EFFECT OF OSCILLATORS ON DEPOSITION CHARACTERISTICS OF AN AIRBLAST SPRAYER

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ABSTRACT

An engine-driven airblast sprayer, equipped with air oscillators, was used to apply a spray solution at travel speeds of 1.6, 3.2, 4.8, and 6.4 km/h. The spray solution contained cupric hydroxide as a deposition tracer and was applied at 240 ppm to grapefruit and orange trees in a randomized complete block experiment. Spray targets (typical shoots with 6-10 leaves from the same type of tree, washed and air dried) were placed at two heights and three radial locations in each sprayed tree. After spraying, three to five leaf samples were taken from each target shoot and the copper deposit on the leaves were measured by colorimetry.

Operation of the oscillators did not have a significant effect on deposition, and travel speed did not have a significant effect on the effectiveness of the oscillators. In general, there tended to be more deposition without oscillators than with the oscillators on both types of trees and at all sample locations (except 3.6 m height on the tree row line). **KEYWORDS.** Sprayers, Oscillators, Deposition, Citrus trees.

INTRODUCTION

Air-carrier sprayers of various designs and sizes are the primary means for tree crop spraying. They are equipped with fans that can produce high velocity airstreams to transport spray droplets toward the target trees. Axial, tangential, or centrifugal fans may provide the air flow that is directed toward the target by adjustable guide vanes, deflector plates, and ducts. Spray droplets are produced by hydraulic nozzles, air shear nozzles, or rotary atomizers (Reichard et al., 1977); therefore, different fan and nozzle (or atomizer) combinations may result in differing designs of the sprayers. Each design may provide an optimum spray deposition for a particular set of targets and application parameters; however, it is traditionally believed that spray-laden air must replace the air in, and around the tree canopy to achieve thorough coverage (Beasley et al., 1976). In general, increased air flow volume improves spray distribution (Matthews, 1982) and sufficient air velocity moves the leaves and allows droplets to penetrate the inner canopy and to reach the top of the tree.

Fleming (1962) concluded that the most efficient ratio of air velocity to flow volume for any given air flow horsepower was largely dependent on the spray droplet size. As droplet size is increased, greater air velocity is required to keep the larger droplets airborne. Brann (1964) reported that air velocity fell off rapidly as the distance from sprayer outlet increased. Hale (1978), using a scale model of a bush tree orchard in a wind tunnel, found that the travel distance of an air jet from the outlet was dependent on the air flow volume and the energy of the air jet (air volume output x air pressure) emitted per unit of forward travel. Randall (1971) compared the spray deposition resulting from three air flow volumes (1.53, 2.46, and 7.67 m^3/s) at two travel speeds (3.2 and 6.4 km/h). He found that the highest air flow volume produced the most uniform deposit throughout an apple tree when the sprayer traveled at the slower speed.

To increase spray penetration inside the tree canopy, some sprayers are designed to generate oscillating air and/or droplet streams. Oscillating air, produced by oscillating plates in the air stream, were often used to break up the 'shingling' effect on citrus leaves caused by the high velocity of air movements (Carman, 1983). Johnstone (1970) reported good penetration of spray droplets into citrus tree canopies with an oscillating air stream (20-25 c/min), produced by oscillating flaps of contra-rotating twin centrifugal fans of a small airblast sprayer (4.7 m^3/s). Brooks et al. (1963) reported better spray deposition with air oscillation than without oscillation in Florida citrus. Their sprayer utilized flat plates positioned upstream of the spray nozzles which oscillated about their upstream edge through an arc of about 30°. Furness and Pinczewski (1985) observed superior spray deposition on citrus with an oscillating boom sprayer when it was compared to that of an airblast sprayer. The boom oscillated in two directions to produce a rapid circular movement of the hydraulic nozzles.

Despite claims and reports of improved spray coverage with air oscillators in airblast sprayers, the utility and usefulness of the oscillators have been questioned by some Florida citrus growers. Oscillators increase the purchase price of the sprayer and require considerable attention to prevent malfunctioning. Some operators disconnect the mechanism and operate their sprayers without oscillators.

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The objectives of this study were: a) to characterize spray deposition within the citrus tree canopy operating an airblast sprayer with and without oscillators; and b) to determine the effect of travel speed on the effectiveness of the oscillators.

Materials and Methods

An engine-driven airblast sprayer (FMC 9100), with an air flow rate of about 50 m^3/s, average air outlet velocity of 41 m/s, and air oscillators, was evaluated in Florida citrus. The sprayer had 10 ceramic disc-core nozzles on each side. The top five nozzles had FMC No. 6 discs with three-hole whirl plates and the bottom five nozzles had FMC No. 6 discs with two-hole whirl plates. This nozzle configuration was selected to follow the normal spraying practice for Florida citrus; to deliver two-thirds of the sprayer discharge toward the top half and one-third toward the bottom half of the tree canopy. Each side of the sprayer was equipped with nine oscillators (fig. 1). They were round steel discs (20-25 cm diameter) mounted at 12-22° angles on five shafts. On one side of the sprayer, the shafts were rotated to oscillate the air stream at about 60 c/min (with oscillators). On the other side, the shafts were not rotated and the flat surfaces of the discs (oscillators) were positioned parallel to the direction of the air flow to minimize obstruction to the air discharge and simulate the discharge "without oscillators".

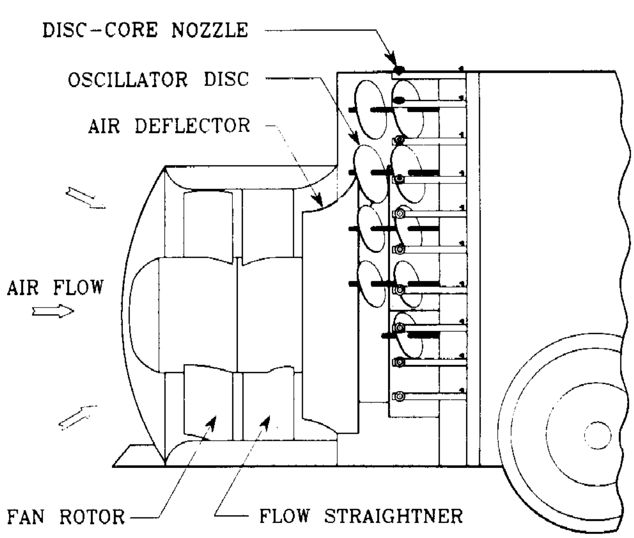
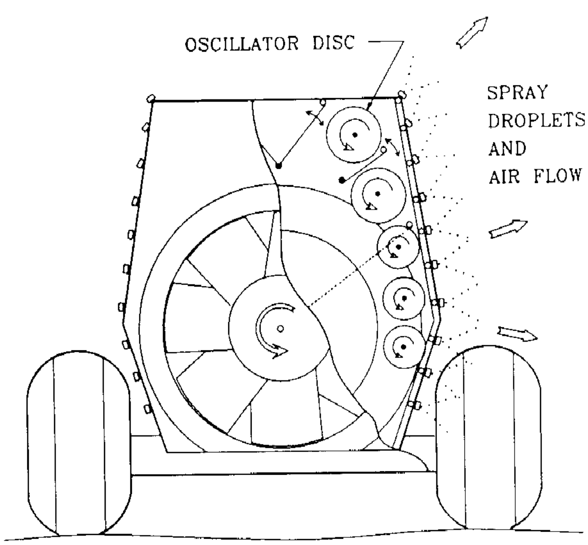


Figure 1–Schematic view of the sprayer air outlet and oscillators: a) Side view.



b) End view.

The sprayer was operated at four travel speeds (1.6, 3.2, 4.8, and 6.4 km/h). It was calibrated to discharge 114.6 L/min at 1 100 kPa and apply 4 680 Lha at 1.6 km/h when spraying from two sides of the tree. Nozzle configuration and sprayer discharge remained the same at all travel speeds; therefore, spray volume rate/ha decreased as travel speed increased (i.e., 4 680, 2 340, 1 560, and 1 170 L/ha, respectively).

The spray solution contained cupric hydroxide with 240 ppm tracer elemental copper. It was applied in the eight sprayer treatments (four travel speeds, with and without oscillators) to six tree blocks (six replications) in a completely randomized block design. Three blocks consisted of grapefruit trees; about 5.5 m high, 7.3 m wide (diameter), 9.1 × 7.6 m row and tree spacings, and adjacent trees in the row had touching canopies. The other three blocks had orange trees; about 4.7 m high, 6.1 m diameter, and 9.1 m row spacing. The orange trees had freestanding canopies and their interiors were comparatively denser than that of grapefruit trees.

Spray targets consisted of typical shoots (with 6-10 leaves) from the same kind of tree. After the shoots were clipped, they were washed in a 0.05 N nitric acid solution and then in deionized water (to remove residual copper deposits), air dried, and placed at six different locations inside each tree canopy (fig. 2). They were located at 1.8 m and 3.6 m heights and at three radial locations: X, Y, and Z. Locations X and Y were 60 to 75 cm inside the canopy at

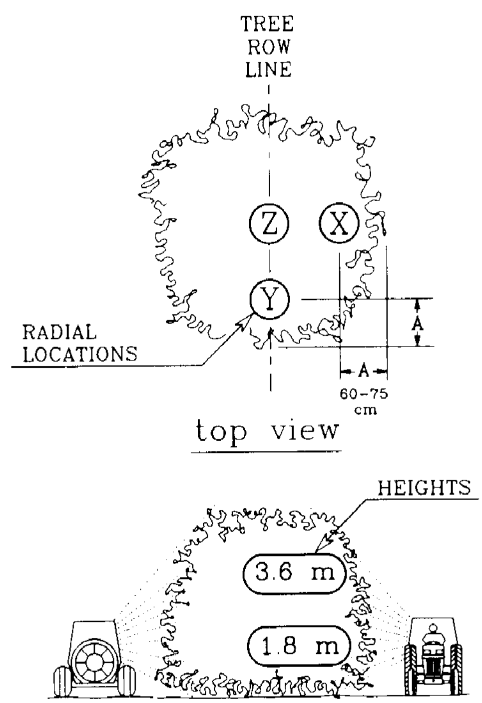


Figure 2–Sample locations within citrus tree canopies.

90° and 0° to the tree row line and location Z was at the center of the tree.

After application of a spray treatment to each of the six trees, the shoots were retrieved from the canopies, three to five leaves of each shoot were clipped randomly, placed in coded plastic bags, and were taken to the laboratory for analysis. The amount of copper deposit on leaf samples was determined by a Hach DR-100 colorimeter and leaf surface area was measured by a Delta-T Type AMB Area Meter (Salyani and Whitney, 1988). Deposition data were expressed in ng of deposit per cm^2 of leaf surface area (both sides) and variability of deposits (among samples) as the coefficient of variation (CV). The data were analyzed as a split-plot design, with oscillation and ground speed as main plot and sample locations as subplot effects, respectively.

Since nozzle configuration, sprayer discharge, and copper concentration were not changed at different travel speeds, raw deposit data corresponding to the speeds of 1.6, 3.2, 4.8, and 6.4 km/h were multiplied by speed factors 1, 2, 3, and 4, respectively, to obtain comparable deposition data at all speeds.

Weather data were recorded with a Campbell Scientific CR-10 weather station. Ranges of temperature during the test were 23.5 to 33° C (at 3.1 m) and 24.5 to 33.5° C (at 6.1 m). Relative humidity was 35 to 65% (at 3.1 m). Wind velocity, measured at 9.1 m, ranged from 5.6 to 8.8 km/h and wind direction ranged from 130 to 310° (measured clockwise with winds from north = 0°).

Results and Discussion

Statistical significance of results refers to F-values at 10% level. Overall, spray deposition without the oscillators averaged 10.2% higher than it was with the oscillators (Table 1); however, this difference was not significant. Grapefruit trees had more deposits per unit leaf area than the orange trees. This may be explained by the comparatively denser foliage of the orange trees that may have hampered spray penetration into the canopy. Inferior deposition with oscillators was observed for both types of trees; however, the differences were not significant (Table 1). Overall, the variability of deposition was higher without oscillators.

The effects of height and radial location of the samples on deposition were significant (Table 2). Mean deposits at 3.6 m height were significantly greater than those at 1.8 m. This was basically due to the larger output from top half of the nozzle manifold. Although this was not a particularly desirable result, it represented deposition with the normal spray practices in Florida citrus. At 1.8 m height, there was more deposit without oscillators than with oscillators and the difference was significant. At 3.6 m height, mean deposits were about the same with and without oscillators; however, variability of deposits was higher without oscillators. The interaction of oscillator with height was significant.

TABLE 1. Mean deposition on grapefruit and orange trees (N = 72)

Trees	With oscillators Deposit ng/cm^2	With oscillators (CV) (%)	Without oscillators Deposit ng/cm^2	Without oscillators (CV) (%)	Difference* in deposit %
All†	471	(75)	519	(78)	10.2
Grapefruit	515	(66)	588	(78)	14.2
Orange	427	(85)	449	(73)	5.2

* Difference = [(Dep. without Osc.-Dep. with Osc.) / Dep. with Osc.] x 100. Differences were not significant at 10% level.

† Overall average for both trees, four travel speeds, two heights, and three radial locations

TABLE 2. Mean deposition at different sample locations (N = 24)

Sample location	With oscillators Deposit ng/cm^2	With oscillators (CV) (%)	Without oscillators Deposit ng/cm^2	Without oscillators (CV) (%)	Difference* in deposit %
X - 1.8 m	609	(49)	744	(47)	22.2*
Y - 1.8 m	166	(66)	258	(97)	55.4*
Z - 1.8 m	341	(54)	402	(54)	17.9
X - 3.6 m	960	(33)	1012	(41)	5.4
Y - 3.6 m	270	(59)	185	(83)	-31.5*
Z - 3.6 m	482	(59)	511	(55)	6.0
Height means (N = 72)					
1.8m	372	(75)	468	(73)	25.8*
3.6m	571	(68)	569	(80)	-0.4
Radial location means (N = 48)					
X	784	(45)	878	(46)	12.0
Y	218	(66)	221	(94)	1.4
Z	411	(60)	456	(56)	11.0

* Difference = [(Dep. without Osc.-Dep. with Osc.) / Dep. with Osc.] x 100. Differences followed by an * were significant at 10% level.

There was no significant interaction between oscillators and radial location. In all three radial locations, mean deposits were greater without oscillators than with oscillators; however, the differences were not significant. The maximum deposit and minimum values of CVs (both with and without oscillators) were observed at location X which was nearest to the sprayer. At location Z (tree center) the amount and variability of deposits had intermediate values for both with and without oscillators. Location Y (on the tree row line), with high density of foliage and increased distance from the sprayer, received minimum deposits with the highest variability of deposition. Although overall mean deposits at location Y were about the same with and without oscillators, spraying with oscillators deposited significantly less material than without oscillators at location Y (1.8 m), but there was significantly more deposition with oscillators at location Y (3.6 m). This trend reversal may be attributed to the effectiveness of oscillators to transport the spray stream to the higher canopy locations. Variability of deposition at both locations was consistently lower with the oscillators.

The overall higher deposition without oscillators suggests that the action of the oscillators may have resulted in excessive shaking of the leaves at some locations; this allowed some portion of the impinged droplets to be blown off leaf surfaces. This hypothesis may explain the fact that the differences in deposits at 1.8 m were much greater than those at the 3.6 m height which was farther from the sprayer outlet (Table 2). At the top of the tree canopy (which is farthest from the sprayer and difficult to spray), oscillators appear to become effective in increasing the deposition. The above argument may not be true at the center of the tree where air velocity is substantially less than that at X locations.

Since only a portion of the spray stream was oscillated by this particular oscillator design (fig. 1), oscillating stream may have interfered with the flow of the non-oscillated stream. Oscillation thus could have resulted in collision of the droplets and as a result some portion of the spray droplets may have settled before reaching the target. Comparatively speaking, the oscillators used in this test were probably not as effective in oscillating the sprayer air discharge as the flat plate oscillators used by Brooks et al. (1963). The main reason for this was the flat plates intercepted and manipulated a higher portion of the discharged air.

Travel Speed Effect

Travel speed (1.6-6.4 km/h) did not have a significant effect on deposition (normalized with speed factors) and its interaction with oscillator was not significant (Table 3). For all speeds, oscillator operation resulted in less average deposition than without oscillators; however, the differences were not significant. Generally speaking, as travel speed increased the difference in deposits increased. In general, there was less variability in deposits with oscillators than without oscillators. For both treatments, CVs increased as travel speed increased.

The effectiveness of oscillation was not significantly affected by travel speed at any sample location (Table 4). Although decreasing the number of oscillations per tree at higher speeds (constant oscillation frequency) might have been expected to leave some part of the canopy unsprayed, there was no data to indicate that effect.

General Discussion

The above results suggest that the oscillators may possibly be effective in dense and difficult to spray foliage or at tree top; however, in most locations, coverage was not improved with oscillators. These results are not in agreement with the results of Brooks et al. (1963). Apart from the difference in design of the sprayer and oscillators and type of the treated trees, the higher application rate and subjective rating method of spray coverage may help explain the difference in the results.

The change of speed from 1.6 to 6.4 km/h in these tests proportionally reduced spray volume per tree and suggest that spray volume may also be a relevant factor affecting the effectiveness of the oscillators. The results in this paper were obtained with a relatively high air volume sprayer with a particular design of the oscillators. Results could be different for lower air volume sprayers or different designs of the oscillators; therefore, general inferences should not be applied to all oscillating sprayers.

TABLE 3. Mean deposition at four travel speeds (N = 36)

Travel speed km/h	With oscillators Deposit ng/cm^2	With oscillators (CV) (%)	Without oscillators Deposit ng/cm^2	Without oscillators (CV) (%)	Difference* in deposit (%)
1.6	486	(58)	492	(61)	1.2
3.2	452	(73)	495	(80)	9.5
4.8	478	(84)	515	(79)	7.7
6.4	469	(84)	573	(88)	22.2

* Difference = [(Dep. without Osc.-Dep. with Osc.) / Dep. with Osc.] x 100. Differences were not significant at 10% level.

TABLE 4. Mean deposition for combination of speed and location (N = 6)

Sample Location	Travel speed km/h	With oscillators Deposit ng/cm^2	With oscillators (CV) (%)	Without oscillators Deposit ng/cm^2	Without oscillators (CV) (%)	Difference* in deposit (%)
X - 1.8 m	1.6	520	(22)	550	(20)	5.8
	3.2	546	(46)	677	(47)	24.0
	4.6	637	(62)	769	(52)	20.7
	6.4	734	(53)	980	(42)	33.5
X - 3.6 m	1.6	917	(12)	920	(16)	0.3
	3.2	906	(36)	936	(55)	3.3
	4.6	1010	(49)	1007	(40)	-0.3
	6.4	1006	(32)	1184	(45)	17.7
Y - 1.8 m	1.6	126	(54)	233	(90)	84.9
	3.2	200	(64)	351	(115)	75.5
	4.8	150	(82)	223	(30)	48.7
	6.4	188	(65)	224	(113)	19.2
Y - 3.6 m	1.6	353	(57)	224	(96)	-36.5
	3.2	227	(61)	187	(66)	-17.6
	4.8	305	(54)	120	(47)	-60.7*
	6.4	193	(48)	210	(92)	8.8
Z - 1.8 m	1.6	389	(37)	400	(38)	2.8
	3.2	324	(73)	395	(63)	21.9
	4.8	294	(57)	463	(59)	57.5
	6.4	356	(61)	349	(62)	-2.0
Z - 3.6 m	1.6	610	(33)	622	(36)	2.0
	3.2	508	(54)	422	(56)	-16.9
	4.8	475	(64)	506	(57)	6.5
	6.4	336	(102)	494	(78)	47.0

* Difference = [(Dep. without Osc.-Dep. with Osc.) / Dep. with Osc.] x 100. Differences followed by an * were significant at 10% level.

Conclusions

Based on the results obtained with the above mentioned equipment, tree types, and sample locations, the following conclusions may be drawn from this experiment:

1. Spray oscillation did not have a significant effect on deposition.
2. Sprayer ground speed did not have a significant interaction with oscillation.

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