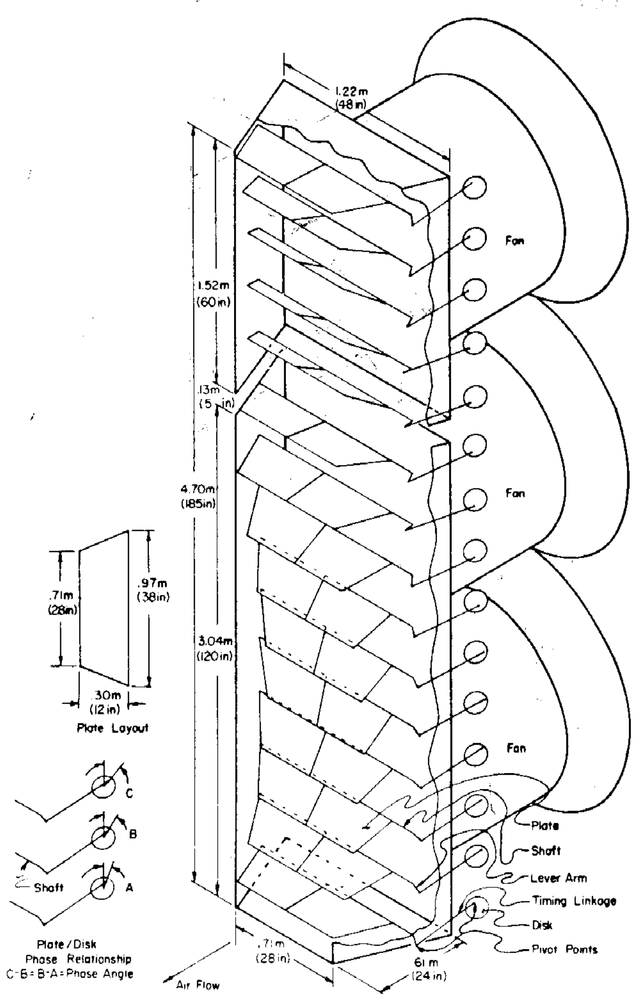

FIG. 1 Isometric view of upstream pivot plate system mounted on three fans of airshaker.

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plate was set 0.21 rad (12 deg) out of phase with adjacent plates.

In the wobble plate system, two vertical shafts 43 cm (17 in.) apart were required for mounting the wobble plates (Fig. 3). Flat, elliptical plates with 65 cm (25.75 in.) major axis and 42 cm (16.5 in.) minor axis were spaced 36 cm (14 in.) vertically with 0.7 rad (40 deg) between the plate major axis and the mounting shaft. The two mounting shafts rotated in opposite directions and synchronized with a chain drive. The vertical spacing of the wobble plates on the shaft was set at 36 cm (14 in.) and was slightly greater than one-half the major axis length of 65 cm (25.75 in.). This spacing relationship was found to be optimum on other air shakers (Whitney and Patterson, 1972). This mounting angle also caused the wobble plates in one rotation cycle to deflect the fan air discharge through approximately the same oscillation angle (1.75 rad or 100 deg) as the upstream pivot plates (1.66 rad or 95 deg).

The out-of-phase relationship of the adjacent plates in all systems was determined by a number of factors. First, the upstream pivot plates had performed fairly well at the out-of-phase adjustment of 0.44 rad (25 deg) per plate (Whitney, 1977). In order for the wobble plate system to develop a pulsating blast of air at the same cyclic rate and at the same speed of vertical movement through the tree, the out-of-phase adjustment about the shaft had to be 0.58 rad (33 deg) per plate. Similarly, the out-of-phase relationship of the center pivot plates had to be 0.21 rad (12 deg).

Air Pattern Measurements

Comparative measurements were made of the air pattern characteristics emanating from the three air manipulation systems and were similar to those described by Whitney, 1977. All measurements will not be presented but those which will be described and illustrated in this paper point out the major differences in the systems.

Air pressures were measured with a pressure transducer and recorded on a storage oscilloscope. The points of measurement were approximately 21 m (7 ft) above ground (between bottom and middle fans) on the vertical center line of the discharge and at 0.6 m (2 ft), 1.8 m (6 ft), and 3 m (10 ft) from the discharge. The plates were operated to develop approximately one air blast or pulse per second. These pressures were characteristic of those along the height dimension of the discharge and indicated what the tree would see as the discharge center line moved by.

Field Performance

Field performance tests were conducted in four groves over a period of 4 months to evaluate the three air manipulation systems. In each grove, an abscission chemical was applied 3 to 5 days prior to harvest with the air shaker to loosen the fruit. One day was required for each manipulation system test because of the time

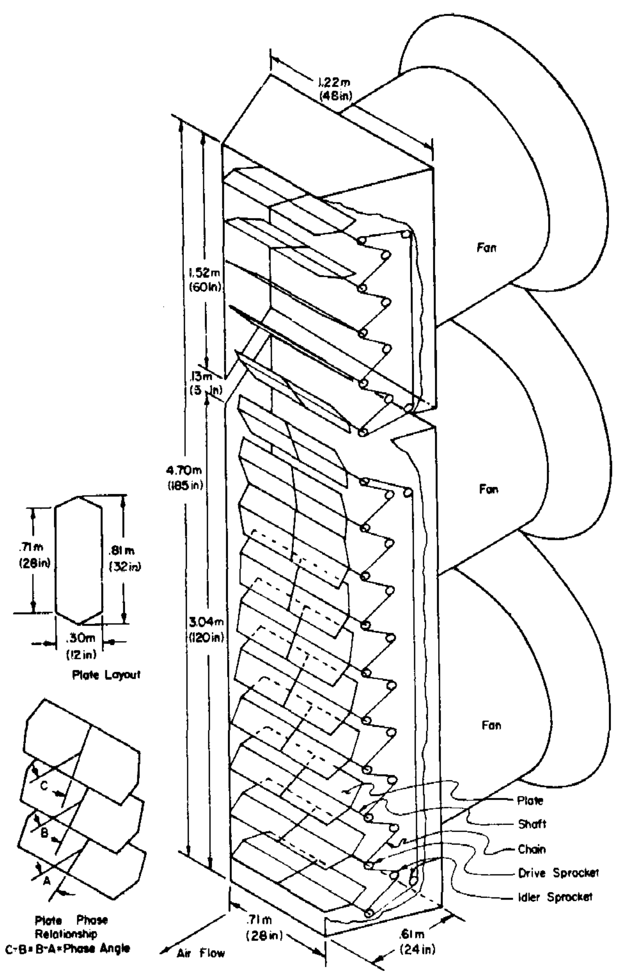

FIG. 2 Isometric view of center pivot plate system mounted on three fans of airshaker.

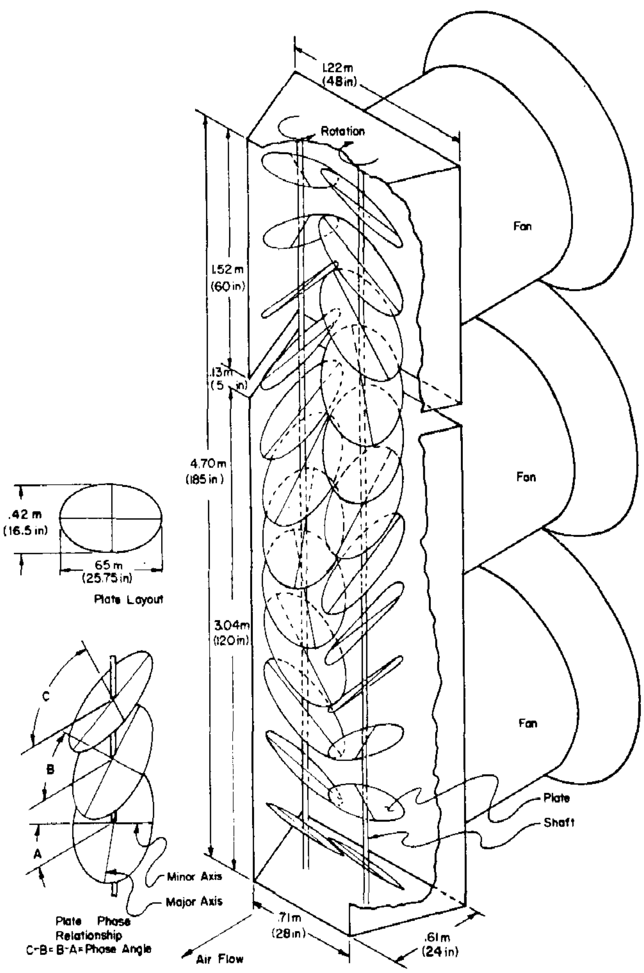

FIG. 3 Isometric view of wobble plate system mounted on three fans of airshaker.

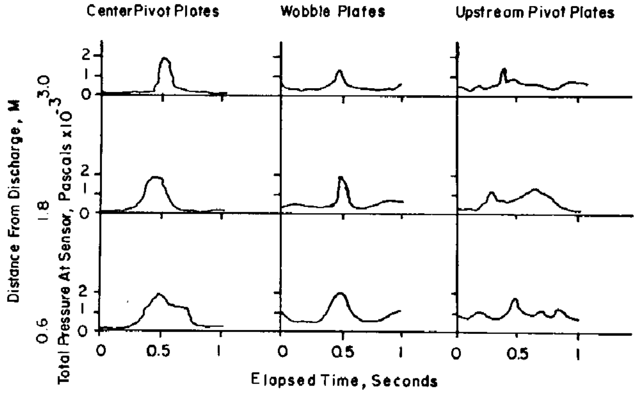

FIG. 4 Air pressures recorded by pressure transducer sensor at 2.1 m above ground in vertical centerline of discharge with plates operating 1 cycle per sec.

required to change systems in the field. Therefore, fruit loosening was rarely the same for all tests within a grove. In each test, preharvest drop was measured, each system was operated at 1 to 1.3 air pulses per second, and the ground speed (time exposure) of the air shaker was adjusted between 0.22 m/s (0.5 mph) and 0.78 m/s (1.75 mph) so that approximately 90 percent fruit removal was achieved.

RESULTS

Air Pattern Measurements

Fig. 4 illustrates the dynamic characteristics of the three air manipulation systems. Air pressures sensed by the pressure transducer are shown for one complete cycle of the plates or for approximately a 1-s time period. Several basic differences can be seen in the patterns. The center pivot plate system developed more distinct air pulses or blasts than did the other two systems. Differential pressures within the cycle (pulses and between-pulses) were also much greater with the center pivot plate system. It should be noted that the differential pressures developed by the upstream pivot plate system were not as great as those reported by Whitney, 1977. The main reason for this is that the vertical spacing between the upstream pivot plates was changed from 29 cm (11.25 in.) (Whitney, 1977) to 32 cm (12.5 in.) in these tests and the greater spacing resulted in reduced differential pressures in the air pattern (see Whitney and Schultz, 1975).

The duration or time-base width of the pulse was considerably greater with the center pivot plate system than with the other two systems. The greater time-base width of the pulse indicates that the pulse had a greater vertical physical dimension as it moved along the duct discharge and had two distinct advantages. First, the pressure front of the pulse was distributed over a larger tree area and should minimize localized tree damage. Second, the time base of the pulse (forcing function) was longer for a given vertical speed of the pulse along the discharge and this provided a greater impulse (force x time) to shake the tree.

Other total pressure measurements (not shown) inside the fan casings indicated that the pressure fluctuations within the casings were greatest with the center pivot plate system and least with the upstream pivot plate system.

TABLE 1. FIELD PERFORMANCE RESULTS OF AIR SHAKER WITH 3 DIFFERENT AIR MANIPULATION SYSTEMS

System		Grove number 1	2	3	4
Center pivot plate	Preharvest fruit drop, percent	0	8	9	18
	Percent fruit removal	80	90-95	98	97
	Ground speed, m/s	0.22	0.36	0.78	0.67
	(mph)	(0.5)	(0.8)	(1.75)	(1.5)
Wobble plate	Preharvest fruit drop, percent	0	25	6	——
	Percent fruit removal	61	90-95	95	——
	Ground speed, m/s	0.22	0.33	0.54	——
	(mph)	(0.5)	(0.75)	(1.2)	——
Upstream pivot plate	Preharvest fruit drop, percent	——	5	10	52
	Percent fruit removal	——	88	97	95
	Ground speed, m/s	——	0.22	0.44	0.54
	(mph)	——	(0.5)	(1.0)	(1.2)

Field Performance

Table 1 summarizes the field performance results in groves 1 through 4.

Grove No. 1 was 'Hamlin' oranges. The trees were approximately 5.5 m (18 ft) high and were spaced 7.6 m x 7.6 m (25 ft x 25 ft). The wobble plate system was compared with the center pivot plate system on a total of 40 trees. Even though an abscission chemical had been applied, little or no preharvest drop occurred. On 20 trees, the center pivot plate system removed 80 percent of the fruit at 0.22 m/s (1/2 mph) ground speed. On the remaining 20 trees, the wobble plate system removed 61 percent of the fruit at 0.22 m/s (1/2 mph) ground speed).

Grove No. 2 was 'Queen' oranges. The trees were 5.5 m (18 ft) to 6.4 m (21 ft) high and set on 4.6 m x 9.2 m (15 ft x 30 ft) spacing. Fruit loosening in grove No. 2 with the abscission chemical was not particularly effective. Fairly aggressive air shaking action was required for fruit removal. On the first 170 trees, with 5 percent preharvest drop, the upstream pivot system removed 88 percent of the fruit at 0.22 m/s (1/2 mph) ground speed. On the next 1400 trees with an average of 8 percent preharvest drop the center pivot plate system removed 90 to 95 percent of the fruit at 0.36 m/s (0.8 mph). The wobble plate system was only used on 100 trees with much looser fruit (25 percent preharvest drop) and removed 90 to 95 percent at 0.33 m/s (0.75 mph).

Grove No. 3 was 'Pineapple' oranges on a 7.6 m x 7.6 m (25 ft x 25 ft) spacing. The trees ranged in height from 5.5 m (18 ft) to 6.4 m (21 ft). The magnitude and uniformity of fruit loosening in grove No. 3 were greater than the other groves. The center pivot plate system averaged 98 percent fruit removal at 0.78 m/s (1.75 mph) with 9 percent preharvest fruit drop on 160 trees. With 6 percent preharvest fruit drop, the wobble plate system removed 95 percent of the fruit from 30 trees at 0.54 m/s (1.2 mph). On 80 trees with 10 percent preharvest fruit drop, the upstream pivot plate system removed 97 percent of the fruit at 0.44 m/s (1 mph).

The last tests in grove No. 4 were conducted with the upstream pivot and the center pivot plate systems. This grove was 'Pineapple' oranges with trees on a 5.2 m x 7.6 m (17 ft x 25 ft) spacing. Tree height ranged from 3.7 m (12 ft) to 4.9 m (16 ft). Fruit loosening with the

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abscission chemical varied considerably. The upstream pivot plate system removed 95 percent of the fruit from 100 trees with a 52 percent preharvest fruit drop at 0.54 m/s (1.2 mph) ground speed. On 700 trees with an 18 percent preharvest drop, the center pivot plate system removed an average of 97 percent of the fruit at 0.67 m/s (1.5 mph).

DISCUSSION AND SUMMARY

The center pivot plate system out-performed the wobble plate and upstream pivot plate systems. According to the air pattern measurements, the center pivot plates developed the most definitive air pulse for air shaking and this pulse had the longest time base and provided the greatest shaking impulse at a given vertical speed of the pulse through the tree. Field performance data and observations established that the more definitive air pulses for longer exposure times did indeed develop more aggressive and efficient air shaking actions. This type of shaking action allowed the center pivot plate system to remove a higher percentage of fruit and/or to remove the fruit at a higher rate (higher ground speed). Based on the field performance data, it was estimated that the center pivot plate system could remove an equivalent percentage of fruit 30 to 50 percent faster than the other 2-plate systems. The center pivot plate system was also capable of removing higher percentages of fruit at a given removal rate where fruit loosening was not satisfactory.

The upstream pivot plate and wobble plate systems were comparable in field performance, although the air pattern measurements indicated that the wobble plate system may be slightly better when using the design described in this report.

References

1 Whitney, J. D. and J. M. Patterson. 1972. Development of a citrus removal device using oscillating forced air. TRANSACTIONS of the ASAE 15(5):849-855, 860.

2 Whitney, J. D. and D. R. Schultz. 1975. Analysis of air shaker principles to remove citrus fruit. TRANSACTIONS of the ASAE 18(6):1061-1064, 1069.

3 Whitney, J. D. 1977. Design and performance of an air shaker for citrus fruit removal. TRANSACTIONS of the ASAE 20(1):52-56.